Beyond the Sticky Note
Towards a Theory of Cognitive Adoption in Digital Health Using the Example of Augmented Living Spaces

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Summary

Pervasive global demographic changes characterized by an aging population are exacerbating healthcare challenges worldwide, leading to an increased prevalence of neurodegenerative diseases and cognitive impairment. In general, cognitive impairment refers to a decline in mental functioning that manifests as impairments in perception, recognition, memory, reasoning, and judgment. Now, the growing integration of digital health technologies into daily life offers unparalleled opportunities to assist individuals with such cognitive impairments. However, the adoption of these systems by individuals with amnestic mild cognitive impairment (aMCI), as the most prevalent form, is limited, primarily due to a misalignment between conventional system design and the cognitive realities of this population. Existing research often underestimates the cognitive, emotional, and behavioral complexity of technology adoption, leading to poor usability, low engagement, and ultimately, the abandonment of digital interventions. Critically, current research lacks an integrative theoretical foundation to explain *how* and *why* specific design approaches might foster or hinder cognitive adoption, autonomy, and beneficial health behavior changes among individuals with cognitive impairments.

This dissertation addresses this critical research gap in Information Systems (IS) research by moving "beyond the sticky note," from simplistic aids to a theoretically grounded understanding of cognitive engagement with digital health. Thus, it is aimed at developing a *Cognitive Adoption Theory* – a theoretically grounded and practically informed IS theory that explains how individuals with cognitive impairments adopt and internalize digital health technologies, leading to sustained health behavior changes. This theory is iteratively driven by and derived from the design, implementation, and evaluation of a practical concept to support individuals with aMCI in everyday life and maintain their autonomy. This concept, termed *Augmented Living Spaces*, envisions living environments enhanced by Spatial Augmented Reality (SAR) and Artificial Intelligence (AI) to provide seamless, intuitive cognitive support in daily living, ultimately addressing the notion of cumbersome and complex wearable Augmented Reality (AR) in digital health. As such, this has resulted in the following overarching objective of this dissertation:

> **Goal:** To develop a *Cognitive Adoption Theory* that explains how cognitive mechanisms influence the adoption and sustained use of digital health technologies, and the resulting health behavior changes, among individuals with cognitive impairments.

Situated within the Design Science Research (DSR) paradigm, this dissertation takes a multi-cycle, artifact-driven approach to systematically uncover and theorize the cognitive, social, and behavioral aspects and mechanisms that drive or hinder technology adoption among individuals with cognitive impairments. Drawing on a variety of theoretical lenses (e.g., Sociotechnical System Theory, Social Cognitive Theory, Cognitive Load Theory, or Zone of Proximal Development), the dissertation is structured around three iterative design cycles, each of which contributes distinct theoretical and empirical insights.

Cycle 1 presents a design theory for the Augmented Living Spaces concept that leverages SAR and AI-based context tracking to provide personalized cognitive support for individuals with aMCI. Using a heuristic design theorizing approach and qualitative theory-building via focus groups, observational studies, and literature, this cycle reveals essential design knowledge for low-threshold situated interactions and cognitive scaffolding mechanisms, paving the way for conceptualizing aspects/mechanisms of cognitive adoption such as cognitive anchoring, temporal synchrony, and semiotic mediation. Moreover, an additionally developed reference architecture illustrates how modular interface components and real-time reasoning can provide cognitive support in daily routines, instantiating the design theory.

Cycle 2 builds upon the findings from the first cycle and introduces a novel human-computer interaction (HCI) approach called ConZones, which integrates AI-driven, position-sensitive, SAR-based interaction zones throughout the Augmented Living Space. Powered by a synthetically trained deep learning model,

this cycle also yields a design theory for the ethical and effective use of synthetic image data in digital health. Through multi-episode evaluations, including user testing, questionnaires, and think-aloud sessions, the ConZones interaction design demonstrates how intuitive, embodied interaction can mitigate technostress, such as techno-overload and techno-complexity, and enhance self-efficacy, usability, and adoption. As such, this cycle was instrumental in uncovering core cognitive-behavioral dynamics, the pivotal role of user trust stemming from perceived system integrity and ethical design, and how these factors directly inform the conceptual underpinnings of the envisioned *Cognitive Adoption Theory*. Findings from this cycle refined the understanding of temporal cognitive fit, indirect interaction, and cognitive relief as core enablers of adoption.

Consequently, the third design cycle represents the theoretical culmination of the prior two cycles, explicitly focusing on generating the *Cognitive Adoption Theory*. Drawing on insights from the preceding cycles and integrating kernel theories such as Cognitive Load Theory, Social Cognitive Theory, and the concept of Metacognition, this cycle articulated a novel explanatory framework. Using a structured theorizing-from-the-literature method grounded in qualitative theory-building techniques, this third design cycle produced three distinct knowledge outputs: (1) a conceptual model of cognitive adoption in digital health, (2) an integrated framework that incorporates cognitive, social, and behavioral dimensions, and (3) a generalizable theoretical artifact classified as a type II explanatory theory. Thus, this cycle bridges theoretical and practical domains by translating insights from the previous artifact development in the context of Augmented Living Spaces into a conceptual structure that accounts for the specific cognitive characteristics of individuals with impairments and their influence on digital health adoption and health behavior change.

The principal contribution of this dissertation is the *Cognitive Adoption Theory*. This theory outlines core constructs – Cognitive Load for Digital Health, Social Cognitive Factors, Digital Health Adoption, and Health Behavior Change – and explains how they are interrelated, with metacognition playing a crucial mediating role. The theory provides a nuanced understanding of how intrinsic and extraneous cognitive loads, self-efficacy, reciprocal determinism, observational learning, usability, accessibility, and learning curves collectively influence the adoption process and subsequent health behaviors in individuals with cognitive impairments. Notably, the model highlights that cognitive adoption is not merely a function of system usability but emerges from the dynamic interplay between cognitive relief, situated action, and semiotic alignment with the user's real-world context and impairments.

Overall, this dissertation offers a dual contribution: 1) a novel, explanatory mid-range IS theory that addresses a critical gap in understanding technology adoption within vulnerable, cognitively diverse populations, and 2) actionable design knowledge, embodied in the design theories for Augmented Living Spaces and synthetic data use, the ConZones interaction design approach, and associated reference architectures, providing practical guidance for the development of more cognitively inclusive and ethically sound digital health solutions. As such, the theoretical implications are aimed at extending our understanding of cognitive factors in digital health IS research, while the practical implications aim to equip developers, practitioners, and policymakers with a framework to design digital health interventions that are more readily adopted, effectively used, and ultimately more beneficial for individuals with cognitive impairments, truly moving beyond simplistic solutions towards profound, human-centered support.

Ultimately, it advances our understanding of *how* cognitively impaired individuals can adopt and benefit from digital technologies – not through better interfaces or novel technology alone, but through systems designed to think *with* their users.

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List of Abbreviations

AAL	Ambient Assisted Living
AD	Aggregate Dimension
ALiS	Augmented Living Space
AI	Artificial Intelligence
aMCI	Amnestic Mild Cognitive Impairment
AP	Average Precision
API	Application Programming Interface
AR	Augmented Reality
AVE	Average Variance Extracted
CCP	Content-Context-Framework
CCR	Composite Construct Reliability
CLT	Cognitive Load Theory
CNN	Convolutional Neural Network
CON	Conciseness
DF	Design Feature
DP	Design Principle
DR	Design Requirement
DSR	Design Science Research
DSRFM	Design Science Research Focus Matrix
EE	Effort Expectancy
EXP	Explanatory Power
EXT	Extendibility
FEDS	Framework for Evaluation in Design Science Research
HCI	Human-Computer Interaction
HMD	Head-Mounted Display
IoT	Internet-of-Things
IS	Information Systems
ISO	International Standard Organization
mAP	Mean Average Precision
MCI	Mild Cognitive Impairment
MFG	Moderated Focus Group
PE	Performance Expectancy
RA	Reference Architecture
RDR	Reusability for Design Requirements
RQ	Research Question
SAR	Spatial Augmented Reality
SCT	Social Cognitive Theory
TAM	Technology Acceptance Model
UI	User Interface
UML	Unified Modeling Language
UTAUT	Unified Theory of Acceptance and Use of Technology
VR	Virtual Reality
WFMS	Workflow Management System
ZPD	Zone of Proximal Development

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1 Motivation and Research Gap

Imagine being in your early 70s. You live independently at home, but you're starting to forget appointments, have difficulty following multi-step instructions, and feel anxious when using digital devices designed to promote your independence. It's nothing too serious, but it's becoming increasingly restrictive in your everyday life. Your son had the great idea to put sticky notes around the apartment, but he lives a couple of hours away, so no one comes to update and renew them. Recently, your daughter installed a digital health assistant on your smartphone to help. However, the screen layout is confusing, the instructions are unclear, and the app is more trouble than it's worth. Since you don't like using your smartphone anyway because it's too complex, you don't want to use this assistance – you find it very hard to adopt it. You close the app. You are not alone. Millions of people with cognitive impairments face a similar challenge. They are the intended beneficiaries of digital health technologies – yet often the very ones these technologies fail to serve.

These pervasive global demographic changes characterized by an aging population are exacerbating healthcare challenges worldwide, leading to an increased prevalence of neurodegenerative diseases and cognitive impairment (Bloom & Canning, 2008; Duggan et al., 2020). In general, cognitive impairment refers to a decline in mental functioning that manifests as impairments in perception, recognition, memory, reasoning, and judgment (von Arnim et al., 2019). Such cognitive impairment is not synonymous with dementia but is often considered a risk factor for its development (Gauthier et al., 2006). Among this classification, cognitive impairments such as Mild Cognitive Impairment (MCI), and especially its most prevalent form (Bai et al., 2022), Amnestic Mild Cognitive Impairment (aMCI), pose significant barriers to maintaining an individual's autonomy and quality of life. Individuals with aMCI, particularly multi-domain aMCI that affects memory along with other cognitive functions such as executive planning, increasingly face difficulties with daily activities such as cooking, managing therapy, socializing, and dressing (Flicker et al., 1991; Petersen, 2016; Yu et al., 2017). This specific condition is characterized by cognitive changes that are noticeable to the individual or others but not severe enough to significantly interfere with daily life, creating challenges in daily activities such as understanding complex instructions, using digital tools, or even remembering to turn off the oven. It is important to recognize that MCI and neurodegenerative diseases are not synonymous with normal aging, although older adults are at higher risk for developing these conditions (Gauthier et al., 2006; Duggan et al., 2020). While they are often able to live independently, they require more intuitive and less cognitively demanding technological support to navigate complex instructions or consistently use digital tools (Petersen, 2016; Petersen et al., 2018; Yu et al., 2017). For this dissertation, MCI and aMCI will sometimes be used interchangeably, with aMCI specified in contextual discussions where the manifestations actually describe only that trait[1].

In parallel with these demographic shifts, the proliferation of digital health applications designed to support patients, caregivers, and providers has highlighted persistent challenges: low user trust and limited adoption, particularly among vulnerable populations such as individuals with cognitive impairment (Gazzaniga et al., 2018; Mathews et al., 2019; Ienca et al., 2021; Böhmer et al., 2024). For individuals with aMCI, concerns about privacy, ethics, and usability are often exacerbated by complex interfaces, high cognitive load, and human-computer interaction (HCI) designs that are not sufficiently user-centered (Blass et al., 2022; Chignell et al., 2023; Vines et al., 2015). Due to the rapid proliferation of technology, the traditional concept of "sticky notes" as an everyday tool to help (cognitively impaired) individuals remember tasks, items, or important routines would seemingly become obsolete. Relying on simple analog reminders, such as sticky notes, underscores a deeper need. These reminders are not successful because of technological sophistication; rather, they offer low-effort, context-aware, personally meaningful cues that fit seamlessly into daily life. They support cognition without overwhelming it, providing timely nudges in familiar environments. However, while sticky notes can support basic memory functions, they lack adaptability, personalization, and integration with dynamic

[1] This may seem counterintuitive at first, but most of the concepts can be applied similarly, while some are explicitly tied to aMCI (Bai et al., 2022; Gazzaniga et al., 2018; Petersen, 2016; Petersen et al., 2018; Yu et al., 2017).

routines or health-related feedback. Digital systems could adopt this concept to preserve the intuitive, cognitively light-touch qualities of tools like sticky notes while offering greater intelligence, personalization, and adaptation to support the autonomy and long-term engagement of people with cognitive impairments.

However, existing digital assistance or decision support systems, often in the form of Ambient Assisted Living (AAL) technologies, tend to focus on passive monitoring rather than actively engaging users in cognitive scaffolding processes that promote self-regulation, preserve autonomy, and facilitate learning (Zhu et al., 2020; Singh et al., 2011; Yu et al., 2021). These systems, while technologically sophisticated, often treat users as passive recipients of care rather than active participants in their own routines and decisions. Their practical design reflects an instrumental logic - focused on task completion and risk avoidance - rather than an understanding of the cognitive processes, learning trajectories, and self-efficacy dynamics that shape meaningful engagement with technology.

This reveals a critical shortcoming: without a theoretically grounded understanding of how individuals with cognitive impairment engage with technology, such systems risk undermining exactly the autonomy they aim to protect. For example, a system that simply switches off the stove after a period of inactivity may prevent harm, but it also removes the opportunity for the user to remember, learn, or be gently guided through the task themselves. This oversight, where the 'how' of the intervention is detached from the 'why' of cognitive support, reveals a critical underlying problem: in the absence of cognitive support mechanisms that are informed by theory, such interventions drift into overprotective automation - subtly reinforcing dependence and passivity rather than fostering adoption and engagement.

Augmented Reality (AR) and Artificial Intelligence (AI), particularly deep learning approaches, hold great promise for developing more accessible, context-aware digital health solutions (Dhiman et al., 2022; Maedche et al., 2019). Still, their success is contingent upon a set of critical conditions: the technological environment must be mature enough to enable real-time responsiveness, the ethical and privacy frameworks must safeguard vulnerable users, and the interaction designs must be rooted in an understanding of the cognitive realities of the target population (Bharati et al., 2023; Ferrari et al., 2019; Yu et al., 2018). Once these contextual, infrastructural, and design-specific prerequisites are met, AR and AI can evolve from novelty to transformational forces that support cognitive autonomy. However, traditional wearable AR devices, such as head-mounted displays (HMDs), pose significant usability challenges for individuals with MCI, including restricted fields of view, limited battery life, and complex interactions (Biocca et al., 2014; Margrett et al., 2022; Seifert & Schlomann, 2021; Steffen et al., 2019; Vertucci et al., 2023). These devices often fail to address the nuanced needs of this vulnerable population because they cannot be worn preventively or for extended periods to provide timely warnings or guidance – let alone for 1-2 hours at a time. Spatial Augmented Reality (SAR), an alternative that utilizes projections rather than HMDs, could alleviate these burdens by reducing cognitive load and enhancing everyday usability (Baumeister et al., 2017; Mousavi Hondori et al., 2013; Raskar et al., 1998; Yang et al., 2018). Despite its potential, SAR is understudied in digital health and cognitive assistance research. Existing solutions often focus on static reminders rather than dynamic, personalized support (Cardoso et al., 2020; Tavares et al., 2019; Yang et al., 2018; Wegerich et al., 2010). Concurrently, synthetically generated image data for training deep learning models has shown promise in improving the predictive performance and efficiency of computer vision, yet it remains largely unexplored in digital health contexts (Aranjuelo et al., 2021; Hinterstoisser et al., 2019; Kucharski & Fabijanska, 2023; Scheck et al., 2020) as well.

This confluence of factors reveals an unresolved research gap: although innovative technologies, such as SAR and AI, show great promise in assisting individuals with aMCI, there is a lack of theoretical and practical knowledge regarding the design and integration of intuitive, indirect, and genuinely user-centered systems. More critically, current research lacks a coherent theoretical foundation explaining *why* or *how* such technologies can foster long-term autonomy and cognitive engagement in this vulnerable population. While existing theories from Information Systems (IS) research, cognitive psychology, and the social sciences offer valuable, albeit fragmented, insights, an integrative theoretical model is needed to explain how cognitive characteristics influence the adoption (i.e., actively choosing

to use a technology) and sustained use (i.e., health behavior changes based on that use) of digital health technologies. This dissertation addresses exactly that gap by seeking to develop a *Cognitive Adoption Theory* – a mid-range IS theory that explains the cognitive mechanisms, aspects, and boundary conditions that shape technology adoption and health behavior change among people with cognitive impairments.

Here, while SAR-based interventions can provide context-aware, cognitively light-touch support and AI-driven HCI approaches show technical potential, these efforts often fall short due to this insufficient theoretical grounding, particularly regarding the cognitive mechanisms that shape the adoption, adaptation, and behavioral changes of people with cognitive impairments (Böhmer et al., 2024). Additionally, although various AI-driven HCI approaches have been explored, they often lack accessibility, affordability, and usability for individuals with aMCI and their specific cognitive conditions (Ando et al., 2022; Iversen & Joshi, 2015; Mavropoulos et al., 2021; Prakash & Das, 2020; Williams et al., 2016). It is precisely this gap that this dissertation aims to address: not merely by theorizing and developing a theoretical model that explains the cognitive adoption of digital health technology, but by grounding it in the iterative development and evaluation of such an assistive information system - particularly the *Augmented Living Space* - as a lens and example to theorize, explain, and develop the cognitive underpinnings of digital health adoption.

Thus, this dissertation's central idea revolves around the *Cognitive Adoption Theory*, which is grounded in and motivated by the concept of Augmented Living Spaces. This concept envisions living environments enhanced by SAR and AI, which provide seamless, intuitive, and adaptive cognitive support – ultimately addressing the cognitive aspects that are often overlooked in conventional AR or wearable-based systems. These traditional solutions tend to prioritize technical novelty or functional automation over user-centered cognitive alignment, leading to designs that are too complex, cognitively demanding, or misaligned with the mental models and capacities of people with cognitive impairments. By laying the practical foundations for the culminating *Cognitive Adoption Theory* as the main objective of this dissertation, the exemplary concept of Augmented Living Spaces aims to move "beyond the sticky note", offering a more intuitive, digitally integrated, and theoretically grounded approach to assisting individuals with aMCI. This approach involves projecting timely warnings and daily guidance directly into their living spaces (e.g., some widgets alert users when the stove has been left on or when it's time to take medicine). Thus, by projecting the right information at the right time and place, it may reduce reliance on cumbersome wearables and foster autonomy in everyday settings, where sticky notes quickly reach their limits. Therefore, the main goal of this dissertation is as follows:

> **Goal:** To develop a *Cognitive Adoption Theory* that explains how cognitive mechanisms influence the adoption and sustained use of digital health technologies, and the resulting health behavior changes, among individuals with cognitive impairments.

To achieve this goal, this dissertation adopts a multi-cyclical Design Science Research (DSR) approach, as advocated by Vaishnavi and Kuechler (2015), coupled with theoretical pluralism (Hirschheim & Klein, 2012; Gioia & Pitre, 1990; Lee et al., 1991; Leidner & Gregory, 2024; Mingers, 2001). This overarching methodology allows for the rigorous examination of the complex interplay between user needs, technological capabilities, and theoretical underpinnings. This approach not only clarifies *what* occurs (e.g., low adoption rates or usability issues) but also explains *why* these occurrences happen by identifying underlying mechanisms, such as cognitive overload, the significance of social support, and the alignment between technology and user needs. The DSR process unfolds across three iterative cycles, each of which is triggered by problem awareness arising from demographic changes, the prevalence of neurodegenerative diseases, low technology adoption among vulnerable populations, and emerging technological advancements. Each cycle aims to produce "useful products" in IS theorizing and practical applications of these concepts (Hassan et al., 2022). To inform and ground this theorizing, the dissertation draws on insights from designing and evaluating an exemplary digital health intervention (the Augmented Living Spaces context), having a practical foundation yet an explicit theoretical and conceptual focus, with the overarching goal of developing a *Cognitive Adoption Theory*.

These design cycles will address specific research questions (see Chapter 2.2) that build upon each other progressively, yet inform each other back and forth. The first design cycle focuses on establishing the foundational design theory and reference architecture for the Augmented Living Spaces concept, paving the way to theorize which aspects/mechanisms drive technology adoption among individuals with aMCI in practice. The second design cycle delves into creating an intuitive, indirect, and user-centered interaction design approach based on the findings from the first cycle using a synthetically trained deep learning model. It also develops design heuristics for the ethical use of synthetic data in digital health contexts, which are based on questions that arose throughout this cycle. These insights refine the practical instantiation of the Augmented Living Spaces concept (i.e., design theory and reference architecture) and reveal key cognitive, behavioral, and ethical dimensions that inform the conceptual foundations and boundary conditions of the *Cognitive Adoption Theory*. Finally, the third cycle culminates in the proposal of the *Cognitive Adoption Theory* as the main artifact of this dissertation, which integrates insights from Cognitive Load Theory (CLT), Social Cognitive Theory (SCT), metacognition, and the prior two cycles, explaining how cognitive factors influence digital health adoption and behavior change.

To structure this dissertation accordingly, Chapter 2 of this dissertation presents the overarching research goal, research questions, and the DSR approach employed across all design cycles.

Chapter 3 details the first design cycle and addresses the inadequate support for the everyday lives of individuals with (a)MCI. This cycle produced two key artifacts: a design theory for Augmented Living Spaces and a reference architecture that instantiates this theory. Although these insights provide the conceptual foundations for the *Cognitive Adoption Theory* and evaluations confirmed the viability of the SAR-based approach, limitations in the granularity of intuitive interaction design and the abstractness of the architecture for real-time applications required a more targeted, technically focused, second cycle.

Based on these findings, Chapter 4 describes the second design cycle, which was initiated to provide a more detailed, technically operationalized, and ethically sound HCI approach within the Augmented Living Spaces context – further developing the conceptual and practical foundations for the *Cognitive Adoption Theory*. First, the "ConZones" HCI approach was developed, which uses an intuitive, location-based interaction mechanism with a synthetically trained deep learning model. It was found to be usable, intuitive, and effective. Second, the cycle conceptualized a design theory for the responsible use of synthetic image data in digital health AI. However, the cycle still revealed a significant research gap: the absence of an explanatory IS theory on how cognitive impairments affect the adoption and engagement with digital health information systems. This gap motivated the third design cycle.

Chapter 5 presents the third design cycle, which shifts from artifact development to a theory-oriented contribution. This cycle developed the *Cognitive Adoption Theory*, which is an explanatory, mid-range theory to understand digital health adoption by individuals with cognitive impairments. This theoretical artifact offers a conceptual model and an integrated framework. Thus, it fulfills the DSR imperative to contribute generalizable knowledge beyond specific solutions. In doing so, it concludes the multi-cyclical DSR approach by addressing the problem both practically and conceptually.

Subsequently, Chapter 6 discusses the cycle-specific and overarching contributions, implications, limitations, and opportunities for future research based on the findings of this dissertation. Finally, Chapter 7 concludes the dissertation with some final remarks.

2 Research Design

Building on the overall goal of proposing a *Cognitive Adoption Theory*, this dissertation explores the complex interplay of factors that influence the design and adoption of digital health technologies by individuals with cognitive impairments. Hence, this dissertation deals with a vulnerable user group (primarily older adults with cognitive impairment) interacting with innovative digital health tools (e.g., memory support apps, cognitive training software, smart home sensors, AR) within a broader socio-technical environment (caregivers, healthcare providers, technology designers, and infrastructure). This scenario is inherently multifaceted: biological and cognitive factors influence technology use, social

support and perceptions matter, and the technical design itself can enable or hinder adoption. Figure 1 shows a very high-level summary of the mentioned DSR-structure and logic applied in this dissertation, presenting the three undertaken cycles, their distinct objectives, and how these contribute to the overall goal of developing the *Cognitive Adoption Theory*.

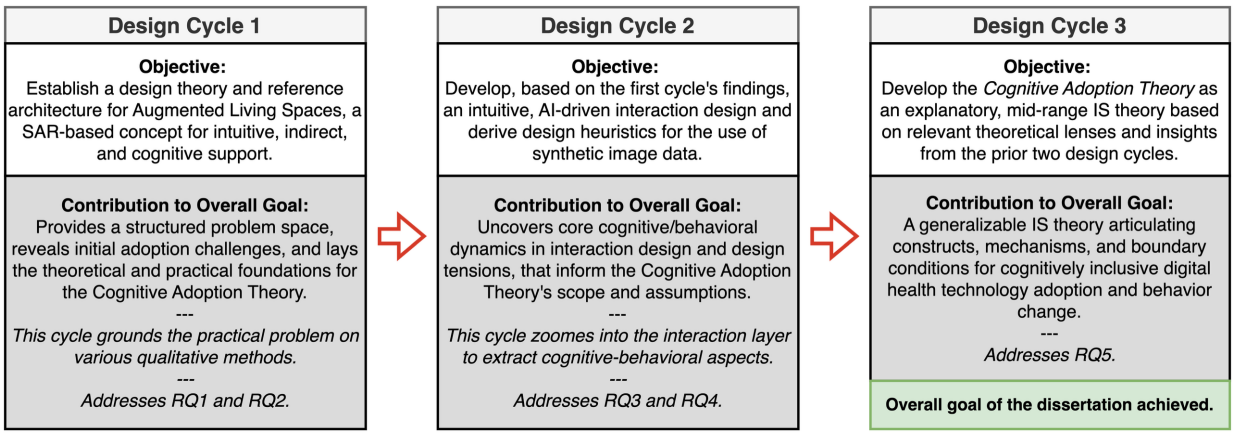


Figure 1. Summary of the research logic towards the overarching goal, following three DSR cycles according to Vaishnavi and Kuechler (2015).

2.1 Guiding Research Questions

To move beyond fragmented insights and ad hoc solutions, we need an integrated, theoretically grounded body of (design) knowledge connecting aspects from cognitive theories, practical design, and real-world technological interventions. In other words, we must develop better systems and understand *why* and *how* they work (or don't) for people with cognitive impairments. This knowledge can then be reused, adapted, and generalized beyond the theoretical discourse in IS. Picking up the overall goal of this dissertation as stated in Chapter 1, this objective reflects both the means (iteratively developed artifacts and a theoretical model of cognitive adoption) and the end (design knowledge that is valid, useful, and generalizable within the IS discipline and digital health domain). As such, the general objective provides a coherent foundation for the research questions and methodology of this dissertation, forming a structured approach to bridging the gap between theory and practice.

This orientation generally aligns well with the DSR methodology, which involves the development of various *socio-technical* artifacts (e.g., decision support systems or digital health interventions) that can take different forms such as more abstract, complete, and mature knowledge (i.e., design theories, constructs, models) or more specific knowledge (i.e., instantiations and/or prototypes) (Gregor & Hevner, 2013) in the domains of *applying*, *solving*, *designing*, and *theorizing* in IS (Brendel et al., 2022). As shown in Figure 1, a multi-cyclical DSR approach was chosen, following Vaishnavi and Kuechler (2015). This approach, in the context of this dissertation, essentially moves from a more practical, specific solution that supports individuals with aMCI in everyday life to a broader, generalizable theoretical model of cognitive adoption among individuals with cognitive impairments in digital health IS. Addressing the overall goal of this dissertation, a variety of research questions have been conceptualized. While being targeted at the cycle-specific research approaches, they were intended to serve the overarching goal of developing the *Cognitive Adoption Theory*, providing both a tailored digital health solution for individuals with aMCI via the Augmented Living Spaces concept (as well as causally occurring phenomena such as synthetic image data) and theoretical (design) knowledge to guide future IS research.

The first design cycle had an explicit focus on laying the conceptual and practical foundations for the *Cognitive Adoption Theory*. Based on the challenge that conventional AR approaches are insufficient, cumbersome, and cognitively overwhelming, the first cycle had the overarching sub-goal of conceptualizing and developing one possible SAR-driven solution to provide adequate digital support in everyday life among individuals with aMCI – just like sticky notes brought to life. By theorizing,

designing, and thus solving the problem of insufficient digital support for individuals with aMCI in everyday life, the idea emerged to develop a design theory (and reference architecture via circumscription) upon which to instantiate the concept of an *Augmented Living Space*. Design theories in IS research provide actionable, theory-informed guidance for developing effective solutions to real-world problems (Young & Zhu, 2021). Unlike purely explanatory theories, their value lies in their ability to inform and shape the design of socio-technical systems (Jones & Gregor, 2007; Leidner & Gregory, 2024). By combining normative insights (*what should be done*) with descriptive understanding (*what is*), they help structure both the design process and the resulting artifacts (Walls et al., 1992; Goldkuhl, 2004). In this dissertation, the goal is not only to develop such design knowledge in the context of digital health systems for individuals with cognitive impairments – but to theorize *why* and *how* certain designs work by working towards the *Cognitive Adoption Theory*.

Similarly, driven by the circumscription in the first design cycle, reference architectures are more practical, actionable, and low-abstract tools to support IS development (Cloutier et al., 2009; Nakagawa et al., 2011; Oussalah, 2023). In other words, these "architectural blueprints" offer structured approaches that guide the design, implementation, and maintenance of information systems, ensuring coherence and manageability across diverse organizational contexts. Thus, at its core, a reference architecture can be understood as a generic architecture that delineates the typical structure of a system, providing a framework of its essential components, their interrelationships, guiding principles, and overarching architectural guidelines (Angelov et al., 2009). As such, reference architectures are a useful product in IS theorizing, possibly embodying a framework, model, or concept (Hassan et al., 2022).

Since a lack of guiding (design) knowledge on how to adequately support people with aMCI in their daily lives with innovative digital health tools was identified, it seemed reasonable to theorize, design, and solve this problem by developing the conceptual foundations for such an assistive IS based on SAR. Consequently, this first design cycle was aimed at answering the following research questions:

RQ1: *How can spatial augmented reality be effectively integrated into an information system to support the autonomy and cognitive functions of people with amnestic mild cognitive impairments, and what are the underlying cognitive aspects/mechanisms driving the adoption of such a system?*

RQ2: *What are the design heuristics as well as the textual descriptions, models, and model elements of a system reference architecture for such an Augmented Living Spaces information system?*

These two research questions, along with the methods used and the findings, are discussed in detail in Chapter 3.

Subsequently, the second design cycle had a stronger focus on designing and solving in the context of the design theory and reference architecture as output from the first cycle. The evaluation results suggested a deeper analysis and development of the proposed interaction design within the Augmented Living Spaces concept, which served as an overarching sub-goal to zoom into the interaction layer and extract cognitive-behavioral aspects/mechanisms for the *Cognitive Adoption Theory*. Especially given the context of cognitive impairments, technology adoption, and use, the design of effective and intuitive interfaces is no longer a secondary consideration but a critical determinant of the usability, user adoption, and ultimate success of information systems across a multitude of application areas (Ienca et al., 2021). There is a fundamental conceptual shift towards design that places the user at the forefront, considering their specific needs, tasks, goals, and the diverse contexts in which they will utilize the technology (especially when it comes to cognitive impairments) (Bala & Damla, 2021).

Viewing these cognitive aspects/mechanisms relevant for the *Cognitive Adoption Theory* from a more technical and implementation-oriented perspective, the idea arose to develop and position a novel interaction design within the broader discipline of HCI. The objective was to offer a rethought approach to intuitive interaction design that aims to empower individuals with aMCI through a practical, solution-oriented approach, based on which aspects, evaluation results, and mechanisms could be extracted to deductively inform the *Cognitive Adoption Theory*. Based on the conceptual knowledge from the first

cycle, an explicit focus on SAR was chosen over other AR approaches because it allows interaction without the need for constantly worn devices, which, in their complexity, are "too hard to handle" and can be cumbersome for people with aMCI due to their physical and cognitive limitations.

Given the lack of such interaction design approaches and the potential benefit wearable-less SAR, it seemed reasonable to conceptualize the interaction design based on a deep learning tracking model, because it enables the system to precisely and unobtrusively (i.e., since people are tracked as a rectangle indicating their position) detect where individuals are within their living space, which is the foundation for triggering timely, context-aware SAR projections that support memory and autonomy. Without this AI-driven tracking of persons and objects in the room, the SAR-based environment would lack the real-time positional awareness needed to deliver intuitive, passive assistance (or would require additional wearables) – rendering the entire interaction design ineffective for the target population's cognitive needs.

Because such datasets (i.e., 360-degree fish-eye room images) to train potential deep learning models are scarce, the idea arose to generate and use synthetic image data (i.e., artificially created but photorealistic data) as a cost-effective, less error-prone, and scalable alternative. This approach led to the circumscription encountered in the second cycle (Figure 2), as there was a lack of knowledge on how to effectively and ethically use synthetic image data in digital health deep learning, which ultimately led to the need to develop a design theory in this context (akin to the first cycle, but in a different context), complementing the novel interaction design approach. Consequently, the second design cycle was aimed at answering the following research questions:

RQ3: *How can AI-based tracking and SAR be leveraged to enable an intuitive, wearable-free interaction design for individuals with amnestic mild cognitive impairments in the context of the augmented living spaces design theory?*

RQ4: *What are the design heuristics to ethically and effectively utilize synthetic image data in digital health computer vision environments, such as the augmented living spaces interaction design, considering potential tensions between ethical compliance and operational effectiveness?*

These two research questions, along with the methods used and the findings, are discussed in detail in Chapter 4.

Finally, the third design cycle, with its explicit focus on theorizing, was based on the idea of building on the knowledge generated in the first two cycles, along with additional theoretical concepts. Addressing the overarching goal of the multi-cyclical DSR approach and dissertation in general, this cycle's objective was to propose a *Cognitive Adoption Theory* that explains the cognitive processes, aspects, and causal mechanisms inherent in technology adoption and health behavior change among people with cognitive impairment. In general, theorizing has deep roots in IS research (Gregor, 2006; Hassan et al., 2022; Leidner & Gregory, 2024), and recent conversations push for rethinking, integrating, and developing new theoretical frameworks (Burton-Jones et al., 2021; Young et al., 2021). Drawing from Leidner and Gregory's (2024) perspective, theory here is not merely a set of constructs or variables but a coherent explanation framed within boundary conditions that elucidates causal mechanisms. Addressing the overarching goal of this dissertation, the third cycle aimed to move beyond artifact design and instead develop a mid-range theory that explains *why* and *how* digital health technologies – such as those conceptualized and prototyped in the first two cycles – can lead to sustained technology use and long-term behavior change in individuals with cognitive impairments.

Hence, the idea was to shift from *designing for cognition* to *theorizing about cognition* in the third design cycle, addressing the lack of kernel theories adequately explaining the cognitive factors that lead to technology adoption and sustained health behavior change in the context of cognitive impairments. By engaging critically with existing literature and surfacing tensions between disparate theoretical perspectives, the third design cycle was aimed at enabling the construction of a theory that is both explanatory and insightful. The resulting *Cognitive Adoption Theory* seeks to offer not only descriptive

and analytical clarity but also revelatory insight, enabling researchers and practitioners to better understand and support cognitive adoption in digital health contexts.

Thus, it addresses a gap in the theoretical discourse around technology acceptance/adoption[2], namely that cognitive adoption in the context of cognitive impairment requires a broader perspective and raises questions about the mechanisms of cognitive adoption and behavior change that cannot be explained by any one theory alone (e.g., CLT or SCT). Consequently, this design cycle was aimed at answering the following research question:

RQ5: *How to theoretically model the influence of cognitive aspects on digital health adoption and health behavior change in the context of cognitive impairment by considering cognitive load, social cognitive theory, metacognition, and the findings from the first two design cycles?*

This research question, along with the methods used and the findings, are discussed in detail in Chapter 5.

2.2 Overarching Design Science Research Methodology

Addressing the overall aim of proposing a *Cognitive Adoption Theory*, this dissertation generally draws on the DSR paradigm (Hevner et al., 2004). With that overarching goal in mind, it shifts from solely *doing DSR* to *using DSR to build theory* in that context. Rather than showcasing DSR, this dissertation uses DSR cycles to enable theory development grounded in real-world interventions and theory. As such, it seeks to provide prescriptive insights for research on cognitive support through digital technology rather than merely descriptive knowledge, as outlined by Gregor and Hevner (2013). In other words, DSR projects evolve around the iterative design and evaluation of artifacts as solutions to prevalent problems (Hevner et al., 2004; Iivari, 2015) and the development of prescriptive knowledge about the effective design of such artifacts (Baskerville et al., 2018; Gregor, 2006).

To achieve a holistic and nuanced understanding of cognitive adoption in digital health, a multi-cyclical DSR approach following Vaishnavi and Kuechler (2015) is adopted, akin to the multi-perspective research orientation in IS (Avison & Wood-Harper, 1990; Avison & Fitzgerald, 1998; Linstone, 1981). This approach, summarized in Figures 1 & 2, generally structures the research design around three subsequent design cycles (Vaishnavi & Kuechler, 2015) that could also be seen as DSR pathways in complex socio-technical research contexts involving multiple perspectives (Tuunanen et al., 2024). Here, the chosen DSR process framework proposed by Vaishnavi and Kuechler (2015) outlines five key phases for conducting research focused on creating such innovative artifacts.

[2] In IS research, especially in the HCI discipline, the terms of ‘acceptance’ and ‘adoption’ are mainly used interchangeably (Blut et al., 2022), whereas acceptance is much more present, mostly due to its use as a major aspect in the TAM and UTAUT contexts. Traditionally, acceptance indicates a passive receipt of what is being offered, akin to someone utilizing a health app even though they have no intrinsic motivation to do so. However, as this dissertation advocates for the seamless assimilation of technological tools and digital health systems, it becomes crucial to shift the vocabulary and mindset to that of ‘adoption’. Adoption, as opposed to mere acceptance, is inherently voluntary and involves a conscious decision to endorse, integrate, and incorporate technology (Karahanna et al., 1999). This nuance adds layers of complexity, suggesting a proactive engagement with the technology rather than a mere acquiescence. Therefore, emphasizing adoption over acceptance offers a richer and more comprehensive understanding of how individuals come to truly embrace technological innovations from a cognitive adoption perspective.



Figure 2. Detailed summary of the DSR cycles conducted within this dissertation.

As shown in Figure 2, the process begins with **Awareness of Problem**, where the researcher identifies an interesting problem, often arising from practice, experience, or gaps in existing literature, and culminates in a research proposal. This leads to the **Suggestion** phase, a rather creative step in which a preliminary design or solution to the problem is conceptualized, possibly drawing on existing knowledge bases or novel configurations. The third phase, **Development**, involves the implementation of the tentative design into a concrete artifact, which could range from a mature design theory (i.e., more formal and theorized knowledge) to a software system built using that design theory; the novelty lies primarily in the design, not necessarily in the construction technique. Development is followed by the **Evaluation** phase, where the performance of the artifact is assessed against implicit or explicit criteria. Deviations from expected results are examined analytically, often leading back to the awareness of problem phase via *circumscription* - a process of learning by observing what doesn't work according to theory – or triggering a new design cycle. This process allows researchers to incorporate valuable "constraint knowledge" gained from analyzing these deviations and artifact performance, thereby refining the understanding and definition of the original problem – whether it is a revision of the problem statement or the start of a new design cycle. Finally, the **Conclusion** phase consolidates the knowledge gained by documenting the research results, identifying established findings ("firm" knowledge), noting anomalies ("loose ends") for future investigation, and positioning the contribution within the field of IS research.

As can be seen in Figure 2, the five process phases proposed by Vaishnavi and Kuechler (2015) served as a framework for structuring three subsequent design cycles, each triggered by either theoretical ambiguity, practical insufficiency, or the identification of novel problem spaces through *circumscription* (i.e., iterative in-cycle refinement through reflection on design performance) (Vaishnavi & Kuechler, 2015; Bider et al., 2020). As such, the first design cycle's initial problem statement was revised mid-cycle as constraints were encountered during development (i.e., lack of guiding technical design knowledge in the context of the developed design theory), marking a canonical form of circumscription as defined in the DSR model. Similarly, in the second cycle, the misunderstanding or partial treatment of the original problem necessitated a midstream redefinition of the problem space, illustrating another instance of circumscription-triggered iteration (i.e., lack of guiding design knowledge on how to utilize synthetic image data in digital health deep learning) as described in the model.

Consequently, to effectively manage the inherent complexity and iterative nature of developing and evaluating novel solutions for technology adoption by people with aMCI across conceptual, technical, and theoretical domains, the echeloned DSR methodology proposed by Tuunanen et al. (2024) is employed as a complementary organizing logic of this dissertation (Table 1). Here, the general DSR process framework (Vaishnavi & Kuechler, 2015; Figure 2) provides the overarching macro-level structure for the research journey, ensuring a systematic progression through the five process stages across the three design cycles. The echelon DSR methodology complements this by providing a micro-level structuring mechanism that breaks down the activities within and across these cycles into five distinct, logically coherent, and self-contained "echelons": *Problem Analysis*, *Objectives & Requirements Definition*, *Design & Development*, *Demonstration*, and *Evaluation*. Similar in terms of its methodical alignment, this echelon approach is not intended to replace the chosen DSR process model, but rather to enhance its application, particularly in complex socio-technical projects where the problem and solution spaces evolve over multiple cycles. As such, each echelon focuses on producing and validating a specific intermediate artifact (e.g., a validated problem statement, validated design objectives, a proof-of-concept, or a proof-of-value), allowing for early feedback, focused iteration, and rigorous validation at each step. As shown in Table 1, these levels serve as pathways within each cycle (Tuunanen et al., 2024), ensuring that specific, validated contributions - from identifying knowledge gaps to developing design theories, reference architectures, novel interaction designs, and theoretical models - are systematically addressed and validated. The interplay between the general DSR cycles and the echelon pathways is necessary; the former provides the overall research trajectory, while the latter provides the fine-grained organizational structure required to navigate the complexity of the project, manage the development of multiple artifacts, and ensure the rigorous, iterative nature of this DSR project.

Echelon Type	Intermediate Artifact	Cycle-specific Micro-level Components and Pathways
Problem Analysis (validated problem statement)	Problem statement articulating the need for adequate digital support and explanatory theory in the context of technology adoption for people with aMCI	**Cycle 1**: Identified lack of conceptual, technical design knowledge for developing SAR-based Augmented Living Spaces to support people with aMCI. **Cycle 2**: Identified a lack of intuitive interaction knowledge (HCI-level) for people with aMCI coupled with synthetic image data usage in digital health AI. **Cycle 3**: Identified a theoretical gap in explaining cognitive adoption of digital health technologies by cognitively impaired individuals → *Guiding problem analysis of this dissertation*
Objectives & Requirements Definition (validated design objectives)	Explicit design objectives and requirements for design theory, technical implementations, and explanatory IS theory	**Cycle 1**: Defined conceptual requirements for SAR-based Augmented Living Spaces supporting daily autonomy. **Cycle 2**: Defined intuitive, indirect interaction design (ConZones) and synthetic image data requirements for effective and ethical deep learning models (echelon redefinition akin to circumscription in Figure 1). **Cycle 3**: Defined theoretical requirements for a cognitive adoption framework integrating relevant cognitive theories.
Design & Development (validated artifact design)	Projectable solution designs: Design principles, reference architecture, novel HCI approach, AI-model, theory model	**Cycle 1**: Developed an emancipatory design theory; conceptualized reference architecture (component, sequence, class, UI-level[3]) for SAR-based Augmented Living Spaces. **Cycle 2**: Developed an intuitive HCI interaction design (ConZones); deep learning model trained on synthetic images; emancipatory design theory for synthetic data use **Cycle 3**: Developed *Cognitive Adoption Theory* (Type-II IS theory) explaining cognitive mechanisms influencing digital health adoption.
Demonstration (validated Proof-of-Concept - PoC)	Instantiated artifact scenarios demonstrating practical feasibility	**Cycle 1**: Scenario-based prototype demonstrating feasibility of SAR-supported daily activities in Augmented Living Spaces. **Cycle 2**: Scenario instantiation demonstrating feasibility of intuitive interaction with ConZones using AI model trained on synthetic data; Instantiation of design theory **Cycle 3**: Conceptual demonstration of the applicability of the *Cognitive Adoption Theory* propositions.
Evaluation (validated Proof-of-Value - PoV)	Contextualized artifact evaluation confirming utility, efficacy, and theoretical rigor	**Cycle 1**: Expert and target-group evaluation strategy validating conceptual clarity and identifying need for detailed HCI interaction design (re-evaluation in echelon pathway). **Cycle 2**: Empirical evaluation via think-aloud sessions, expert and user evaluations, deep-learning benchmarks; validated reusability, effectiveness, and ethics of synthetic data approach. **Cycle 3**: Conceptual evaluation through methodological approach and theoretical coherence, explanatory power, and generalizability of theory aspects/concepts.

Table 1. Complementary organizing logic of complexity for the dissertation following the DSR echelons approach proposed by Tuunanen et al. (2024).

[3] The UI-level refers to the mode of representation (e.g., forms, colors, fonts, widget-size, animations, etc.).

To navigate the inherent complexity of the overarching goal of this dissertation, the DSR Focus Matrix (DSRFM) by Brendel et al. (2022) is employed. It serves not merely as a classificatory tool but as an ex-ante strategic instrument to reflect and articulate the alignment between the research questions, artifact types, and the evolving theoretical/practical contributions across the three design cycles. In other words, it classifies the focus under which this dissertation and its artifacts should be viewed. While the Vaishnavi and Kuechler (2015) process model structures the macro-sequence of the research and the Tuunanen et al. (2024) echelon framework guides the micro-level execution of each cycle, the DSRFM provides a meta-perspective to reflect on the research focus and position the resulting artifacts and contributions across the design cycles, showing how the research questions have been addressed.

As such, the DSRFM offers a valuable framework to position and clarify the specific focus of DSR efforts across multiple research cycles by distinguishing two key dimensions: the nature of the *contribution* (ranging from instantiations to design theories) and the *research approach* (balancing rigor and relevance). Given the ongoing challenge of presenting DSR contributions to an IS community traditionally grounded in the social sciences and focused on descriptive knowledge (Gregor, 2006; March & Smith, 1995), the DSRFM enables a more transparent articulation of the theoretical and practical value embedded in design-oriented work. Moreover, it directly addresses the conceptual confusion in the DSR community (Iivari, 2015; Kuechler & Vaishnavi, 2008), where diverging understandings of strategy, contribution, and genre have led to inconsistent evaluations by reviewers and editors (Tremblay et al., 2018; Rai et al., 2017). By using the DSRFM, this dissertation avoids the so-called "area of confusion" - an unfocused approach that attempts to maximize all aspects simultaneously - and instead demonstrates a strategically positioned, multi-cycle DSR process that balances contribution and approach to create both actionable solutions and theoretical advances (Brendel et al., 2022).

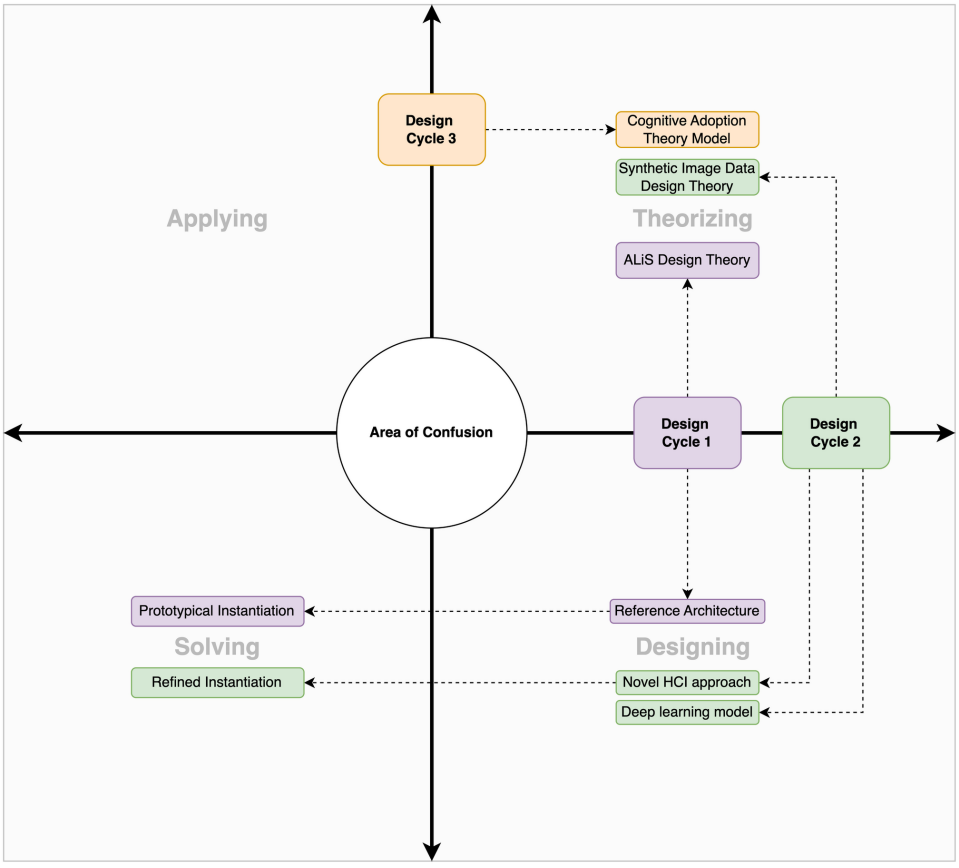


Figure 3. DSR focus matrix allocation of this dissertation according to Brendel et al. (2022).

As shown in Figure 3, in this dissertation, three distinct but interrelated design cycles are positioned within different quadrants and intersections of the DSRFM. Driven by the conceptual and practical nature of **RQ1** and **RQ2**, the first design cycle lies at the intersection of the *Theorizing* and *Designing* quadrants, reflecting a focus on heuristic theorizing and the development of a design theory, complemented by the instantiation of the Augmented Living Spaces concept to demonstrate problem-solving utility in the *Solving* quadrant. This cycle is positioned at the intersection of the designing and theorizing quadrants, as it embodies the dual goals of exploring a wicked real-world problem - supporting autonomy in people with aMCI through SAR - and generating abstract design knowledge for the ultimate goal of developing the *Cognitive Adoption Theory*. The design theory artifact developed here may reflect a high value in *rigor* through reasoning informed by various knowledge bases, while the instantiation of the Augmented Living Spaces concept in a scenario-based prototype may reflect *relevance* and a focus on tangible utility. Thus, the contributions span *abstraction* (design theory) and *specification* (instantiation), capturing the iterative "learning by building" nature based on circumscription typical of the designing quadrant and formalizing prescriptive design knowledge for a broader class of problems (Brendel et al., 2022).

Addressing the more granular and technical demands of **RQ3** and **RQ4**, the second design cycle continues within this intersection, now emphasizing the *Designing* quadrant through its focus on developing HCI artifacts through deep learning, while again contributing to the *Solving* quadrant through instantiation, and to the *Theorizing* quadrant through abstracted knowledge about the effective and ethical use of synthetic data. It continues to emphasize the designing quadrant but shifts closer to the solving quadrant, as it seeks to address a concrete, wicked problem: enabling intuitive interaction design for individuals with aMCI using a deep learning model trained on synthetic image data, which is aimed at providing (design) knowledge to inform the development of the *Cognitive Adoption Theory*. The cycle foregrounds *relevance* through the practical exploration of under-researched requirements (interaction design and synthetic training data), while simultaneously deriving an emancipatory design theory, representing *abstraction* through a reflective theorizing process grounded in observed design tensions (Brendel et al., 2022). As such, it resonates with the "designing by exploring" paradigm, where artifact instantiation supports action and informs a higher-level abstraction, demonstrating both creativity and methodological rigor.

Ultimately serving the theoretical and conceptual demands of **RQ5**, the third design cycle, while not explicitly a formal DSR study, aligns with the *Theorizing* quadrant and partially with the *Applying* quadrant as it synthesizes existing theoretical and practical knowledge into a new explanatory IS theory (Gregor, 2006). Here, the contribution of the *Cognitive Adoption Theory* is characterized by *rigor*, drawing heavily from existing kernel and mid-range theories, and focuses on the *abstraction* of theory rather than the specification of an artifact. At the same time, by synthesizing insights from prior cycles and aligning them with broader theoretical traditions, this cycle also implicitly touches on the applying quadrant, where instantiation is less important than theory-informed reasoning that deepens understanding and positions the findings within the scientific knowledge base (Brendel et al., 2022).

2.3 Multi-Method Paradigm

Addressing the complex problem of facilitating technology adoption and cognitive support among individuals with cognitive impairments requires more than a singular methodological lens. As shown in Chapter 2.1, each of the three design cycles in this dissertation addresses distinct research questions – ranging from conceptual design and system instantiation to theorizing cognitive adoption – that demand different types of evidence and analytical perspectives. As such, the choice of methods in this dissertation is explicitly driven by the research questions and knowledge objectives, not by an abstract commitment to methodological pluralism.

Anchored in the multi-cycle DSR approach outlined by Vaishnavi and Kuechler (2015) and recent conceptualizations of DSR as multi-echelons or "pathways" (Tuunanen et al., 2024), this dissertation employs a multi-method research design. This approach responds to a central insight from IS research methodology: that different forms of knowledge require different methods of inquiry (Gregor & Hevner,

2013; Mingers & Brocklesby, 1997; Venkatesh et al., 2013). As such, the multi-method design of this dissertation reflects the view that methodological rigor in IS stems not from methodological purity, but from alignment between the method and the knowledge to be produced.

Design Cycle	Applied Methodologies & Relevant Research Questions
First *(Design Theory & Reference Architecture)*	• *Heuristic Design Theorizing* (Gregory & Muntermann, 2014) in a theory-driven DSR approach (Schoormann et al., 2024) (**RQ1**) • Observational study for data gathering (**RQ1**) • Focus groups for data gathering and artifact evaluation (**RQ1**) • Qualitative content analysis (Mayring & Fenzl, 2019) (**RQ1**) • Complementary evaluation strategy via the *FEDS* framework (Venable et al., 2016) to get user experience insights (**RQ1 & RQ2**) • Think-aloud sessions for artifact evaluation (**RQ1 & RQ2**) • Questionnaires for artifact evaluation (**RQ1 & RQ2**) • Evaluation by operationalization and instantiation (**RQ1 & RQ2**) • *Design Science Validity Framework* for artifact validation (Larsen et al., 2025) (**RQ1**)
Second *(Novel HCI Approach & Design Theory for Synthetic Image Data)*	• AI research approach following the *DASC-PM* (Kuehnel et al., 2023) methodology and deep learning rigor (Schmidt et al., 2019) (**RQ3**) • Think-aloud sessions for data gathering and artifact evaluation (**RQ3**) • AI model training & benchmark evaluation (**RQ3**) • *Heuristic Design Theorizing* (Gregory & Muntermann, 2014) in a theory-driven DSR approach (Schoormann et al., 2024) (**RQ4**) • Qualitative and conceptual theory-building (Gioia et al., 2013; Magnani & Gioia, 2023) (**RQ4**) • Complementary evaluation strategy via the *FEDS* framework (Venable et al., 2016) and artifact reusability evaluation (Iivari et al., 2021) (**RQ4**) • Evaluation by operationalization and instantiation (**RQ3 & RQ4**)
Third *(Cognitive Adoption Theory)*	• *Theorize-from-the-Literature* approach following Leidner and Tona (2021) (**RQ5**) • Qualitative and conceptual theory-building (Gioia et al., 2013; Magnani & Gioia, 2023) (**RQ5**) • Theoretical synthesis and conceptual modeling, including causal explanations and relationships among theory constructs (**RQ5**) • Means of representation include words, descriptions, diagrams, and tables • Applied components of an IS theory (Gregor, 2006) (**RQ5**)

Table 2. Applied methodologies across all design cycles of this dissertation.

For example, the first design cycle, which addressed foundational conceptual and design-oriented questions (**RQ1** and **RQ2**) that were aimed at laying the conceptual and practical foundations for the *Cognitive Adoption Theory*, employed a mix of qualitative methods such as focus groups, think-aloud sessions, and observational studies alongside heuristic design theorizing to surface theoretical and practical foundations, requirements, and principles. The second design cycle, focused on operationalizing interaction design and synthetic data use (**RQ3** and **RQ4**), required a more technical perspective. Deep learning model techniques trained on synthetic image data, user-centered evaluation episodes, and heuristic design theorizing were applied to examine both the effectiveness and adoption implications of the proposed SAR-based interaction design. Finally, the third cycle, culminating in the *Cognitive Adoption Theory* (**RQ5**), utilized theorizing from the literature and theory integration methods

to conceptualize the cognitive aspects underlying digital health technology adoption and behavioral change. This theory-building process was further informed by findings from the first two cycles, as well as relevant kernel theories from IS, cognitive science, and behavioristic literature.

This layered and contextualized use of methods reflects the multi-perspective approach advocated by Churchman (1971), Mitroff and Linstone (1993), and Mingers and Brocklesby (1997). In the context of vulnerable populations and cognitively sensitive digital health systems, integrating personal, social, and technical perspectives is essential. In the context of this dissertation, such an approach allows to go beyond surface-level observations (e.g., solely focusing on practical feasibility or the theoretical discourse) to uncover the underlying cognitive, social, and technological mechanisms that govern technology interaction and adoption in this specific digital health context, ultimately serving the goal of proposing a *Cognitive Adoption Theory* that contributes to both theory and practice in the design of effective assistive technologies.

As shown in Table 2, various methods were used throughout the three design cycles, each selected to best suit the research questions and contextual requirements of the respective echelon pathway as per Tuunanen et al. (2024). A detailed explanation of how these methods were used and applied will follow in the respective design cycle chapters of this dissertation (i.e., Chapters 3, 4, and 5).

Thus, the overarching DSR framework on macro (Vaishnavi & Kuechler, 2015) and micro (Tuunanen et al., 2024) levels applying multiple methods within each and across the design cycles results in a methodological approach that is both comprehensive and deep: comprehensive in that it covers multiple facets (user, technology, context, theory) and deep in that it seeks explanatory depth (underlying causal forces and conditions).

This combination, which is based on the narrative of the research questions, strengthens the research in several ways: **(1)** It guards against oversimplified conclusions (because it doesn't look through a single theoretical/methodological lens). **(2)** It increases validity by triangulating findings - if a mechanism is suggested by focus group or think-aloud data (user perspective) and is also reflected in usage logs or observations (technical/actual events), one can have more confidence in its reality and can draw theoretical conclusions (theory perspective) for the overall goal of developing the *Cognitive Adoption Theory*. **(3)** It is well suited for making theoretical and practical recommendations - by understanding which factors (and at what level) are key enablers or barriers, interventions, and theoretical constructs can both be targeted accordingly (for example, if the study finds that "lack of caregiver support" is a critical mechanism behind non-use, stakeholders know to focus on caregiver training or involvement programs when rolling out the technology), which is crucial for the development of the *Cognitive Adoption Theory*.

In essence, this approach ensures methodological integrity and theoretical robustness by integrating multiple sources of evidence and modes of reasoning throughout the research journey. Each method is chosen not for the sake of methodological pluralism, but to serve a specific epistemic function within the DSR process - whether to uncover latent user needs, validate emerging design artifacts, or surface conceptual tensions that require theorizing.

2.4 Theoretical Pluralism

To achieve the overarching goal of developing a *Cognitive Adoption Theory* that robustly explains how cognitive mechanisms influence digital health technology adoption among individuals with cognitive impairments, this dissertation requires theoretical depth and integration across multiple perspectives. The five distinct research questions (RQ1–RQ5) address specific dimensions, ranging from the cognitive and behavioral factors that influence interaction designs to the ethical and socio-technical considerations involved in digital health interventions. Due to the multifaceted nature of these questions, theoretical pluralism is both reasonable and necessary. Drawing from diverse theoretical perspectives (kernel theories) from cognitive psychology, the social sciences, and socio-technical systems, the dissertation systematically applies and integrates insights precisely tailored to the conceptual and practical challenges posed by each research question. This approach will ultimately contribute to a comprehensive and coherent explanatory theory of cognitive adoption.

As such, similar to the multi-method approach applied across the three design cycles, this dissertation follows what IS scholars call theoretical pluralism (Hirschheim & Klein, 2012; Gioia & Pitre, 1990; Lee et al., 1991; Leidner & Gregory, 2024; Mingers, 2001). In general, this term refers to the practice of drawing on multiple theoretical lenses (e.g., kernel theories, theories from social sciences, etc.) within a single study to investigate a phenomenon (Siregar & Tan, 2004). Rather than adhering to a single theory or paradigm, a pluralistic approach embraces multiple perspectives, with the rationale that complex IS phenomena (e.g., digital health support for vulnerable populations) are better understood when viewed from multiple perspectives. In other words, theoretical pluralism assumes that each theory has unique virtues that, when used in combination, can provide a richer, more holistic explanation than any single theory alone (Hoque et al., 2013).

In general, theory is essential for IS scholars to generate unique disciplinary knowledge and theorize emerging phenomena arising from interactions between people and digital technologies within diverse socio-technical contexts (Gregor, 2006; Leidner & Gregory, 2024). Within design-oriented and HCI-focused IS research, in particular, kernel theories drawn from the cognitive, social, and natural sciences are critical for structuring the research process, shaping design decisions, and guiding theory building (Bederson & Shneiderman, 2003; Walls et al., 1992). To systematically address the dissertation's goal of building a *Cognitive Adoption Theory* and its associated research questions (RQ1–RQ5), this dissertation applies kernel theories via an *analyze-with-lens* mechanism across each design cycle (Möller et al., 2022). This approach explicitly acknowledges and addresses the challenges of selecting and combining kernel theories, ensuring theoretical consistency and robust analysis of diverse data sources (Möller et al., 2024; Niederman & March, 2019).

Especially within the broader DSR context of this dissertation, the DSR paradigm itself encourages combining insights from behavioral science (theory-building) and design science (artifact-building) (Tuunanen et al., 2024). Hevner et al. (2004) note that relying solely on artifact construction without theory can lead to well-designed artifacts that are irrelevant in real organizational settings, while relying solely on behavioral theory without design can lead to failure to exploit technological opportunities. The recommended remedy is to integrate both-in effect, a call for pluralism that combines the rigor of theory with the relevance of design. In practical terms, a DSR study might use design theories or principles during artifact creation and then draw on explanatory or evaluative theories during artifact evaluation in context. Each design iteration can incorporate feedback and insights grounded in a theoretical lens appropriate to the dominant questions of that iteration (Tuunanen et al., 2024).

Overall, the multi-method and theoretical pluralism approach for this dissertation is about being holistic and inclusive towards the overall goal of the *Cognitive Adoption Theory* - theoretically, it is rooted in systems thinking and the notion of "wicked problems" (Lönngren & Van Poeck, 2021) that require technical and human elements to be examined together; methodologically, it encourages looking at an IS phenomenon from different lenses (be they stakeholder groups or disciplinary/social theories) to better deal with the complexity of modern information systems and phenomena.

The combination of multiple methods and theories for this dissertation allows for moving beyond surface-level observations (the *epistemic*) and specific instances of technology use (the *actual*) to uncover the underlying *real* mechanisms – cognitive, social, and technological – that govern how individuals with cognitive impairments interact with and adopt digital health technologies.

As such, in addressing **RQ1** and **RQ2**, the first cycle employs these theoretical lenses to establish foundational design and usability criteria relevant in the context of cognitive adoption. Addressing **RQ3** and **RQ4**, the second cycle extends theory usage towards ethical and interaction-specific aspects and mechanisms relevant in that context. Finally, addressing **RQ5**, the third cycle synthesizes these cognitive, behavioral, and technological insights into an integrated *Cognitive Adoption Theory*.

Table 3 shows the theoretical pluralism approach for each of the three design cycles employed in this dissertation, based on the respective research questions these theories aim to inform.

Cycle	Research Questions	Theoretical Foundation	Application of Theoretical Lens
Design Cycle 1	RQ1 & RQ2	*Zone of Proximal Development Theory* (Vygotsky & Cole, 1978; Wertsch, 1984)	To design adaptive cognitive scaffolding suited to the user's evolving cognitive capabilities in the context of the Augmented Living Spaces IS, building the conceptual foundation of cognitive scaffolding for the *Cognitive Adoption Theory*.
	RQ1 & RQ2	*Unified Theory of Acceptance and Use of Technology* (Venkatesh et al., 2003)	To assess and guide usability and technology acceptance (i.e., Performance & Effort Expectancy) from a behavioral and cognitive perspective, focusing on adoption mechanism relevant to the *Cognitive Adoption Theory* development.
Design Cycle 2	RQ3 & RQ4	Socio-technical Systems Theory (Trist & Bamforth, 1951; Emery & Trist, 1960)	To integrate ethical, social, and technical considerations in designing synthetic data use and inform the inherently socio-technical complexities of digital health adoption and use.
	RQ4	*Value-Sensitive Design Theory* (Friedman et al. 2013)	To ensure ethical alignment, transparency, and inclusivity in synthetic data and HCI interaction design in the context of the Augmented Living Spaces concept, ultimately incorporating user values into the development of the *Cognitive Adoption Theory*.
	RQ3	*Social Cognitive Theory* (Bandura, 1977; 2001; 2013)	To operationalize self-efficacy and reciprocal determinism in the intuitive SAR-based HCI approach, laying the conceptual foundations of social cognitive aspects in technology adoption among individuals with cognitive impairments.
	RQ3	*User-centered Design* (Abras et al., 2004)	To directly involve users with cognitive impairments and adapt the interaction design, ensuring usability, adoption, and cognitive support.
Design Cycle 3	RQ5	*Cognitive Load Theory* (Sweller, 1988, 2011; Sweller et al., 1998)	To articulate how cognitive load aspects (intrinsic, extrinsic, germane) shape technology adoption and usability among cognitively impaired users, laying the conceptual foundations of cognitive load as a core concept for the *Cognitive Adoption Theory*.
	RQ5	*Social Cognitive Theory* (Bandura, 1977; 2001; 2013)	To explain reciprocal interactions between user cognition, social context, and health behaviors, further developing the conceptual foundations of social cognitive factors as another core concept for the *Cognitive Adoption Theory*.
	RQ5	*Metacognition* (1979)	To clarify the role of users' cognitive self-regulation in managing technology adoption and interactions.
	RQ5	*Unified Theory of Acceptance and Use of Technology* (Venkatesh et al., 2003)	To explain how user perceptions of usability, accessibility, and effort influence sustained technology use, adapting acceptance factors and rethinking their role in technology adoption.

Table 3. Applied theoretical pluralism to each of the design cycles of this dissertation.

This focus is especially valuable in IS, where simple cause-effect relationships are rare; instead, outcomes (such as a system's success or a technology's adoption) often result from a configuration of technical features, human actions, and social structures. As such, this dissertation is not merely about *building* a system (which is, e.g., often DSR's primary focus) but rather about trying to *understand* the underlying mechanisms that make a system such as the Augmented Living Space IS *effective* for people with cognitive impairments (especially aMCI). Interestingly, if we adopt the perspective of critical

realism and its dual commitment to ontological realism and epistemological relativism (Bhaskar, 2013; Mingers et al., 2013; Rieder et al., 2021), we find a reality independent of human cognition, composed of structures and mechanisms that exist and function independently of our awareness. In the context of the overall goal of this dissertation, the neurological and cognitive structures underlying aMCI and the inherent affordances and limitations of digital health technologies exist objectively. And while reality exists independently, our knowledge of it is socially and theoretically mediated. This fits well with the complexity of understanding the technology adoption behavior of people with cognitive impairments, as findings are inevitably influenced by theoretical perspectives such as CLT or SCT.

However, while theoretical pluralism is a well-established and promising practice in IS research, the approach taken in this dissertation attempts to avoid the *paradigm absolutism* sometimes encountered (Hoque et al., 2013). Instead of seeing the theoretical lenses and methods of the respective design cycles as mutually exclusive silos, theoretical pluralism views them as toolkits that can be pragmatically combined or sequentially employed. To address potential theoretical incoherence (e.g., mixing theories with fundamentally conflicting assumptions), this dissertation maintains a clear boundary for the application of each theory (see Table 3) and avoids attempting to merge them at a single level of analysis where their assumptions may conflict.

2.5 Overarching Evaluation Strategy

The overarching goal of this dissertation – to develop a *Cognitive Adoption Theory* that comprehensively explains digital health adoption among individuals with cognitive impairments – requires a targeted and artifact-specific evaluation strategy. Given the diverse nature of research questions (RQ1–RQ5), each addressing unique theoretical, practical, and methodological dimensions, evaluation must be explicitly tailored to demonstrate how effectively each artifact addresses its intended goal.

In DSR, evaluation is crucial for demonstrating an artifact's utility, validity, and applicability within its intended context, emphasizing both rigor and relevance (Hevner et al., 2004; Vaishnavi & Kuechler, 2015). Methods range from formative evaluations during iterative refinement to summative evaluations assessing artifact effectiveness post-development (Venable et al., 2016). Given the dissertation's diverse range of knowledge outputs – including DSR-derived design theories, reference architectures, interaction design approaches, and general IS theories developed independently of DSR methods – a single uniform evaluation approach would be impractical. Therefore, an overarching evaluation strategy must explicitly accommodate these varying artifact types, ensuring scientific rigor and practical relevance across all research cycles and outputs (Gregor & Hevner, 2013).

Therefore, this dissertation adopts the *Content-Context-Process* (CCP) framework (Andargoli et al., 2017) as a meta-evaluation lens to guide and structure the overarching evaluation strategy. Originally developed for complex health information systems, the CCP framework provides a robust and adaptable foundation for the contextual aspects of each research questions and multi-cyclical DSR approach of this dissertation by emphasizing the interplay between *what* is being evaluated (content), *who* is involved, *why* the evaluation is being conducted (context), and *how* and *when* the evaluation takes place (process). This allows tailoring evaluation activities to the characteristics and goals of each artifact type – such as the explanatory adequacy of a design theory, the conceptual validity of a general IS theory, the architectural feasibility of a reference architecture, or the usability and user acceptance of a novel HCI prototype – while maintaining methodological consistency and coherence across the dissertation. As shown in Figure 4, through this approach, evaluation becomes both artifact-sensitive and cumulative, allowing the results of each cycle to be critically evaluated within their unique epistemological and practical constraints while contributing to the overarching research contribution. As such, the evaluation episodes for each design cycle should be viewed as tailored to that specific DSR echelon or pathway (Tuunanen et al., 2024), similar to the use of different theoretical lenses for each of the cycles.

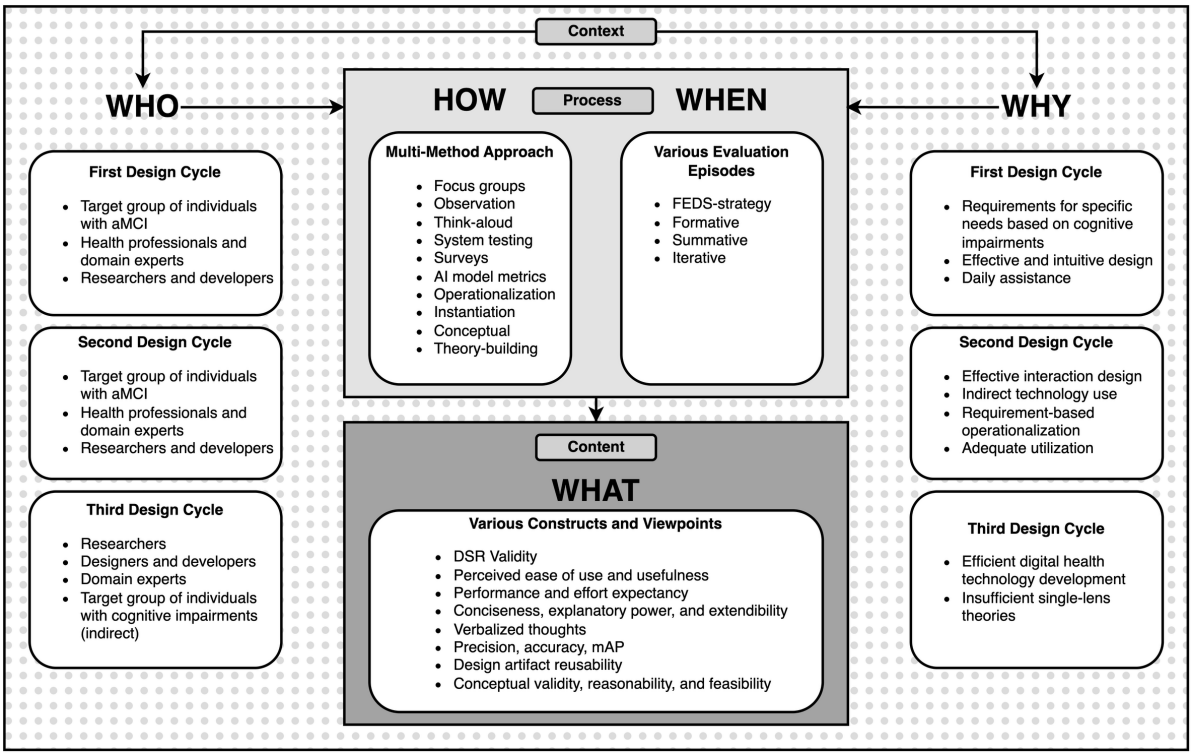


Figure 4. Overarching meta-evaluation lens following the CCP framework for health information systems research and summarizing all evaluation aspects collectively (Andargoli et al., 2016).

Based on the DSR theory-driven orientation of this dissertation (Schoormann et al., 2024) with the overarching goal of developing a *Cognitive Adoption Theory*, it should be noted that the evaluation approaches employed in every design cycle are intended to be complementary rather than mandatory. While evaluation episodes for theorized artifacts (i.e, design theories for cycles 1 and 2; *Cognitive Adoption Theory* in cycle 3) are neither integral nor necessary to (heuristic design) theorizing (Gregory & Muntermann, 2014; Leidner & Gregory, 2024), the decision was made to evaluate the design theories (and subsequent reference architecture for cycle 1) and prototypical scenarios (specifically for the HCI approach) to validate their actionability, practicality, and relevance to ensure that they "work" in real-world applications and meet the needs of the target audience. Thus, the overall focus of the first two cycles was to ensure that the heuristic search generated sufficient depth and breadth of design insights for the *Cognitive Adoption Theory* rather than a formalized and conclusive evaluation of the Augmented Living Spaces design theory (Gregory & Muntermann, 2014).

Nonetheless, it is acknowledged that general DSR emphasizes the importance of actionable and validated artifacts, consistent with its practical orientation (Larsen et al., 2025), so the heuristic design theorizing was complemented with an evaluation to operationalize and instantiate the design theory artifacts. The goal was to translate the design theories into actionable models and prototypical scenarios, ensure their applicability and relevance, and iteratively refine them to meet both theoretical and practical goals. While providing a form of "pre-validation" that enhances their clarity and actionability for readers, further evaluation is contemplated through the theoretical discourse that these artifacts could initiate. Moreover, it just seemed reasonable to evaluate and assess the developed system and interaction design together with digital health experts and the target group instead of assuming that the theoretical foundations laid by the design theories and reference architecture would work well in real-life scenarios, especially when dealing with vulnerable populations.

Generally, based on the research questions, the set of stakeholders is twofold: 1) individuals with cognitive impairments, for whom the developed artifacts may directly affect their digital health adoption

and health behavior change, and for whom the evaluation episodes assessed the usability and usefulness of the implementation; and 2) researchers, developers, and practitioners, who can theorize and use the artifacts/findings to develop digital health tools tailored to the specific needs of people with cognitive impairments, and for whom the evaluation episodes complemented and validated the conceptual foundations (i.e., design theories, reference architecture, HCI approach). Therefore, the focus of these evaluation episodes was inherently socio-technical and target group-oriented, for which the *Framework for Evaluation in Design Science Research* (FEDS) by Venable et al. (2016) was adopted, specifically applying the *Human Risk and Effectiveness* evaluation strategy over other strategies such as Quick & Simple, Purely Technical, or Technical Risk & Efficacy.

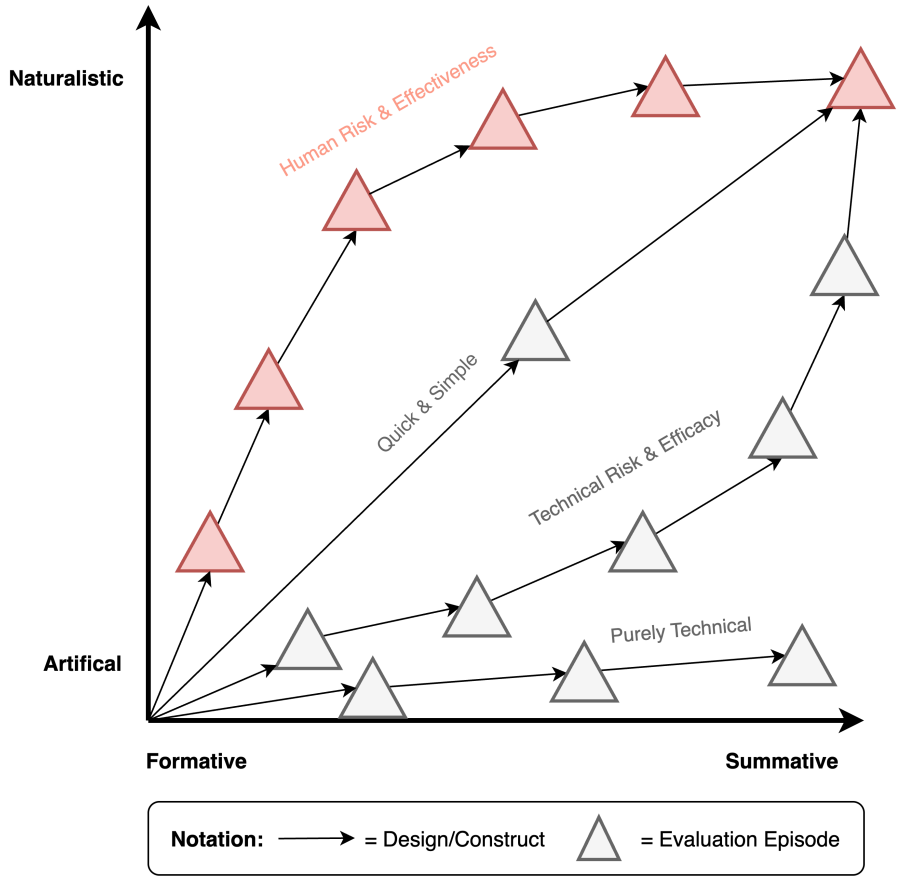


Figure 5. *Adopted Human Risk & Effectiveness Strategy from the FEDS-framework (Venable et al., 2016) for this dissertation.*

As shown in Figure 5, the FEDS framework is characterized by a two-dimensional conceptual space that includes the functional purpose of the evaluation (formative vs. summative) and the evaluation paradigm (artificial vs. naturalistic). These orthogonal dimensions allow the placement of evaluation episodes anywhere within the evaluation space, enabling both temporal (early to late-stage) and methodological (controlled to contextualized) evaluation paths. Having chosen the human risk and effectiveness path, evaluation episodes serve two primary purposes: First, they reduce human and social risks early on through formative (artificial) evaluations in controlled environments (i.e., early prototypical scenarios in design cycle 1), allowing for the identification and mitigation of usability and adoption challenges. Second, they later validate the effectiveness of the artifact through summative evaluations in naturalistic settings (i.e., more mature prototypical scenarios in design cycle 2), assessing its utility and integration into real-world practice. This phased approach ensures that the artifact is not only theoretically sound but also practical and acceptable to the intended user group. Especially when working with vulnerable populations, this strategy ensures ethical responsibility, human-centeredness,

and practical relevance (Venable et al., 2016). Consequently, the evaluation approach adopted in this dissertation is not merely methodological rigor but a conscious theoretical choice that emphasizes human-centered and context-sensitive artifact validation, thereby ensuring both scientific robustness and meaningful, practical contributions. As such, this framework complements the CCP meta-evaluation lens by offering a concrete strategy to operationalize artifact-sensitive evaluations for each of the design cycles with DSR knowledge output that aligns with ethical, epistemological, and practical concerns central to this dissertation. The specific evaluation episodes conducted via the FEDS framework will be explained and discussed in the evaluation chapters of the respective design cycles (i.e., Chapters 3.4; 4.4)

To provide an initial overview of all evaluation strategies, episodes, and methods conducted, Table 4 summarizes these activities across all three design cycles.

Perspective	**Knowledge Output**	**Evaluation or Validation Strategy**
Design Cycle 1	*Design Theory*	• Complementary evaluation episodes with domain experts o Two formative evaluation episodes on perceived usefulness (n=22) – FEDS episode o Summative evaluation on performance & effort expectancy, conciseness, explanatory power, and extendibility (n=12) – FEDS episode
	Reference Architecture	• One evaluation episode with domain experts o Summative evaluation on performance & effort expectancy, conciseness, explanatory power, and extendibility (n=12) – FEDS episode
	Prototypical System Scenario	• Two usability test episodes o Think-aloud session with target group (n=10) – FEDS episode o Think-aloud session with experts (n=11) – FEDS episode
Design Cycle 2	Deep Learning Model	• Empirical model training and testing episodes o Model train, test, and validation metrics o Benchmarking against similar models
	HCI ConZones Approach	• Three evaluation episodes with target group and domain experts o Survey-based usability test with target group on performance & effort expectancy (n=12) – FEDS episode o Survey-based usability test with domain experts on performance & effort expectancy (n=14) – FEDS episode o Think-aloud session with target group on general system use, concerns, and interaction design(n=12) – FEDS episode
	Design Theory	• Complementary evaluation episodes with domain experts o Think-aloud session on design principle reusability o Reconvened think-aloud session on design requirements and design principles • Evaluation by operationalization and instantiation o Prototypical scenario with design features
	Conceptual Model	• Conceptual validation as by-product of the heuristic design theorizing approach
Design Cycle 3	*Theory*	• Conceptual evaluation (explanatory IS theory) o Taxonomic theory perspective according to Gregor (2006) o Evaluation, refinement, and validation via theoretical discourse

Table 4. Summary of all evaluation/validation episodes for the knowledge output of each of the perspectives used in this dissertation.

Since this dissertation has practical artifacts on the one hand (i.e., the Augmented Living Spaces IS and HCI approach) and more theoretical artifacts on the other hand (i.e., design theories, reference architecture, and ultimately, the *Cognitive Adoption Theory*), maintaining this balance for the evaluation seemed reasonable. Following the DSR process model by Vaishnavi and Kuechler (2015), the third design cycle does not culminate in a traditional DSR artifact but rather in a general IS theory with the *Cognitive Adoption Theory*. As such, the evaluation phase is not omitted but is instead realized through theoretical argumentation and conceptual validity (this will be explained in detail in Chapter 5.4). Specifically, the theory is evaluated for logical coherence, internal consistency, and its grounding in established kernel theories. This is consistent with the recognition that evaluation in DSR can take the form of logical argumentation and conceptual validation when the output is not artifactual (Brendel et al., 2022; Larsen et al., 2025; Vaishnavi & Kuechler, 2015). Thus, the rigor of this cycle is ensured by sound theorizing rather than empirical artifact testing.

3 Design Cycle 1: Design Theory and Reference Architecture Echelon Instances

Driven by RQ1 and RQ2, as well as the inadequate support of digital health assistance for individuals with aMCI, the focus of the first design cycle was to lay the conceptual, qualitative, and practical foundations for the development of the *Cognitive Adoption Theory*. As such, this design cycle explicitly focuses on the subjective experiences, cognitive realities, and personal needs of people with aMCI adopting and interacting with digital health technologies. Based on the notion that wearables and handhelds (especially when using AR) are cumbersome and inappropriate for people with aMCI due to their limited battery life, complex interfaces, reduced field of view, and increased cognitive distractions (Biocca et al., 2007; Steffen et al., 2019; Vertucci et al., 2023), the idea of a projection-based SAR assistance system was pursued in this design cycle. Kernel theories such as the zone of proximal development theory (Vygotsky & Cole, 1978; Wertsch, 1984) and constructs from the UTAUT model (Venkatesh et al., 2003) guide the examination of subjective factors such as cognitive load, self-efficacy, and perceived usefulness. As such, this design cycle centers on the lived experiences, needs, challenges, and cognitive processes of individuals with aMCI – and how this can be adequately addressed with a tailored yet flexible information system. Thus, the first design cycle prioritizes understanding their interactions with technology from *their* point of view. This perspective provides foundational insights into the lived experiences and cognitive realities of individuals with aMCI by revealing practical user requirements and theoretical design heuristics – which are used to inform the *Cognitive Adoption Theory*. The deep qualitative insights generated here are crucial for informing intuitive system interactions and grounding theoretical assumptions, ensuring that technological and theoretical frameworks remain responsive to actual user needs. As such, insights from the user perspective serve as both a trigger and a validation point for subsequent technological implementations and theoretical conceptualizations in this dissertation.

3.1 Awareness of Problem

The initial awareness of the problem for this design cycle stemmed from a critical societal observation: the global demographic shift toward an aging population has led to a significant increase in neurodegenerative diseases, particularly mild cognitive impairment, of which amnestic mild cognitive impairment is the most common type. aMCI is characterized by a decline in memory and executive functions, while individuals generally retain basic autonomy in daily life (Petersen, 2016; Petersen et al., 2018). However, subtle cognitive impairments significantly interfere with higher-order tasks such as planning, decision-making, or remembering critical information (Yu et al., 2017). Böhmer et al. (2025a) found that current healthcare systems are increasingly exploring digital health solutions to support this population, but there remains a distinct lack of tailored technological interventions that promote autonomy rather than increase dependency. While ambient assisted living systems have made advances in passive monitoring (e.g., fall detection, activity logging), their support mechanisms do not sufficiently scaffold users' cognitive processes to promote resilience and long-term independence

(Singh et al., 2011; Zhu et al., 2020; Yu et al., 2021). In addition, digital health solutions often overlook the specific needs of users with cognitive impairments. As research has shown, these individuals engage with technology in ways that differ from neurotypical populations (Gazzaniga et al., 2018). Cognitive load, task complexity, and the social context of use play a significant role in adoption and sustained interaction in the context of cognitive impairments (Böhmer et al., 2024). This highlights a gap in the design of cognitively inclusive, intuitive, and context-aware technologies that are not only accepted but also sustainably adopted.

As stated in Böhmer et al. (2025a), while AR has been explored as a promising modality for real-time task support, traditional AR implementations, such as those using head-mounted displays, have proven to be cognitively overwhelming for individuals with aMCI (Biocca et al., 2007; Steffen et al., 2019; Vertucci et al., 2023). These systems introduce distractions, reduce field of view, and often increase cognitive demands – ultimately compromising rather than supporting user autonomy. An alternative, SAR, offers a more promising and intuitive way forward. SAR projects digital content directly onto the physical environment without the need for wearable devices, reducing complexity and cognitive load (Raskar, 1998; Baumeister et al., 2017). However, SAR remains significantly underexplored in the context of cognitive health applications, particularly in the context of adaptive, personalized cognitive support (Cardoso et al., 2020; Tavares et al., 2019).

As this design cycle progressed, the initial framing of the problem – the lack of supportive digital systems for autonomy in aMCI and the proposed design knowledge to address this with SAR (**RQ1**) – was further refined through *circumscription*, a reflective and iterative process characteristic of the DSR process model (Vaishnavi & Kuechler, 2015). During this process, it became clear that there is not only a lack of intervention tools but also a lack of formalized and actionable design knowledge at the systemic and technical level on how to conceptualize and implement such systems (see Figure 2). While the proposed design theory (Section 3.3.1) provided foundational and theoretical design knowledge on how to support individuals with aMCI in SAR-based Augmented Living Spaces, a refinement of the problem awareness was necessary due to the lack of guiding technical knowledge on how to instantiate and implement the design theory (**RQ2**).

This refinement led to sharper problem identification and formulation: the lack of theoretically grounded and technically implementable design knowledge for SAR-based Augmented Living Spaces that promote autonomy, learning, and cognitive scaffolding for people with aMCI. The absence of a reference architecture for such systems and the lack of design theory artifacts to guide the development of the *Cognitive Adoption Theory* emerged as the central problem to be addressed in this first cycle across two main DSR echelon instances.

3.2 Suggestion

In response to RQ1 and the identified lack of theoretically grounded and technically actionable design knowledge for SAR-based digital assistance systems that support individuals with aMCI in maintaining autonomy, this design cycle proposes the development of two interrelated design foundations: a **design theory** and a corresponding **reference architecture** for an Augmented Living Spaces information system as one possible solution to enhanced digital health adoption for individuals with aMCI. The design theory provides a heuristically theorized and structured conceptualization of how SAR-based cognitive support systems – called Augmented Living Spaces – can be designed to provide adaptive, interactive, and personalized assistance in everyday contexts. It defines key Design Requirements (DR) and Design Principles (DP) that guide the development of systems capable of scaffolding cognitive processes, supporting gradual task internalization, and promoting long-term autonomy in everyday settings.

To complement and operationalize the design theory as well as addressing RQ2, a reference architecture is proposed as a technical blueprint that translates abstract DPs into implementable system components and interactions. This architecture outlines how SAR can be integrated with context-aware sensors, cognitive state modeling, and workflow-based task support to enable a responsive and adaptive system environment. The proposal of both a design theory and a reference architecture reflects a deliberate

delineation of the DSR problem space for this design cycle: the need to move beyond general notions of assistive support for people with cognitive impairments to formalized, multi-level design knowledge that bridges conceptual understanding and practical instantiation (Lukyanenko & Parsons, 2020). Together, these two design artifacts form the theoretical, conceptual, and practical foundation for the envisioned *Cognitive Adoption Theory*, using the example of Augmented Living Spaces.

3.2.1 Theoretical Foundations & Lens

This section is based on Böhmer et al. (2025a). As such, parts of the text are reused with minor edits for clarity and coherence.

To ground the design of the proposed digital assistance system in a robust conceptual framework, this design cycle adopts Vygotsky's (1978) Zone of Proximal Development (ZPD) as a theoretical lens. Consistent with recommendations to ground DSR studies in established theories (Walls et al., 1992; 2004; Gregor & Hevner, 2013), the ZPD serves as a kernel theory to inform the formulation of DRs and DPs by providing normative and explanatory guidance. As suggested by Möller et al. (2022), the use of such a theoretical lens enables structured analysis and concept extraction through an *analyze-with-lens*-mechanism that aligns theory, data, and design objectives. ZPD conceptualizes the distance between what an individual can do unaided and what they can achieve with the support of a more knowledgeable other (Vygotsky, 1978). In this cycle, that idea is extended to the concept of the Augmented Living Spaces information system, a digital SAR-based assistant that acts as a more knowledgeable other by adaptively scaffolding users' cognitive activities, particularly when cognitive impairments come into play. Following Wertsch's (1984) elaboration, the lens is operationalized through three central constructs: (1) situation definition, which addresses the need for an Augmented Living Space to negotiate shared representations of tasks with users; (2) intersubjectivity, which ensures mutual understanding through semiotic and interactive feedback; and (3) semiotic mediation, which translates abstract tasks into manageable steps through visual, auditory, and contextual cues. This lens enables this cycle's heuristic design theorizing not as a static support system, but as an adaptive learning environment that promotes autonomy by progressively reducing support as users internalize strategies. In this way, the ZPD framework guides the system's evolution from external assistance to integrated cognitive support, making it particularly suited to the dynamic needs of individuals with aMCI, while aligning with the broader goal of promoting independence rather than dependency of users.

Moreover, to define the objectives of a solution and ensure a rigorous basis for design, this design cycle draws on three overlapping research streams: SAR, Ambient Assisted Living and digital assistance systems, and Workflow Management Systems. Although each domain provides valuable insights, a holistic and integrative approach that unifies these perspectives for the development of adaptive cognitive and daily support systems for people with aMCI is still lacking.

In the SAR literature, previous work has focused on projection techniques (Huang et al., 2021), surface suitability (Ro et al., 2019; Di Donato et al., 2015), projection manipulation (Lindlbauer et al., 2017; Miyamoto et al., 2018), and emerging AI-driven methods for dynamic environments (Gomes et al., 2021; Kobayashi & Hashimoto, 2014; Lee et al., 2019). While foundational work by Raskar et al. (1998) and Grundhöfer and Iwai (2018) established the technical capabilities of SAR, its application in personalized digital health remains nascent, with only isolated examples such as cooking assistance for cognitively impaired users (Kosch et al., 2019).

In the field of AAL and digital assistance, several conceptual and technical reference architectures have been proposed (Tazari et al., 2010; Antonino et al., 2011), in addition to research on sensor integration (Luis-Ferreira et al., 2019), projection design (Morris, 1994), and SAR for healthcare support (Yang et al., 2018). However, these systems often lack modularity, contextual intelligence, and cognitive specificity (Garces et al., 2020; Memon et al., 2014). Studies have emphasized ethical design (Mueller & Heger, 2018), user needs (Block et al., 2020; Saborowski & Kollak, 2015), and cognitive task modeling (Kosch et al., 2019), but fail to provide an integrated system capable of cognitive scaffolding.

Finally, workflow-oriented design for adaptive cognitive systems is underexplored. While basic WFMS architectures exist (WFMC, 1995; Grefen & Vries, 1998; Pourmirza et al., 2019) and service-oriented

WFMSs have been developed for scientific contexts (Lin et al., 2008; Rodriguez & Buyya, 2017), their application to SAR-based cognitive assistance remains superficial and mostly limited to niche cases such as surgery (Xu et al., 2020).

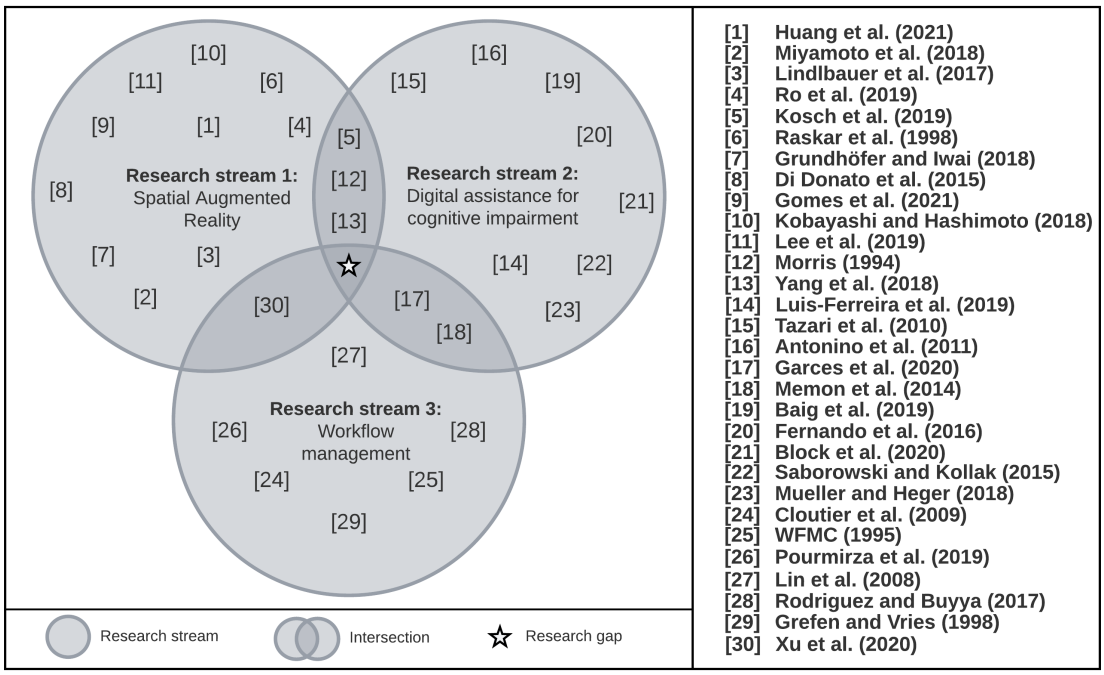


Figure 6. Venn diagram for classifying the research streams and research gap for this design cycle (Böhmer et al., 2025a).

Taken together and as shown in Figure 6, the literature reveals a clear research gap: existing systems are either narrowly focused, lack integration of SAR and workflow mechanisms, or do not sufficiently address the cognitive needs of users with aMCI. This design cycle responds to this gap by proposing a unifying design theory and reference architecture that draws from all three streams, while explicitly focusing on adaptability, cognitive scaffolding, and laying the foundations for the *Cognitive Adoption Theory*.

3.2.2 Research Design

To address research questions RQ1 and RQ2, a multi-method (Mingers & Brocklesby, 1997), theory-driven (Schoormann et al., 2024) heuristic design theorizing (Gregory & Muntermann, 2014) approach was chosen. Generally, the research design for this perspective draws on the DSR paradigm (Hevner et al., 2004), as this DSR echelon instance (Tuunanen et al., 2024) seeks to provide both theoretical and prescriptive practical insights for research on cognitive support via Augmented Living Spaces, rather than merely descriptive knowledge, as outlined by Gregor and Hevner (2013). Given that the DSR paradigm can be instantiated through a variety of methodological processes (Venable et al., 2017), and that design theories, in general, embody a form of theorizing in IS research (Brendel et al., 2022; Burton-Jones et al., 2021; Dehling & Sunyaev, 2023; Gregory & Muntermann, 2014; Kane et al., 2021; Lee et al., 2011; Mandviwalla, 2015; Young et al., 2021) this DSR echelon instance can be placed in the *theorizing* domain of the DSR focus matrix (Brendel et al., 2022), which implies a higher focus on rigor and derivation of theoretical artifacts. In general, the focus of this pathway is aimed at developing a design theory that embodies a theoretical framework for how such digital assistance information systems in the context of Augmented Living Spaces can be conceptualized. Thus, as a by-product of the heuristic design theorizing process and the circumscription encountered in this design cycle, the focus is also shifted toward a reference architecture that illustrates how the developed design theory can be

instantiated to create an adaptive IS decision support system that functions as an interactive cognitive learning environment – addressing the individual needs of people with aMCI. This reference architecture is then used in the ideation and prototyping steps of the heuristic theorizing to operationalize the developed design theory in a prototypical scenario and decision support system, which is evaluated by both the target group of individuals with aMCI and digital health experts. This ensures that the theorized design insights are not only conceptually rigorous but also practically actionable, establishing new DPs for cognitive scaffolding in digital assistance systems.

As shown in Figure 7, a theory-driven design configuration (Schoormann et al., 2024) as an overarching framework was chosen, supporting the systematic derivation of design theories by iterating between abstraction and application (Böhmer et al., 2025a). Such a configuration enables this perspective to align DRs and DPs with an iterative intake of a kernel theory and (complementary) evaluation findings, ensuring their theoretical grounding before operationalization. As such, this approach enabled this DSR echelon instance to iteratively refine design knowledge through abductive reasoning, balancing theoretical rigor with practical applicability as well as the option to reflect and refine the (nascent) design theory whenever a non-satisficing solution was encountered.

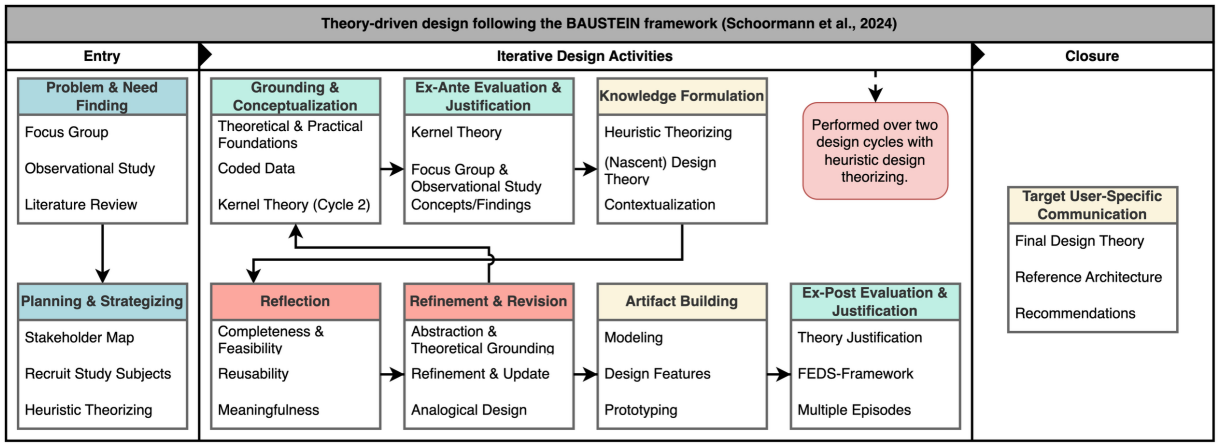


Figure 7. Theory-driven design configuration following the BAUSTEIN DSR framework (Schoormann et al., 2024) for design theory and reference architecture (Böhmer et al., 2025a).

Following the heuristic design theorizing framework proposed by Gregory and Muntermann (2014), this echelon instance emphasizes the iterative and intertwined processes of problem structuring, artifact design, and theorizing, which is consistent with proactively generating design theory (Gregor & Jones, 2007). Heuristic theorizing, as applied in this dissertation's echelon instance (Figure 8), integrates problem-solving activities with theorizing through heuristic search and synthesis. This framework guided the development of the design theory through two iterative design cycles[4]. These cycles alternated between structuring wicked problems (Lönngren & Van Poeck, 2021) (e.g., addressing the individual needs of individuals with amnestic mild cognitive impairment), playing with kernel theories, and synthesizing new knowledge through iterative artifact design and modeling (i.e., both the design theory and the reference architecture) (Böhmer et al., 2025a). Each iteration involved abstraction (i.e., deriving general design knowledge) and de-abstraction (i.e., applying general knowledge to specific problems), as described in Gregory and Muntermann (2014).

As such, the design theorizing approach can be located in the abstract theoretical domain, seeking an abstract solution that solves an abstract problem and using abductive reasoning because there is an objective to guide learning and problem-solving (Lee et al., 2011). Based on several revisions and iterative refinements throughout the heuristic theorizing process, different types of representation of the

[4] These design cycles should not be confused with the overarching design cycles of this dissertation (Figures 1 & 2), but rather with the design cycles used within the DSR echelon of the dissertation's first design cycle.

problem solution were used to graphically, conceptually, or technically capture artifact solution components for both the design theory and reference architecture as a kind of digital health IS decision support system (Rowe, 1987; Smith, 1992; Gregory & Muntermann, 2014).

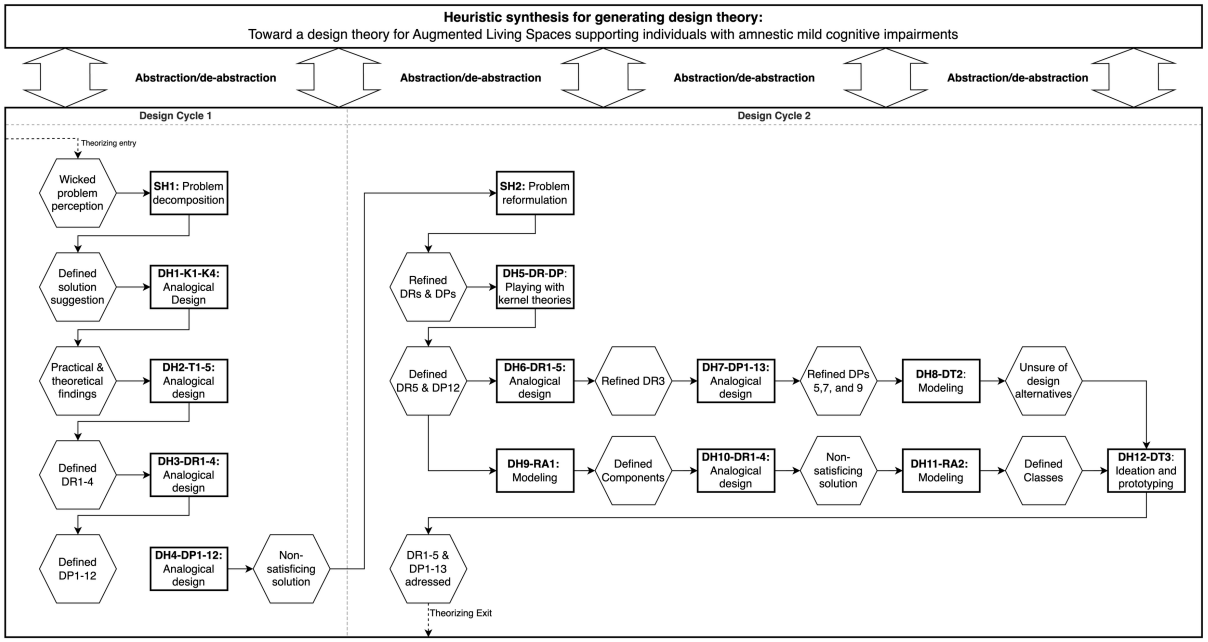


Figure 8. Heuristic design theorizing approach for the first DSR echelon instance of the first cycle, adapted from Gregory and Muntermann (2014) (Böhmer et al., 2025a).

Since the first design cycle's echelon instance has an explicit focus on the lived experiences, needs, challenges, and cognitive processes of individuals with aMCI to understand their interactions with technology from *their* point of view, a focus group with caregivers and healthcare experts, and an observational study in a dementia care facility were conducted. The main objective was to develop user-specific requirements and needs for varying degrees of aMCI; however, for the focus group following Morgan (1997), it seemed reasonable not to directly involve the target group because they tend to have reduced and biased assessments of their daily lives/abilities with cognitive impairments (Chung & Man, 2009). On the other hand, the accompanying caregivers tend to have a more unbiased view regarding the needs, actions, and challenges of aMCI people and thus can provide a more rigorous data foundation.

As shown in Böhmer et al. (2025a), utilizing a qualitative content analysis according to Mayring and Fenzl (2019), four categories (K1-4) as the central instrument of the analysis were developed: 1) everyday life of mild cognitively impaired and care-dependent people; 2) challenges regarding cognitively impaired people; 3) development of cognitively impaired people over time; and 4) cognitive and physical condition. As shown in Figure 9 and complementing the theoretical foundations, the focus group highlighted the critical role of structured daily routines, particularly meals, as essential anchors for individuals with aMCI, emphasizing the need for predictable and manageable activities. Communication strategies, such as calm and clear speech, were considered critical for effective interaction, along with tailored application scenarios that support guided and reminder activities to mitigate cognitive regression. Participants also emphasized that cognitive decline, while often progressive, can potentially be slowed or revitalized through targeted training and the use of neural plasticity, underscoring the need for personalized care that recognizes individual variability and promotes independence.

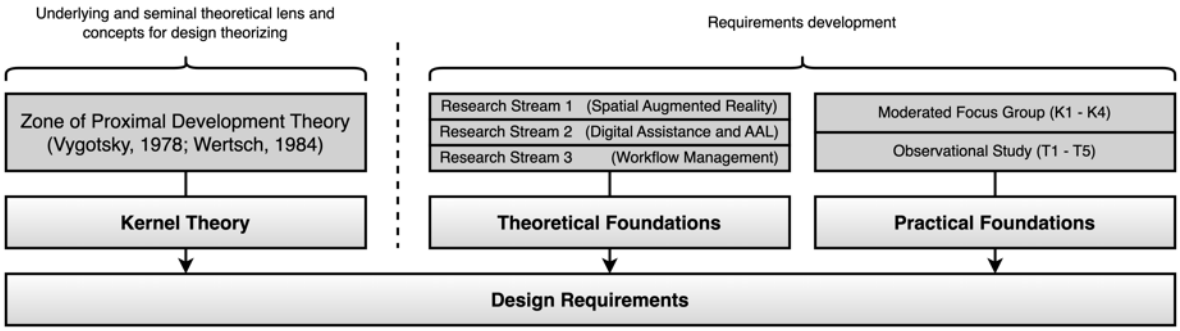


Figure 9. Synthesis of the theoretical and practical foundations for the first DSR echelon instance of the first cycle (Böhmer et al., 2025a).

To gather more meaningful data on daily living with cognitive impairments, conducting an observational study in a dementia care facility involving aMCI people seemed reasonable. Residents in this particular care facility live in their residential units and go about their daily lives largely independently (depending on their level of cognitive impairment), with caregivers acting as a monitoring and supportive authority. For the observational study, the *CSOR* framework proposed by Morgan et al (2017) was followed, as it explicitly focuses on observational data for complex issues in health care. Morgan et al. (2017) argue that observation is an optimal method for studying healthcare phenomena, which are mostly qualitative in a naturalistic setting. Therefore, the focus group analysis categories were adapted, and cross-case themes with their corresponding observational case reports were created.

In Böhmer et al. (2025a), these themes (T1-5) were developed directly through the observational study methodology and are categorized as T1: daily routine; T2: daily life challenges; T3: daily life activities; T4: physical and mental condition; and T5: communication and interaction. Observations revealed that individuals with aMCI maintain a largely independent daily routine, relying on caregivers for additional information and support, with a strong reliance on external structure and memory aids. Common challenges include forgetfulness and problems with spatial awareness, which caregivers address with patience. Daily activities, while typically routine, highlight the need for cognitive stimulation and social interaction, despite limited engagement with handheld technology. Variability in physical and cognitive conditions requires personalized care that emphasizes clear and gentle communication to effectively navigate their environment.

3.3 Development

As briefly mentioned in the previous chapter, the artifact development for this design cycle included a moderated focus group and an observational study in a dementia care facility, which was used primarily for the design theory echelon instance of this cycle (Böhmer et al., 2025a). Complementing the kernel theory and theoretical foundations from the literature, the findings from these two qualitative methods directly influenced the theorized design heuristics and the development of the DRs and DPs from the design theory. To avoid a possible order bias (e.g., focus group prior to observation), the focus group and observational study were each conducted with different subjects.

While the core aspects of the findings from the focus group (mainly categories K1-K4) are given in Chapter 3.2.2, the following Table 5 provides the relevant descriptive reports of the observation study as well as their cross-case themes (T1-T5) according to Morgan et al. (2017).

As shown in Chapter 3.2.1 and Böhmer et al. (2025a), the analysis of current research streams revealed that existing digital assistance systems using SAR and projection techniques in the healthcare sector primarily address specific disease patterns and often provide only superficial support for users' daily activities. Findings from the MFG and the observational study reinforce the need for digital assistance solutions that do not merely compensate for impairments but actively scaffold cognitive processes to prolong independent living at home. However, the lack of strategic and theoretical guidance in the current literature hinders the systematic design and development of such systems.

Cross-case theme	Descriptive reports from observation
T1 *Daily routine*	• Most daily routines are carried out independently by the subjects (e.g. hygiene measures, cooking, or minor household activities). When a need arises, caregivers support the residents. • Subjects retrieve information from caregivers on everyday life topics such as meal times, news, grocery shopping opportunities, or daily activities. • The structure of each day is centered around key commitments, appointments, and meals. It therefore rather depends on external than intrinsic variables. • Subjects use some form of tool to support memorization, e.g., paper-based calendars, or simple notes, or these tools are verbally expressed through caregivers. • Subjects have anchoring objects that accompany their daily routines (e.g. radio, TV, pictures, or general memorabilia). These can be considered as fixed points in everyday life and make them feel comfortable.
T2 *Everyday life challenges*	• Subjects tend to forget minor things such as object locations (e.g. cups, remote, or keys), appointments, and turning off appliances (e.g. stove or microwave). However, the latter is uncommon but bears a high risk. • Objects standing in the way are usually not noticed and therefore represent a potential source of danger. • Caregivers act calm and indulgent in situations of forgetfulness, which makes subjects feel comfortable.
T3 *Daily life activities*	• Subjects engage in many different activities throughout the day. Most common are watching TV, playing board games, eating, and talking to other residents or caregivers. • Subjects barely use any handhelds (e.g. smartphones, tablets, etc.). • Subjects generally pursue the same activities daily, which often is only interrupted by doctoral appointments or social activities. However, new activities are generally well received as long as they do not break the routine. • Subjects need certain daily activities (see above) to not break down mentally and cognitively. There is a need for activation and cognitive stimuli.
T4 *Physical and mental condition*	• The cognitive, as well as the physical condition, differs substantially between the subjects. However, all of them manage the majority of their daily lives alone. • Subjects seem to be aware of their surroundings, living environment, and the purpose of the care facility. No one seems out of place or in discomfort. • Some subjects show signs of obliviousness and feel a little bit caught when they are helped. • Their cognitive perception and physical condition often lead to them not perceiving objects and fall hazards. • Motor skills are quite limited and instructions must be repeated.
T5 *Communication and interaction*	• Subjects react better to a calm, persistent, yet gentle and definite tone when getting instructions or help from caregivers. • Subjects show great joy in interacting among themselves. However, they do not like intrusive behavior and need their personal space. • Subjects receive and process both, written and spoken, messages equally as good.

Table 5. Cross-case themes and descriptive observations from the observation study (Böhmer et al., 2025a).

As shown in Figure 10 and complementing the theoretical foundations from the kernel theory and literature, the practical foundations from the focus group and observational study served as direct input for the design theory (and later on the reference architecture) development.

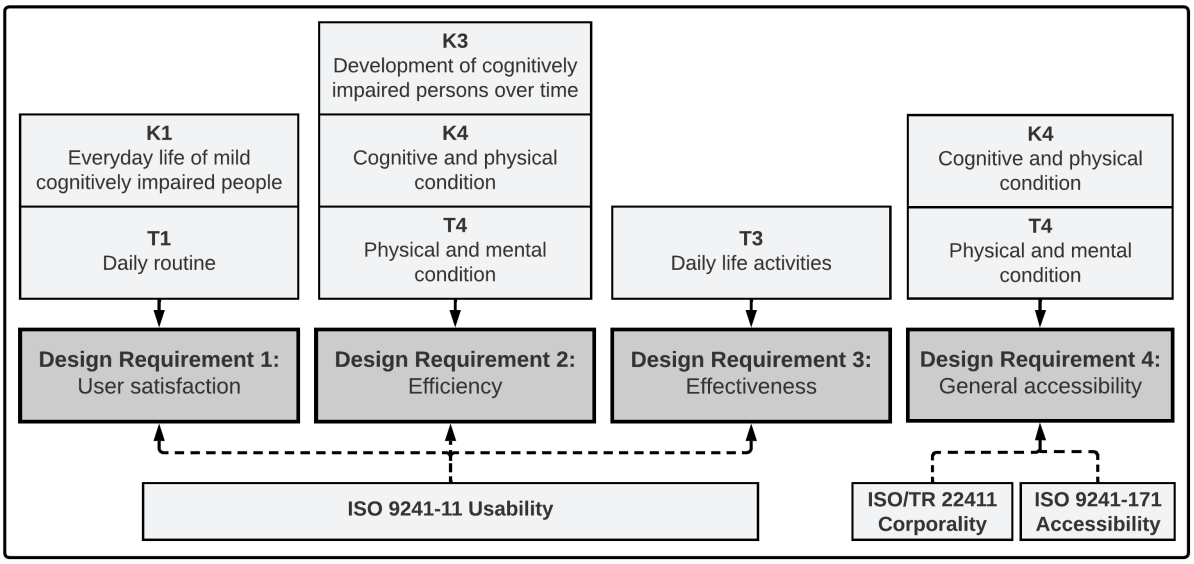


Figure 10. Assignment of the practical foundations and their categories (K1-K4) and cross-case themes (T1-T5) to the DRs of the design theory (Böhmer et al., 2025a).

As mentioned in the explanation of this cycle's research design (Chapter 3.2.2) and shown in Figure 8, heuristic design theorizing was used to iteratively refine the DRs and DPs to ensure their alignment with the kernel theory of ZPD. As stated in Böhmer et al. (2025a), this developmental refinement process was guided by circumscription and thus, *Problem Reformulation* (Figure 8; SH2), where it was re-evaluated how cognitive support in Augmented Living Spaces should be structured as a learning-oriented system rather than a static tool, and how this should be implemented conceptually on a technical level. Through iterative ideation by playing with kernel theory (Gregory & Muntermann, 2014) and theoretical grounding (Schoormann et al., 2024), existing principles were revised to emphasize adaptive scaffolding, intersubjectivity, and semiotic mediation to ensure that an Augmented Living Space dynamically adapts its interventions as users internalize cognitive strategies, as cognitive adoption processes in individuals with aMCI differ from those of unaffected individuals (Böhmer et al., 2024). This allowed for the introduction of new DRs and DPs that explicitly capture progressive autonomy-building and preservation mechanisms, thereby strengthening the theoretical coherence of the emerging design theory. As a result, the second internal design cycle led to a deeper operationalization of ZPD within Augmented Living Spaces, transforming it from a system of contextual reminders into an interactive cognitive learning environment, thereby strengthening both theoretical rigor and practical applicability. The latter was achieved through the refinement of the design theory, which led to the conceptual development of the reference architecture based on it (Figure 8; DH9-RA1 and DH11-RA2).

3.3.1 Design Theory

As the main heuristic design theorizing output, this echelon instance within the first design cycle proposes a design theory that addresses the lack of formalized guiding design knowledge for information systems using SAR for comprehensive support of the elderly and people with aMCI in their daily lives. The analysis of the literature findings, the moderated focus group, and the observational study results, coupled with the iterative refinements and revisions based on the evaluation findings and the incorporation of the kernel theory, resulted in 5 essential DRs, which are further addressed by 13 DPs and 13 specific use case-derived design features (DF) for an instantiation of the Augmented Living Spaces concept (Figure 11). Thus, the DRs and DPs describe components upon which any Augmented Living Space for the elderly and cognitively impaired should be built. In contrast, the DFs refer to the prototype development features and represent only one possible operationalization of the DPs.

The DRs outlined here serve as the main objectives for the theoretical and conceptual artifact. Theoretically grounded on the ISO 9241-11:2018 standard for "usability", the paradigm of user-centered

design (Abras et al. 2004), value-sensitive design (Friedman et al., 2013), and the kernel theory of ZPD (Vygotsky, 1978; Wertsch, 1984) as well as practically grounded on the moderated focus group and observational study findings, the DRs *User Satisfaction* (**DR1**), *Efficiency* (**DR2**), *Effectiveness* (**DR3**), *General Accessibility* (**DR4**), and *Adaptive Learning & Scaffolding* (**DR5**) were derived. They are further theoretically underpinned by the ISO 9241-171 standard for ergonomics of human-system interaction and the ISO/TR 22411 report for corporality that helps to apply a universal design according to Connell (1997) and the Center for Universal Design (2008).

The following paragraphs follow Böhmer et al. (2025a) with minor edits and provide a brief overview and description of the DRs and DPs, focusing on how they lay the conceptual and practical foundations of cognitive adoption aspects/mechanisms and thus inform the development of the envisioned *Cognitive Adoption Theory*. A detailed description of the DRs and DPs and their practical/theoretical link-up can also be found in the respective publication (Böhmer et al., 2025a) in Appendix B.

DR1 requires users to prefer Augmented Living Spaces over alternatives like wearable-based AALs, enhancing everyday life (*K1*) and routines (*T1*). Non-wearable, intuitive systems ease technology acceptance and reduce frustration. Efficiency and effectiveness should be task-relevant, not economic. It must promote cognitive engagement to foster comfort and autonomy through cognitive empowerment, not just ease of use (Vygotsky, 1978; Wertsch, 1984). **DR2** states that an Augmented Living Space must be easy for users to use and configurable for administrators, and tailored to users' cognitive and physical needs (*K4; T4*). To accommodate cognitive decline, interaction should be low-effort yet efficient in optimizing learning within the ZPD for long-term internalization (Vygotsky, 1978; Wertsch, 1984), not in speed. **DR3** calls for dynamic scaffolding that supports autonomy in daily activities, such as cooking or therapy (*T3*). Ineffective functions should be discarded, and assistance should adapt and fade over time to enable users to internalize strategies and reduce dependency (Böhmer et al., 2024; Vygotsky, 1978; Wertsch, 1984). **DR4** promotes universal accessibility through equitable, flexible, and intuitive design (Center for Universal Design, 2008) that considers users' cognitive and physical conditions (*K4; T4*). Interfaces should scale from guided to independent use to foster cognitive adoption via progressive scaffolding (Böhmer et al., 2024; Vygotsky, 1978; Wertsch, 1984). **DR5** positions ALS as an adaptive learning system that aligns assistance with users' cognitive states (*K2; K3*) and reduces support as competence grows. This approach (*T5*) shifts from static decision support to dynamic learning guided by the ZPD principles of fading scaffolds and growing independence (Vygotsky, 1978; Wertsch, 1984).

Collectively, these DRs did more than just define the functional and usability goals for an Augmented Living Space; they began to reveal the core conceptual aspects/mechanisms essential for the envisioned *Cognitive Adoption Theory*. For example, **DR1** emphasizes user preference for non-wearable, intuitive systems over conventional AAL solutions. This contributes directly to perceived cognitive accessibility, or the idea that users are more likely to engage with systems that impose minimal cognitive load, as exaggerated in the introductory example of this dissertation. **DR2** and **DR5** focus on dynamic effort reduction and adaptive learning curves. These mechanisms inform cognitive effort-benefit calibration, which is a critical predictor of sustained engagement and health behavior change. **DR3** and **DR4** lay the groundwork for aspects of scaffolded autonomy by emphasizing dynamic scaffolding and universal design, respectively. Furthermore, **DR2**'s reframing of efficiency as optimizing the learning curve within the ZPD, **DR3**'s mandate for dynamic scaffolding to allow users to internalize cognitive strategies, and **DR5**'s vision of an adaptive learning system that provides tailored assistance and progressively reduces intervention all point toward the necessity of incorporating adaptive learning mechanisms (such as observational learning), personalized cognitive support, and management of intrinsic cognitive load as central tenets of a theory explaining sustained digital health adoption by this user group. They highlight how phased, adaptive assistance, observational learning, and self-efficacy promote internalization and reduce dependence over time. Each DR translates into a design imperative with theoretical significance, forming the basis for abstracting cognitive alignment mechanisms – the dynamic fit between user capabilities and system behavior – which are critical to adoption and sustained use. This alignment allows the envisioned theory to progress from surface-level usability to a deeper understanding of how digital systems can become integrated into the daily lives of vulnerable users cognitively.

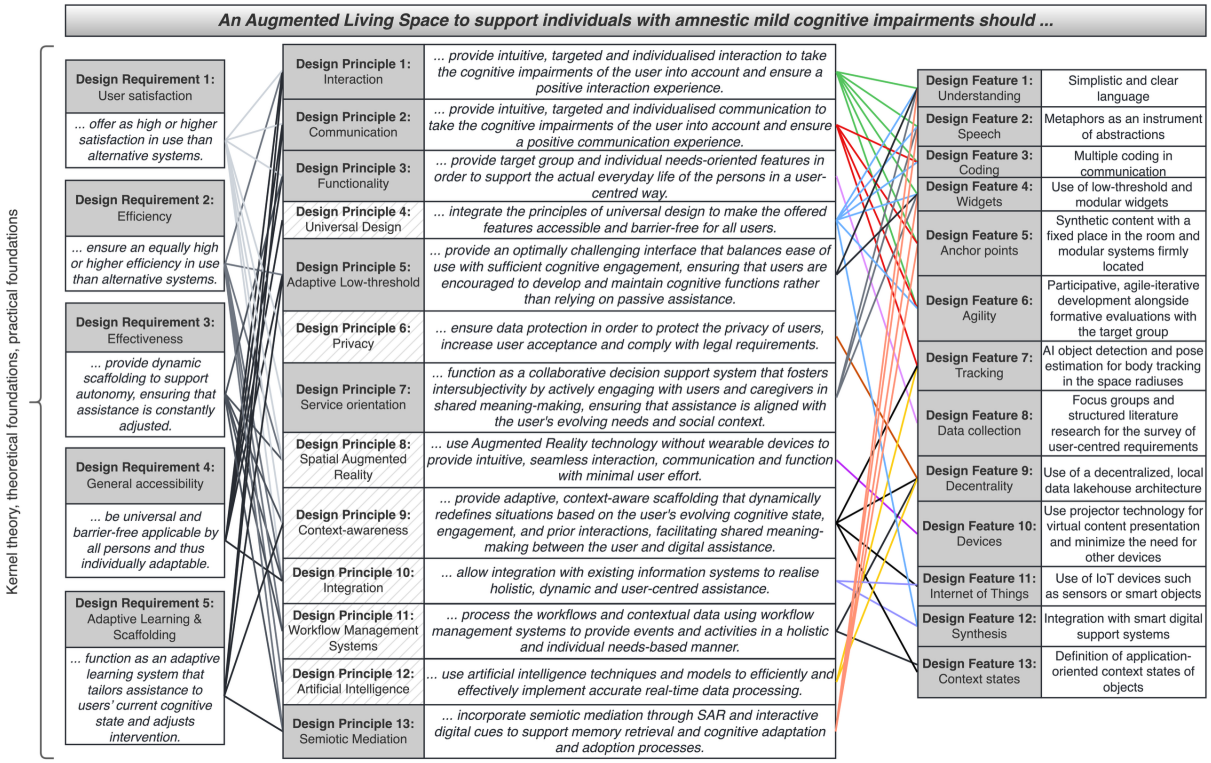


Figure 11. Simplified visualization of the design theory for Augmented Living Spaces (Böhmer et al., 2025a).

The DPs of an Augmented Living Space are prescriptive and universal in the context of prototype design, meaning that they specify how a prototype should be designed to meet the above-mentioned DRs of our target group (Fu et al., 2016; Gregor et al., 2020; Schoormann et al., 2022). The DPs were derived within the *selective application category* (Chandra Kruse et al., 2022) using a supportive approach, as suggested by Möller et al. (2020), which involves specifying the DPs in advance and a prescriptive manner (Fu et al., 2016). This approach allows for the creation of clear and specific guidelines for prototype design as well as value-sensitive design (Friedman et al. 2013), ensuring that the result meets the needs of the target group.

As stated in Böhmer et al. (2025a), **DP1** emphasizes user-centered, personalized, and intuitive interactions that support individuality in digital assistance (Abras et al., 2004; Blackler et al., 2020; Graf et al., 2019; Morris, 1994). Interactions should be accessible (*T5*), tailored to cognitive states (*K4, T4*), and promote learning to minimize system dependence over time (Vygotsky, 1978; Wertsch, 1984). **DP2** ensures that communication is personalized (*T5*) and impairment-aware (*K4; T4*). It also supports cognitive adaptation via structured, multimodal learning (Friedman et al., 2013; Abras et al., 2004; Kosch et al., 2018; Morris, 1994). Semiotic mediation turns external prompts into internal schemas (Böhmer et al., 2024; Vygotsky, 1981). **DP3** uses modular functionality to adapt to changing user needs (Antonino et al., 2011; Garcés et al., 2020; Graf et al., 2019; Tazari et al., 2010), providing flexible and effective support for daily activities (*T3*) and fostering autonomy (*K2; T2*). Features should adapt to cognitive progress and promote the internalization of strategies (Böhmer et al., 2024; Vygotsky, 1978). **DP4** integrates universal and participatory design principles (Abras et al., 2004; Connell, 1997; ISO 9241-11, ISO/TR 22411) and adapts to users' cognitive and physical changes (*K4; T4*; and *K3*). Support should dynamically scale with users' ZPD to foster autonomy (Vygotsky, 1978; Wertsch, 1984). **DP5** promotes low-threshold interfaces that reduce cognitive load (Garcés et al., 2020; Tazari et al., 2010) while balancing ease of use with an optimal level of challenge to stimulate development (*K4*; *T4*) (Böhmer et al., 2024; Vygotsky, 1978). **DP6** protects personal data, thereby boosting acceptance and aligning with the moral value of privacy (Friedman et al., 2013; Garcés et al., 2020; Tazari et al., 2010; Nielsen, 1994). Privacy settings should evolve with users' cognitive independence.

DP7 ensures that an Augmented Living Space is perceived as supportive, not patronizing (*T5*), which aligns with the findings of the focus group and observation study (*K2; T2*). ZPD's concept of intersubjectivity calls for collaborative autonomy regulation through interaction between caregivers, users, and systems (Vygotsky, 1978; Wertsch, 1984). **DP8** uses SAR to enable minimal-effort, non-wearable interaction (Raskar et al., 1998), thereby increasing accessibility (*K4; T4*; and *T5*). SAR should guide users through their ZPD using semiotic mediation. **DP9** incorporates context awareness based on established architectures (Alegre et al., 2016; Costa et al., 2005; Grubert et al., 2016; Strang & Linnhoff-Popien, 2004). Augmented Living Spaces should interactively adjust support to foster autonomy and meaningful engagement (*K1; T1; T3*) (Vygotsky, 1978). **DP10** ensures seamless integration with existing systems (e.g., calendars and therapy tools) to enable adaptive, user-centered experiences (Friedman et al., 2013; Abras et al., 2004). Support should transition smoothly based on users' cognitive needs (*T1*) (Vygotsky, 1978). **DP11** focuses on the WFMS architecture (WFMC, 1995) to process sensory data and trigger context-sensitive output. This supports daily routines (*T1*) by providing timely, relevant information. **DP12** adds AI for real-time context reasoning via object detection and tracking to enable intuitive interaction (*T5*). Deep learning should dynamically adjust support to match users' ZPD (Vygotsky, 1978; Wertsch, 1984). **DP13** uses semiotic mediation via SAR cues to improve memory and cognitive development (Böhmer et al., 2024; Vygotsky, 1978; Wertsch, 1984). SAR should evolve from reminders into interactive tools that promote meaning-making and self-regulation (*K2; K3*; and *T5*).

As such, the DPs also actively instantiate and expose core aspects/mechanisms of cognitive adoption. At their core, the DPs encode semiotic, interactional, and system-level logic that brings the cognitive dimensions of the *Cognitive Adoption Theory* to life. **DP1** and **DP2**, for instance, establish personalized, low-threshold communication interfaces that align with users' impairments. This forms the conceptual foundation for aspects such as semiotic mediation and cognitive anchoring, which create a reference to abstract forms of representation in SAR-based projections. These principles allow users to translate external cues (visual, auditory, and symbolic) into internal strategies. This reduces cognitive load and fosters the internalization of support structures, often described as reciprocal determinism. Similarly, DPs emphasizing adaptive, user-centered support, such as functionality that evolves with user progress (**DP3**), universal design accommodating ZPD stages (**DP4**), and AI-driven adjustments to cognitive assistance (**DP12**), lay the groundwork for understanding how systems can facilitate germane cognitive load and foster the internalization of strategies. As such, **DP5** emphasizes optimal cognitive challenges, pushing beyond conventional ease-of-use toward calibrated cognitive activation. This strikes a balance between guidance and autonomy, which is essential for ZPD-based engagement. Critically, principles like **DP13**, which aim to support memory, cognitive adaptation, and self-regulation, directly point to the importance of metacognitive processes and scaffolded learning in the adoption journey. Even DPs that address socio-emotional aspects, such as privacy (**DP6**) and service orientation that avoids patronizing interactions (**DP7**), highlight the importance of trust and self-efficacy, which are key social cognitive aspects, in making users feel comfortable and empowered to adopt new technologies.

At the system level, **DP8** and **DP13** leverage SAR to create situated semiotic scaffolding, where projected cues (widgets, symbols, metaphors, visual affordances) become embedded within the user's physical environment – supporting memory, triggering situated action, and contributing to embodied cognitive adaptation mechanisms. **DP12** integrates AI-based pose estimation and gaze detection to enable context-sensitive cognitive cueing. This mechanism allows the system to adapt its feedback in real time based on the user's physical and attentional state, which is an essential dynamic for cognitive adoption mechanisms. **DP9** (context-awareness) and **DP11** (workflow management) further ensure that assistance is provided just-in-time, enabling what could be defined as a temporal cognitive synchrony aspect – the alignment of system interventions with users' cognitive "rhythms".

Overall, the DPs can be considered not only as implementation heuristics, but also as design-theoretic mediators. Each DP is a lens through which observed system behavior and user responses are abstracted into theoretically relevant constructs. This process transforms the DPs into theory-generative concepts that systematically lay the foundation for the envisioned *Cognitive Adoption Theory*, enabling both vertical (depth) and lateral (breadth) development of its cognitive adoption mechanisms.

Following general design theory communication, justification, and cumulation, this design cycle adopted the outlined process for design theory "anatomy" proposed by Gregor and Jones (2007). Table 6 provides a summary of this process and shows how this echelon instance has theorized along it. While Figure 11 shows the core constructs and a simplified representation of the design theory artifact, Table 6 shall be treated as the theorized artifact, accompanied by the aforementioned models, textual descriptions, and prototypical scenarios. As such, the design theory enables this DSR echelon instance to classify an Augmented Living Space as a *passive pervasive assistant* (type 4) according to Knote et al. (2019), since it acts unobtrusive and suggestive and converges into a digitally enhanced experience.

Component	Description
Purpose and scope	The current trajectory of AAL and digital health is burdensome and may hinder technology adoption among aMCI individuals. The purpose of the design theory is to enable the development of Augmented Living Spaces that will not only alter this trajectory but also maintain the autonomy of this population through SAR. The goals of an Augmented Living Space are: providing a satisfactory user experience for interaction (**DR1**); improving digital health efficiency and therefore low effort use (**DR2**); providing holistic health care and everyday life functionalities (**DR3**); ensuring a universal design that is generally accessible for everyone (**DR4**); and enable adaptive learning and scaffolding with tailored cognitive interventions (**DR5**).
Constructs	Augmented Living Space are conceptualized as consisting of SAR, context-aware deep learning, diverse sensors, and workflow management. These constructs range from daily living augmentation to individually tailored healthcare for aMCI individuals.
Principles of form and function	Features of current AAL and digital health solutions are fundamentally epitomized by high entry barriers, burdensome wearables, and overall low usability for people with neurodegenerative diseases. The dynamic nature of digital health hence requires novel innovative approaches to enhance usability, autonomy, and adoption. Through theorizing, the following DPs were developed to address this goal: **DP1**: interaction, **DP2**: communication, **DP3**: functionality, **DP4**: universal design, **DP5**: low-threshold, **DP6**: privacy, **DP7**: service orientation, **DP8**: augmented reality, **DP9**: context-awareness, **DP10**: integration, **DP11**: workflow management systems, **DP12**: artificial intelligence, **DP13**: semiotic mediation (Figure 11).
Artifact mutability	Augmented Living Spaces are theorized as an alternative type of AAL system that works in a complementary and symbiotic relationship to current digital health solutions for elderly and aMCI individuals, emphasizing innovative, intuitive, and efficient interaction with health IS. They can be used in different environments, are accessible to everyone, and do not relate to specific hardware/software. The projection design, communication, and scenario functionality are modular and can be adapted for different user use cases. It can be tweaked based on specific practical, personal, or theoretical requirements.
Testable propositions	Augmented Living Spaces for supporting people with aMCIs offer higher user satisfaction, efficiency, effectiveness, and accessibility than alternative AAL approaches. Developers and researchers can design AAL systems in such a way as to support human autonomy, not hindering it, by altering the design theory and its implementational features. The testable propositions are viewed as varying in their degree of generality and as truth statements about the design theory, meaning that these general statements describe expected outcomes (i.e., addressing the DRs) based on the application of the DPs. Thus, it is hypothesized that in the context of digital support for people with aMCI, if System A uses the design theory, it will work or be more effective/efficient than a System B that does not. On a more granular level, the testable propositions here refer to the relationships between DRs and DPs, as shown in Figure 11, emphasizing that if someone has similar DRs in a different context, the corresponding DPs from this design theory can be applied and their effective relationship can be tested. To give a specific example, if DP5 (Adaptive Low-threshold) is applied during system development, the resulting outcome will (partially - since multiple DPs address DR5) satisfy DR5 (Adaptive Learning & Scaffolding), leading to improved cognitive adoption and health interventions, which can be tested by conducting cognition and perception tests with users.

Justificatory knowledge	A literature review, moderated focus group, and observation study alongside established theories of user-centered design, value-sensitive design, and ZPD that remain consistent across various applications in various settings justify the derivation of DRs and DPs. A multi-episode evaluation strategy containing artificial and naturalistic settings justified the theorized artifact which was overall perceived as useful for developing Augmented Living Spaces from a theoretical and practical perspective. An evaluation of user satisfaction, effectiveness, efficiency, and accessibility was conducted to further assess and validate the derived system architecture. Close evaluation with the target group is vital since Augmented Living Spaces offer novel functionalities for non-wearable devices and digital, smart, and context-aware health assistance.
Principles of implementation	The universal design knowledge suggests various implementation criteria that yield the desired user-centered outcomes. These are defined as design features and guide the implementation alongside the second DSR echelon instance of this design cycle, which is the reference architecture (Figures 12 & 13).
Expository instantiation	A series of DRs and DPs is developed that, alongside an reference architecture, show how researchers and developers can apply the proposed characteristics to create Augmented Living Spaces. A technical IS architecture is developed and thereupon a prototype implementation, encompassing the derivable components of the design theory within two reference scenarios.

Note. AAL= ambient assisted living, aMCI = amnestic mild cognitive impairment, DP = design principle, DR = design requirement, IS = information system, SAR = spatial augmented reality, RA = reference architecture, WFMS = workflow management system.

Table 6. Components of the first cycle's design theory according to Gregor and Jones (2007) (Böhmer et al., 2025a).

3.3.2 Reference Architecture

Being the second DSR echelon instance of the first design cycle and a „by-product" of the heuristic design theorizing approach, a reference architecture was developed in Böhmer et al. (2025a) by creating and experimenting with different graphical types of representation of the problem solution (Gregory & Muntermann, 2014). Reference architectures generally represent theoretical guidance and a kind of template solution for information systems regarding a particular application domain (Angelov et al., 2009; Nakagawa et al., 2012). In this regard, Oussalah (2023) states that the design of a reference architecture should incorporate and establish pre-defined requirements, while also identifying domain concepts and ontologies. Thus, this approach can use DRs and DPs of a general design theory as they respectively depict application-specific meta-requirements (Baskerville & Pries-Heje, 2010; Walls et al., 1992; 2004) and the prescriptive implementation of these (Fu et al., 2016) to represent a theoretically sound foundation for the reference architecture. As such, the reference architecture for an Augmented Living Space depicted in this DSR echelon instance is constituted by a component system architecture, a universally applicable UML class diagram, and a reference user interface (UI) design, supplemented with textual descriptions in addition to the respective figures. Therefore, the reference architecture is the second main artifact of the first design cycle and is intended to support the practical implementation of Augmented Living Spaces, generally depicting an instantiation of the design theory.

A conceptual model for cognitively supporting aMCI people without wearables requires four main components at a higher level of granularity: (1) a sensor interface consisting of smart sensors and an AI-powered tracking module; (2) a database interface to store the sensory and contextual data; (3) a workflow interface to process the contextual data; and (4) a projection interface to adequately present the relevant information. These four interface components are highly modular, meaning that every sub-component can be addressed by an individual solution, which reduces the overall complexity of the system. Figure 12 visualizes the developed technological artifact instantiated as a component system architecture and derived from the design theory. Considering that the component representation aims to portray the IS architecture at an elevated level of abstraction, certain underlying characteristics (e.g., pre-processing unit, messenger workflow) are merely referenced and shall be expounded upon subsequently through the class diagram (Figure 13).

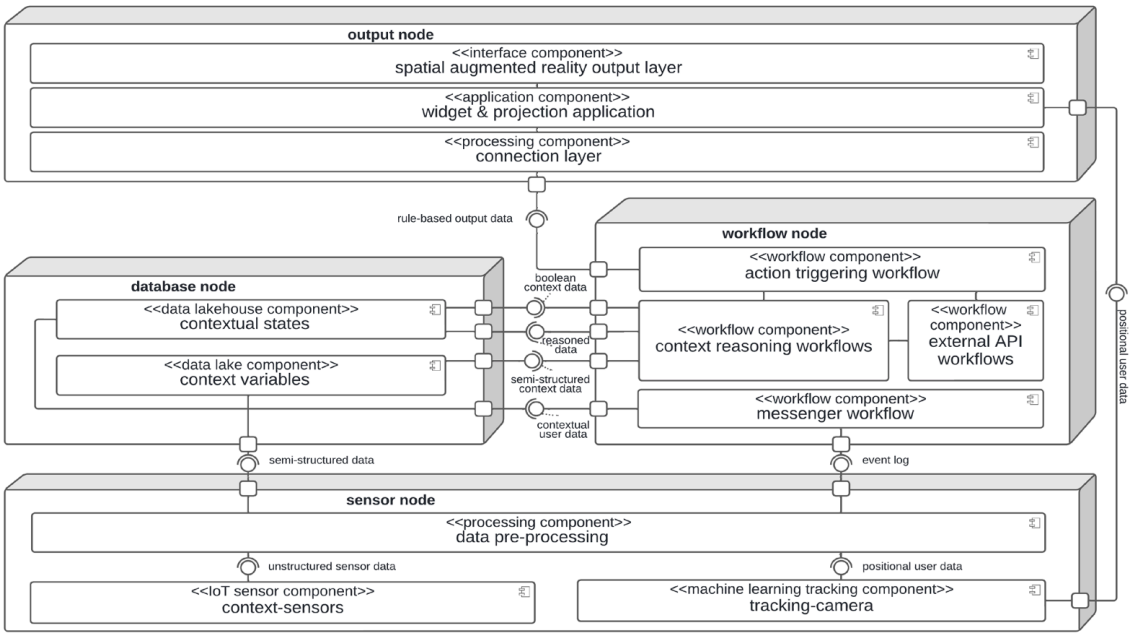


Figure 12. System architecture on the component level (Böhmer et al., 2023).

To ensure a coherent narrative, the following paragraphs of this section (especially the descriptions of the component and class diagrams) are mainly based on Böhmer et al. (2025a) and were edited slightly for integration into the dissertation.

The *sensor interface* bundles all sensory hardware as well as machine learning-powered tracking. The semi- or unstructured data of sensors (e.g., heat sensors, water level sensors, or fall detection sensors) is forwarded to the pre-processing unit, where the data is parsed and every sensor is given a specific ID for further processing. The data pre-processing unit then specifies the destination, data content, and format of the sent data, enabling higher efficiency (**DR2**). On the other side, synthetically trained deep-learning models track people and create context-aware zones for gaze projection. (**DP12**). This data will be pre-processed and sent to the *workflow interface* as well as directly to the *projection interface*, allowing fast process time for real-time information delivery, which is essential for the conceptualization of RAs for AAL and the realization of **DR1, DR2**, and **DR5** (Böhmer et al., 2025a).

The *database interface* is structured as a data lakehouse (Armbrust et al., 2021), enabling near real-time data storage, processing, and retrieval. Hence, the data structure is irrelevant upon storage. Furthermore, the *database interface* creates context variables through the incoming and pre-processed data, e.g., storing the stove temperature at a specific time with a defined ID. This specific context data is sent as a variable to the workflow interface, which then reasons the data. Nonetheless, the *database interface* also contains contextual states that come from the *workflow interface*, storing context states (e.g., stove is hot, door is open) based on the context variables in circulation (**DP9**) (Böhmer et al., 2025a).

Moreover, the workflow interface acts as a reasoning engine for the Augmented Living Space, establishing contextual connections between raw sensory data and its implications for the user, and thus, following the reference architecture for context-aware information systems by Alegre et al. (2016) and Costa et al. (2005) as well as addressing **DP11**. The WFMS defines, interprets, instantiates, and manages the execution of workflows, integrates external applications, and interacts with human workflow participants according to the definition of the Workflow Management Coalition (1995). Moreover, it manages and controls the sequences. Hence, it is responsible for creating, reasoning, and combining context (**DP9**). For example, a raw temperature context variable from the *database interface* has generally no meaning. However, if the stove has to be off at a certain time (e.g., after 10 pm) but the WFMS detects a hot temperature, it creates a reasoned context for the raw variables and adds value to it. Furthermore, the WFMS also integrates external services such as the user's phone, personal health

applications, smart home systems, or health insurance services via secured API sockets (**DP7**, **DP10**). Lastly, the *workflow interface* triggers projection or auditory communication, which is implemented through the application (e.g., triggering and augmenting the information of a hot stove plate) (Böhmer et al., 2025a).

Lastly, the *projection interface* includes the SAR application, which parses the sent information to project or communicate with a certain widget or widget bubble (**DP8**). Widgets can be seen as a form or expression of information representation, embodying a kind of visual container that consists of various visually represented information or data. With pre-defined, yet highly modular and flexible widget appearances, it is possible to assemble certain widgets as well as orchestrate them. This allows the application to change color schemes or data composition according to the individual needs of the user (Antonino et al., 2011; Garces et al., 2020; Kosch et al., 2018; Tazari et al., 2010), accounting for individual impairments (**DR4**, **DP3**, **DP4**). Since the application is equipped with positional user data, suitable projection mapping is enabled, and the right projector or speaker is selected automatically (Böhmer et al., 2025a).

The UML class diagram for the Augmented Living Space concept, as shown in Figure 13, maps out the structure of the particular system by modeling its classes, attributes, methods, and relationships between them on a lower level of abstraction. Thus, it extends and instantiates the simplified component architecture. Below, the elements of the UML class diagram are briefly linked with the design features (see Figure 11) to bridge the abstraction gap between design theory and implementation. A detailed description of the Augmented Living Spaces reference architecture on the class level can be found in the respective publication (Böhmer et al., 2025a) in Appendix B.

The reasoning workflow interface consists of the *Workflow Management System*, *Workflow, Java, Area Decision, External Services API*, and the *Context Reasoning* classes. The *Workflow* class connects to and operates under the *Workflow Management System* class. It coordinates and processes workflows to generate context (**DF13** – Context States). Methods process and transmit contextual data, triggers, and states. Workflows can be active, idle, or on hold. The *Java* class acts as a scripting bridge that links workflows to the database and projection interfaces and relays reasoned data. The *Area Decision* class parses tracking data to determine spatial zones for gaze-based projection (**DF7** – Tracking; **DF10** – Devices). External services, such as Alexa and Google Calendar, are connected via the WFMS and provide data for widget selection (**DF12** – Synthesis) (Böhmer et al., 2025a).

The database interface includes a single *Data Lakehouse* class that stores workflow and sensor data (**DF9** – Decentrality). According to Armbrust et al. (2021), the data lakehouse merges structured data warehouse storage with unstructured, fast-processing, deep-learning data that is isolated from external services. As such, it does not perform context reasoning; it only stores data (Böhmer et al., 2025a).

The sensor interface consists of *Sensor, Sensor Module, Camera, Tracking Module*, and *Data Pre-Processing* classes. It forms the first data acquisition layer (**DF11** – IoT), with sensors embedded in objects (e.g., stoves), placed manually (e.g., humidity), or worn. *Sensor Module* manages data flow; *Tracking Module* runs a deep learning model on 360° camera input, compensating for distortion. *Data* is passed to *Data Pre-Processing*, using NodeRED for unified handling, despite the semi-/unstructured nature. The interface also links sensors to the *Data Lakehouse*. A node-state enumeration (open/closed) governs connection status (Böhmer et al., 2025a).

The projection interface includes the *Application, Projector, Speaker*, and *Widget* classes. It delivers user-centered cognitive support through timely projection and sound (**DF4** – Widgets). *Application* matches widget data from workflows with user position data for precise delivery. Final widget output considers comprehensibility (**DF1** – Understanding), clear visuals/sound (**DF3** – Coding), and simple speech (**DF2** – Speech), supporting users with sensory impairments. In urgent cases (e.g., stove left on), overlays highlight critical info instantly. Application triggers projections via *Projector* or sound via *Speaker* (Böhmer et al., 2025a).

Finally, two human classes exist: *User* and *ALiS*-Engineer. Users interact with the system, submit feedback, or initiate emergency calls. The engineer installs, customizes, and maintains the system's functionalities based on user preferences and feedback – remotely or on-site (Böhmer et al., 2025a).

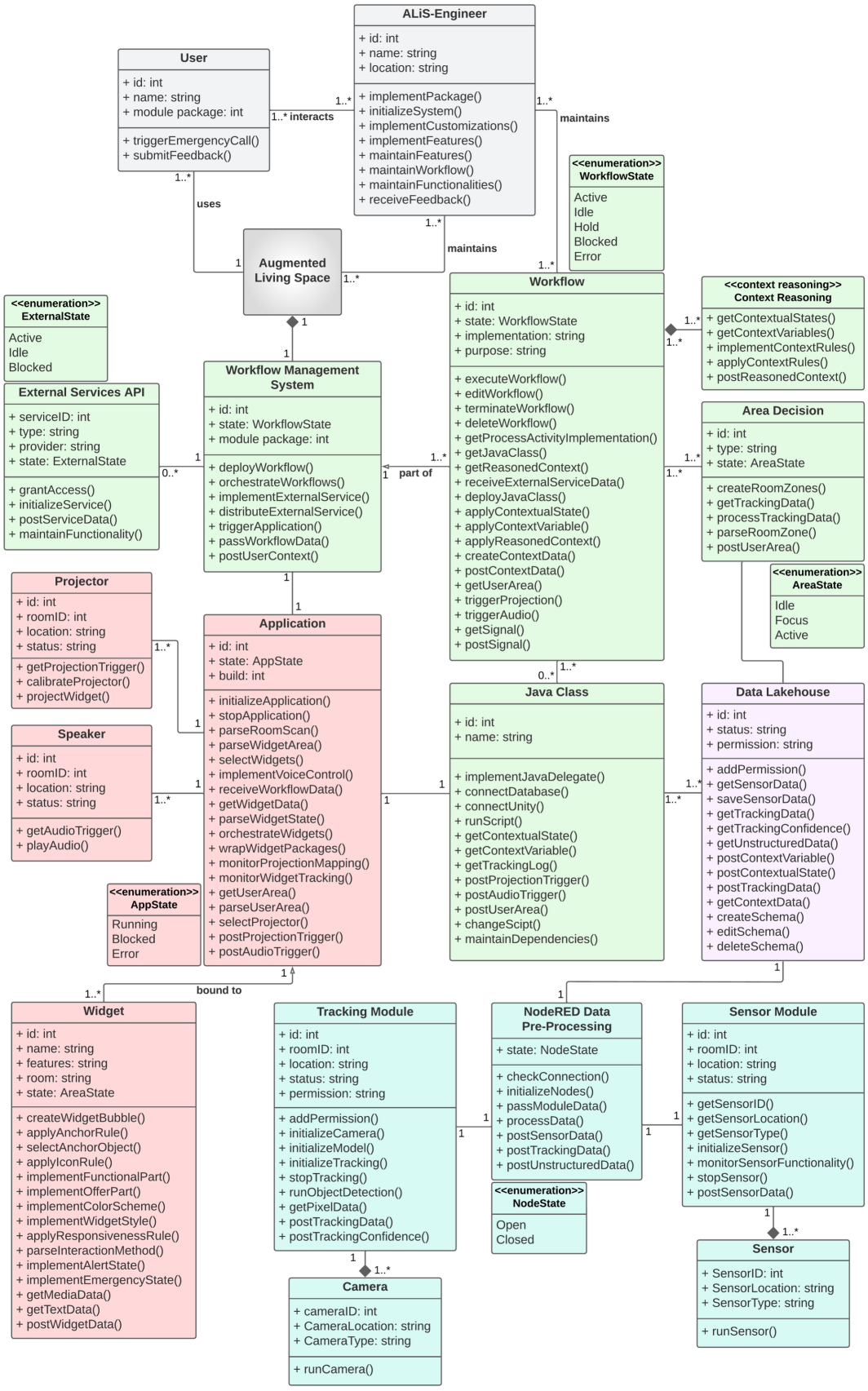


Figure 13. System architecture on the class level (Böhmer et al., 2025a).

The development of this reference architecture for the Augmented Living Spaces concept, while primarily an act of instantiating the design theory, served as a valuable lever for refining the conceptual underpinnings of cognitive adoption aspects/mechanisms. Conceptualizing the four highly modular interface components – sensor, database, workflow, and projection – and detailing their interactions (as illustrated in Figures 11, 12, and 13) moved abstract principles into a more concrete operational space. The sensor and tracking interface translates into mechanisms that manage cognitive load, ensuring passive, unobtrusive data collection that eliminates the need for wearable technologies and reduces interaction friction (**DR1**, **DP12**), thereby minimizing cognitive overhead in daily interaction. The challenge of seamlessly integrating diverse data inputs and translating them into timely, relevant, and easily digestible SAR projections via the projection interface and its customizable widgets directly informed the understanding of how *usability* and *accessibility* (central to cognitive adoption) are architecturally enabled. Furthermore, the architectural emphasis on features like a data lakehouse for efficient contextual state management and the ability to trigger projections based on precise positional data and reasoned context (**DP9**, **DP11**, **DP12**) highlighted how system responsiveness and personalization are not just desirable features but may be fundamental enablers of cognitive support and, by extension, adoption. By acting as an "extended cognitive memory," it anchors one of the central propositions: that distributed information architectures can scaffold weakened memory functions and reduce information processing burden. The process of designing this reference architecture, therefore, provided tangible insights into how specific architectural choices could either facilitate or hinder the cognitive ease, perceived supportiveness, and ultimately, the cognitive adoption of such assistive systems by individuals with aMCI.

3.3.3 Prototypical Instantiation

To instantiate and implement both the design theory and reference architecture, a prototypical scenario was developed in Böhmer et al. (2025a), whose visual design for such an exemplary Augmented Living Space is depicted in Figure 14. Based primarily on the results of the focus groups and observational studies, it seemed reasonable to develop the Augmented Living Space system as an unobtrusive design object for the living room, rather than a bulky projector that the target group would perceive as "being diseased". As can be seen in Figure 14, the flexible design allows the system to be placed anywhere in the living room, projecting relevant widgets wherever they fit or are needed. It also shows the interaction approach (right side of the figure), where widgets pop up whenever the user comes near them and show the relevant information (this interaction design will be the core of the second design cycle of this dissertation).



Figure 14. Visual instantiation of a prototypical scenario for an Augmented Living Space (Böhmer et al., 2025a).

Instantiating this vision of an Augmented Living Space, a prototype for showcasing the prototypical scenario was built that included a range of widgets and potential use cases for the target group (e.g., medication reminders, calendars, stove warnings, or activations) (Böhmer et al., 2025a). The hardware components for the prototype included a Raspberry Pi 4, a Samsung mini-projector, an internal Wi-Fi network router, and a necessary power supply. As shown in Figure 15, the actual implementation of the prototype has been very close to the vision and was instantiated in several artificial (demo living rooms) and natural settings (actual living rooms), which will be discussed as part of the evaluation in Chapter 3.4. As such, the prototypical instantiation can be seen as the practical artifact (in contrast to the design theory and reference architecture as theoretical echelon instances and artifacts) of the first design cycle.



Figure 15. Actual implementation of the prototypical scenario.

3.4 Evaluation

As already mentioned in Chapter 2.5 for the overall evaluation strategy of this dissertation, the strategy for this design cycle follows the FEDS framework proposed by Venable et al. (2016), focusing on the defined two stakeholder groups to evaluate both the theoretical soundness and practical feasibility of the design theory, reference architecture, and prototype instantiation. As shown in Figure 16 and also following the *Human Risk and Effectiveness* strategy (Venable et al., 2016), the complementary evaluation episodes in Böhmer et al. (2025a) were conducted both formatively during the design theory and prototype development and summatively after the artifacts had been finalized.

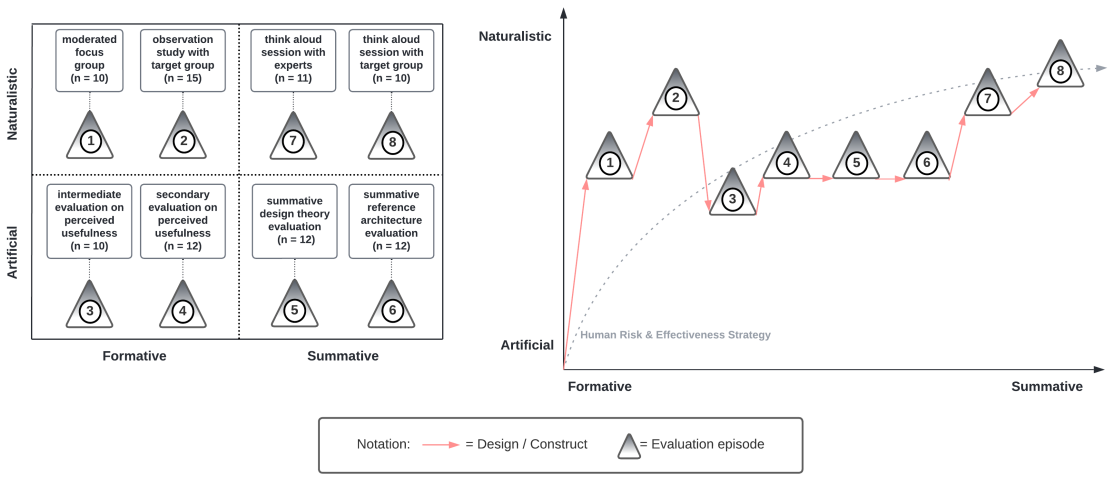


Figure 16. Summary of the specific evaluation strategy and episodes of the first design cycle (Böhmer et al., 2025a).

Some parts of the following paragraphs in this section reuse wording from Böhmer et al. (2025a), with minor edits for integration.

As shown in Böhmer et al. (2025a), two naturalistic, formative evaluation (or rather data collection) episodes (n=10 and n=15) (Figure 16, episodes 1 & 2) were conducted early in this cycle to inform the design theory development. Subsequently, two formative evaluations via questionnaires on the perceived usefulness (n=22) were conducted during and after the heuristic design theorizing of the design theory, which are extensively described in Böhmer et al. (2022) (Figure 16, episodes 3 & 4) and included an *artificial* scenario where subjects were asked to utilize the design theory and reason its constructs. Using the six items of Davis (1989) to ask researchers, practitioners, and experts in the field of IS and healthcare for their perceived usefulness of the design theory in the hypothetical scenario of conceptualizing, designing, or developing an Augmented Living Space, generally positive results were obtained. The subjects stated that they could accomplish tasks more quickly and that their overall job performance (i.e., designing and developing an Augmented Living Space) and effectiveness would be improved. They found the design theory useful, expressing that the specific DPs helped them visualize a possible solution. Overall, the subjects agreed with the statement that the number of DRs and DPs makes the design theory meaningful without being unwieldy or overwhelming.

After the development of both the design theory and reference architecture, two summative, artificial evaluations to ascertain the *performance expectancy* (PE) and *effort expectancy* (EE) of the design theory and reference architecture were conducted via a survey of potential users, i.e., IS researchers, developers, and practitioners (n=11 respectively for the design theory and reference architecture) (Figure 16, episodes 5 and 6) (Böhmer et al., 2025a). Since PE and EE as constructs are not directly measurable, the approach drew on the well-known scale items by Venkatesh et al. (2003). For PE: usefulness (PE1), quickness (PE2), productivity (PE3), and increased chance of getting a raise (PE4). For EE: clarity (EE1), easiness to master (EE2), easiness to use (EE3), and easiness to learn (EE4). Here, PE and EE were specified for the relevant application context, i.e., for the development of Augmented Living Spaces for aMCI individuals. Additionally, experts were asked about the conciseness (CON), extendibility (EXT), and explanatory power (EXP) of the artifacts, following Nickerson et al.'s (2013) approach to subjective ending conditions from their well-known taxonomy development method. The questionnaire included: 1) an introductory text about the research project, 2) the design theory as presented in this paper, 3) a prompt to imagine an application scenario for the design theory, 4) the statements on the EE, CON, EXT, and EXP, 5) the reference architecture as presented in this paper, 6) a prompt to imagine an application scenario for the reference architecture, 7) the statements on the PE, EE, CON, EXT, and EXP, and 8) some socio-economic questions. For data collection, interval-scaled verbal numeric 7-point Likert-style scales were used. In choosing the sample size, the so-called "10±2 rule" (Hwang & Salvendy, 2010) was considered, which states that 8 to 12 respondents are sufficient for usefulness evaluations. Based on an expected response rate of 50%, the design theory questionnaire was sent to a total of 21 DSR experts and received 11 completed questionnaires (actual response rate: 52.4%), while the reference architecture questionnaire was sent to 19 conceptual modeling and reference architecture experts and also received 11 responses (57.9%). The respondents included CEOs, project managers, senior researchers, research assistants, senior consultants, and AR developers, all active in the healthcare and IS domain, possessing 3-25 years of experience in their roles. Among the experts, 18 worked in large, and four in micro-sized companies/organizations.

Figure 17 depicts the box plots of the responses from Böhmer et al. (2025a). Both the design theory and reference architecture received high levels of agreement on all items, with medians of m=7 (design theory) and m=6 (reference architecture). The sum scores of the PE and EE for the design theory and reference architecture, with medians of m=25 (PE-DT), m=27 (EE-DT), m=25 (PE-RA), and m=26 (EE-RA) on a 7-28 scale, summarize the overall positive evaluation well. The subjects stated that using both artifacts would enable them to accomplish tasks (e.g., developing and implementing an Augmented Living Space) more quickly while also increasing the productivity and understanding of the artifacts. Overall, subjects found the design theory and reference architecture useful and easy to use/comprehend. Moreover, both artifacts are perceived to be easily extendable while simultaneously being sufficiently concise and explained.

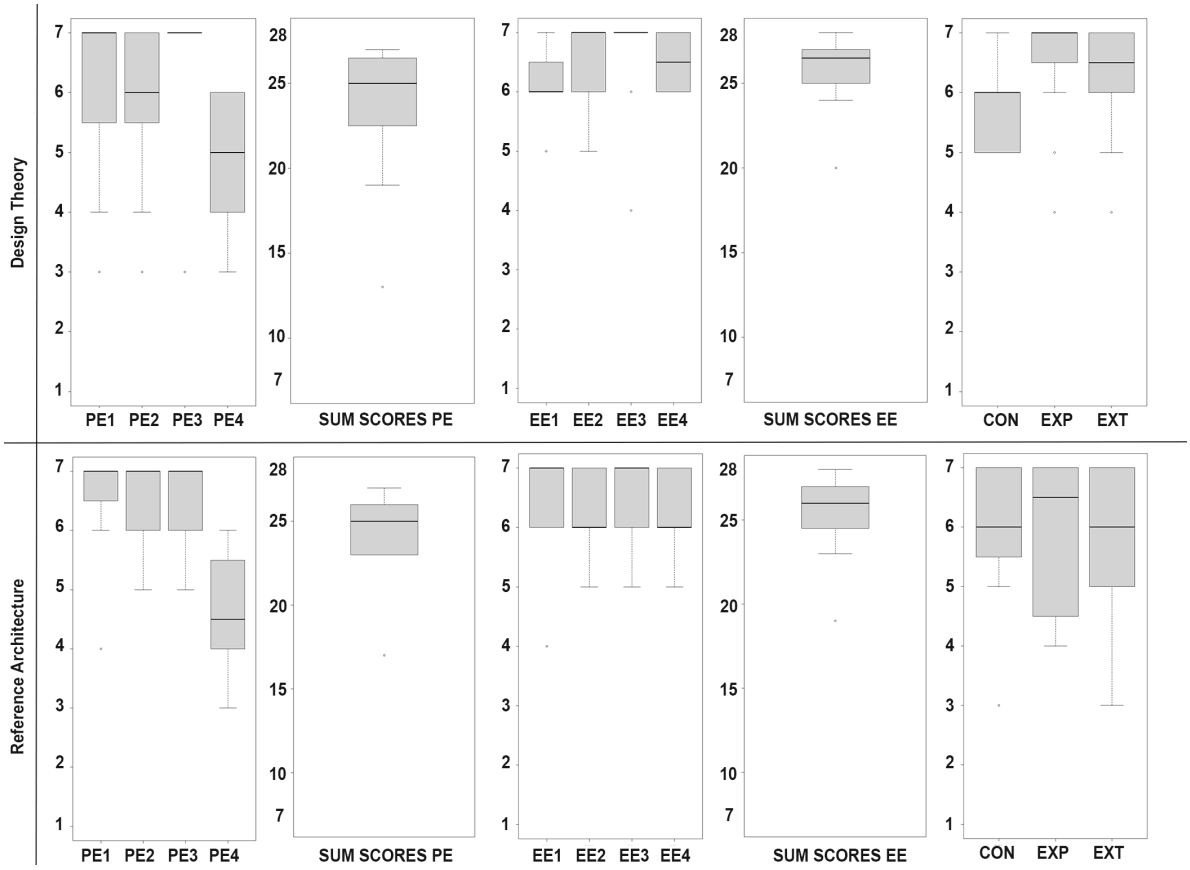


Figure 17. Box plots for design theory (top row) and reference architecture (bottom row) evaluations (Böhmer et al., 2025a).

As stated in Böhmer et al. (2025a) and to validate the quality of the constructs PE and EE, individual item reliability (loadings), composite construct reliability (CCR), and average variance extracted (AVE) (Hulland, 1999) were examined. Item reliability is examined by evaluating the loadings of the measured items on their respective construct. A confirmatory factor analysis was performed in R for this purpose (Table 7). Items with low loadings (rule of thumb: < 0.4) should be carefully scrutinized as they offer little additional explanatory power but attenuate (and thus bias) parameter estimates (Nunnally, 1978; Hulland, 1999). In the models of this cycle, all item loadings exceed the 0.4 limit. The average variance extracted (AVE) is also above the limit of 0.5 for all items and artifacts, indicating that the variance captured by the construct is greater than the measurement error (Fornell & Larcker, 1981). Composite construct reliability (CCR) measures the overall reliability of items loading on a construct and should exceed the threshold of 0.7 (Hulland, 1999; Nunnally, 1978), which is given for all items and artifacts. Discriminant validity was evaluated through the comparison of the AVE and the squared correlation among the constructs, as outlined by Fornell and Larcker (1981). To compute the correlation, the Kendall tau coefficient, specifically suited for Likert-style scales as suggested by Jamieson (2004), was employed. The comparison shows that the AVE of PE and EE (see Table 7) is each higher than the squared correlations (cor) between PE and EE for both the design theory ($cor^2 = 0.007$) and the reference architecture ($cor^2 = 0.204$). Based on these validity criteria, the measurement models with four items each for the constructs PE and EE are suitable for evaluation. The evaluation focused on conclusion validity (the relationship between treatment and outcome) and construct validity (accurate measurement), using established measures from prior research (Wohlin et al., 2012; Venkatesh et al., 2003). While internal validity (risk of other factors influencing results) was a concern, the detailed scenario and participant expertise mitigated it (Wohlin et al., 2012). External validity (generalizability) was addressed by the design's broad applicability, expert participants, and consistent results, suggesting similar positive outcomes in future evaluations (Wohlin et al., 2012; Haynes et al., 1995).

Performance Expectancy		Design Theory	Reference Architecture	**Effort Expectancy**		Design Theory	Reference Architecture
Loadings	Usefulness	.888	.699	Loadings	Clarity	.789	.739
	Quickness	.777	.754		Easy to Master	.718	.720
	Productivity	.723	.866		Easy to Use	.665	.877
	Chance of Raise	.580	.792		Easy to Learn	.740	.712
	AVE	.563	.609		**AVE**	.532	.585
	CCR	.834	.861		**CCR**	.819	.848

Table 7. Construct validation in the first design cycle (Böhmer et al., 2025a).

Pursuing a summative and natural evaluation as well as ensuring scientific rigor and a functioning system, the reference architecture was implemented in a prototype scenario (similar to the ones shown in Figures 14 and 15) and evaluated in two independent naturalistic sessions (n=21) (Figure 16, episodes 7 & 8). The first session was directed to get feedback from IS researchers and cognitive caregiving experts (n=11), whereas the second session was aimed at evaluating the system use by the target group of aMCI individuals (n=10). The theoretical lens of user-centered design was followed for evaluation (Abras et al., 2004) and used the qualitative research method of *Concurrent Think-Aloud* (Van Den Haak et al., 2003), where users are asked to use the system or complete a set of tasks and verbalize their thoughts to evaluate the software design and implementation. To conduct the think-aloud sessions, the three steps applied in Schoormann et al. (2018) were followed: (1) provision of information about the system prototype and the task to be performed, (2) systematic protocoling of verbalized user thoughts, and (3) analysis of protocols. Seeking qualitative rigor in these sessions, the well-known method of Gioia et al. (2013) was used, developing *first-order concepts*, *second-order themes* as well as *aggregate dimensions* based on the thoughts expressed by the subjects. Subsequently, the clustered comments were assigned to the respective DPs to assess how the design theory was implemented through the IS architecture of the Augmented Living Spaces system. Table 8 contains the clustered results, as both positive aspects (marked by "+") and potential for improvement (marked by "o") could be derived.

Design Principle	Clustered verbalized thoughts
DP1 *Interaction*	+ Intuitive user interface and technology access without the need for extra devices + Overall positive user experience due to low entry barriers and fast understanding
DP2 *Communication*	+ Color schemes and animations are helpful regarding information assimilation o Certain objects within the living space could be emphasized through projection techniques
DP3 *Functionality*	+ Different use cases and scenarios are well-implemented + Necessary functionality and information are provided in a needs-oriented manner + Transition between action areas and the respective widget state is perceived as useful
DP4 *Universal Design*	+ Communicated information is easily accessible and comprehensible o Auditory information could be improved by adding different voices and alert types
DP5 *Low-threshold*	+ Cognitive relief due to minimized complexity + Cognitive relief due to easily understandable and object-oriented information
DP6 *Privacy*	+ A data privacy concept fosters user acceptance o Privacy and data protection should be made more transparent
DP7 *Service Orientation*	+ Individual and functionality-oriented widgets are perceived as useful + Content of communicated information is sufficient o Widgets should always represent the real object (i.e. number of stovetops)
DP8 *SAR*	+ Cognitive relief due to pleasant and naturally fitting projections o Some widgets within the active state area could be displayed in smaller

DP9 *Context-awareness*	+ Context-specific information is useful and communicated + Cognitive relief due to individual needs-oriented assistance
DP10 *Integration*	+ Cognitive relief due to the reduced amount of specialized smart systems o ALiS should cooperate with and integrate local community initiatives
DP11 *WFMS*	+ Intuitive workflow management interface for developers + Use of process-oriented data streams fosters user experience regarding delays
DP12 *AI*	+ Gaze-based projection facilitates the perception of communicated information + Monitoring was perceived as useful regarding anomaly detection or emergencies
DP13 *Mediation*	+ Differences in required cognitive effort are appreciated rather than static reminders + (Subjective) perception that such decision support helps structure cognition
Note. ALiS = Augmented Living Space; DP = design principle; + = positive aspect; o = potential for improvement	

Table 8. Results of the summative think-aloud session in the first design cycle (Böhmer et al., 2025a).

In summary, the findings from Böhmer et al. (2025a) indicate an Augmented Living Space with user-tracking event-based projections is intuitive to use and doesn't require additional devices, e.g., wearables (Böhmer et al., 2025d). The widget view provides useful information intuitively, while aMCI users perceived the cognitive support as cooperative rather than intrusive, consistent with the idea of addressing their zone of proximal development (Vygotsky, 1978; Wertsch, 1984) as well as cognitive load and social cognitive aspects relevant to technology adoption. Using color schemes and SAR reduces cognitive load, especially suitable for aMCI individuals. The subjects felt comfortable with the system's communication style and could imagine themselves using it every day, as it provides them with useful functionalities, which confirmed the adoption-related assumptions made by the design theory and its instantiation.

3.5 Conclusion

Laying the conceptual foundations of what drives cognitive adoption of digital health technologies, the first design cycle of this dissertation focused on theorizing and conceptualizing a digital health IS tailored for individuals with (a)MCI. Triggered by an *Awareness of Problem* – the insufficient support for cognitive adoption and autonomy in existing AAL or digital health assistance systems – this design cycle culminated in the development of two core artifacts serving the overarching goal of the *Cognitive Adoption Theory*: (1) a **design theory** for Augmented Living Spaces, and, based on the encountered circumscription, (2) a **reference architecture** to instantiate it. Effectively answering both **RQ1** and **RQ2**, these artifacts emerged from a theory-driven, user-centered process as two DSR echelon instances that combined heuristic design theorizing with theoretical grounding and data from focus groups and observational studies. The design theory encapsulates 5 DRs and 13 corresponding DPs that integrate theoretical foundations from Vygotsky's ZPD theory and practical insights from the everyday experiences of the target group. These principles enable adaptive scaffolding, semiotic mediation, and context-aware interaction, which are relevant aspects and mechanisms regarding the cognitive adoption of digital health technology. The reference architecture operationalizes the design theory by defining a modular system of sensor interfaces, workflow management systems, AI-based tracking, and SAR projection components. Through iterative development and formative evaluations, the design cycle produced a functioning prototype that demonstrates the practical viability of an Augmented Living Space in real-world settings. Evaluation results confirm the conceptual soundness, usability, and user acceptance of the developed artifacts. Moreover, shown in a secondary publication of this first design cycle, a comparative analysis of the Augmented Living Spaces prototype showed that subjects with cognitive impairments would prefer the SAR-based approach over conventional AR (i.e., wearables), confirming the assumption of its enhanced usability (Böhmer et al., 2025d).

Despite the promising results shown by Böhmer et al. (2025a), the first design cycle revealed some limitations, especially in terms of technical implementation and granularity. While the design theory provides a theoretically rigorous and prescriptive foundation, it lacks fine-grained conceptual knowledge about the concrete mechanisms of intuitive adoption and interaction design, especially when it comes to cognitive impairments. Similarly, while the reference architecture provides an overarching system blueprint, it remains abstract in several key implementation domains, especially regarding real-time interaction, adaptive feedback mechanisms, and personalized user trajectories. These limitations became apparent during the circumscription phase, where formative evaluations and prototyping activities demonstrated the need for deeper insights into how adoption and interaction design can dynamically evolve in response to the changing cognitive states of aMCI users. The challenge of translating theoretical constructs such as “semiotic mediation” or “adaptive scaffolding” into seamless technical interfaces and workflows became an interesting challenge that needed to be explored more thoroughly.

In the context of the overarching goal of developing a *Cognitive Adoption Theory*, reflecting on the results of this design cycle reveals that, while the design theory and reference architecture provide essential conceptual guidance, they are insufficient to address the complexities of intuitive, adaptive, and user-cooperative interaction in SAR-based environments. The evaluations revealed a gap between high-level design knowledge and low-level interaction logic, particularly when it comes to designing multimodal, event-based feedback that aligns with the ZPD constructs. Consequently, these findings triggered the second design cycle, which aims to refine and deepen the understanding of intuitive interaction design for people with cognitive impairments using the example of Augmented Living Spaces. This upcoming design cycle adopts a lower level of abstraction, focusing on the technical and cognitive operationalization of interaction DPs proposed by design theory. It addresses the limitations encountered here by developing more granular models, mappings, and implementation strategies to bridge the theory-practice gap identified in this cycle. Consistent with Vaishnavi & Kuechler’s (2015) notion of DSR as a reflective and iterative learning process, the first cycle served not only as a foundation for theoretical innovation but also as a heuristic lens that illuminated gaps in need of deeper exploration towards the proposed *Cognitive Adoption Theory*. This reflective insight solidifies the transition to a more focused, technical second cycle that builds on the strengths and addresses the shortcomings of this initial phase.

4 Design Cycle 2: Novel Human-Computer Interaction Approach and Design Theory for Synthetic Image Data Echelon Instances

Driven by RQ3 and RQ4, the focus of this design cycle is twofold due to the circumscription encountered, ultimately leading to two pursued DSR echelon instances (Böhmer et al., 2025b; 2025c). Since the first design cycle concluded that the theorized interaction design and technical implementation of the Augmented Living Spaces concept were not sufficiently understood to provide the best possible adoption and support for people with aMCI in real-world settings, the focus of the second design cycle was explicitly set on conceptualizing and implementing the interaction design at a deeper level of granularity. As such, an intuitive interaction design based on deep learning with synthetic images and SAR projections was addressed, while second, as a causal effect, design heuristics for the ethical and effective use of such synthetic images were explored to guide future research in this rapidly evolving field of digital health. While people with aMCI can often live independently, they may require more intuitive and less cognitively demanding technological support (Petersen, 2016; Petersen et al., 2018; Yu et al., 2017). In parallel, the proliferation of digital health applications to support patients, caregivers, and healthcare professionals highlights a persistent challenge: low user confidence and limited adoption, particularly among vulnerable populations (Böhmer et al., 2024; Ienca et al., 2021; Mathews et al., 2019). For individuals with aMCI, concerns about adoption, ethics, and usability persist, exacerbated by complex interfaces, cognitive load, and nonuser-centered HCI design (Blass et al. 2022; Chignell et al. 2023; Vines et al. 2015). By investigating how the design theory and reference architecture from the

first design cycle can be translated from their theoretical and conceptual concepts, this perspective explores how (presumably) intuitive interaction design (i.e., through an indirect HCI approach) can facilitate or hinder adoption, explicitly operationalizing kernel theories such as socio-technical systems theory (Trist & Bamforth, 1951; Emery & Trist, 1960), SCT (Bandura, 1977; 2001; 2013), value-sensitive design (Friedman et al., 2013), and user-centered design (Abras et al., 2004). Thus, this design cycle with its two DSR echelon instances ensures that technological affordances and usability aspects are methodologically assessed to capture crucial technical mechanisms behind individuals' successful or unsuccessful adoption of and interaction with digital health technologies. This perspective explicitly focuses on the *actual* domain of technology-mediated events and interactions, analyzing *how* technological mechanisms concretely enable or inhibit user adoption (Mingers et al., 2013) – further developing the conceptual foundations of the *Cognitive Adoption Theory*.

4.1 Awareness of Problem

Following the initial findings and limitations identified in the first design cycle, the second cycle focuses on improving the HCI aspects of digital health technologies, specifically in the context of assisting individuals with multi-domain aMCI and given the context of Augmented Living Spaces. As mentioned in the problem awareness phase of the first design cycle (Chapter 3.1), which served as the overall starting point for this dissertation, global demographic shifts toward an aging population are increasing the demand for health care, particularly for neurodegenerative diseases such as dementia and aMCI (Bloom & Canning, 2008). Individuals with aMCI struggle with daily activities due to memory and executive function impairments (Flicker et al., 1991; Petersen, 2016; Petersen et al., 2018), and despite their potential for independent living, these individuals require more accessible and cognitively easier technological interventions (Yu et al., 2017).

The proliferation of digital health applications has not been matched by equitable adoption among vulnerable groups, including those with cognitive impairments (Mathews et al., 2019; Ienca et al., 2021; Böhmer et al., 2024) – even if theoretical foundations such as the proposed design theory and reference architecture developed in the first design cycle exist. Persistent issues such as poor usability, cognitive overload, and ethically questionable design paradigms hinder adoption (Blass et al., 2022; Chignell et al., 2023; Vines et al., 2015) and still embody a challenge in the context of the envisioned *Cognitive Adoption Theory*. Building on the findings of the first design cycle, it has become clear that intuitive and user-centered interaction design approaches in the HCI paradigm are central to driving adoption and empowering people with aMCI in their daily lives. This realization, driven by the limitations of head-mounted AR devices (Biocca et al., 2014; Margrett et al., 2022; Seifert & Schlomann, 2021), led to a pivot toward SAR as shown in the first design cycle. SAR, which uses projections, has been recognized as a less intrusive and more contextual alternative that can reduce cognitive demands (Baumeister et al., 2017; Raskar et al., 1998; Yang et al., 2018), which may be more effective in cognitively demanding technology settings. As such, this phase is driven by a lack of conceptual knowledge on intuitive interaction design in digital health technologies for individuals with aMCI in the context of the Augmented Living Spaces design theory and reference architecture, highlighting that the HCI component is critical, as the mode of implementation (e.g., projections, wearables, handhelds) needs to provide an intuitive and accessible approach for users with cognitive impairments. Addressing **RQ3**, the second design cycle adopts a lower level of abstraction, focusing on the conceptual, technical, and cognitive operationalization of interaction DPs proposed by design theory.

While refining the problem space, a critical *circumscription* (Vaishnavi & Kuechler, 2015) was encountered: the chosen mode of HCI implementation and interaction design relies heavily on deep learning models that demand vast image datasets (Alzubaidi et al., 2021). Authentic data collection for such purposes is costly and prone to bias (Seib et al., 2020; Hinterstoisser et al., 2019). This has led to the adoption of synthetic image data, which, while scalable and efficient, introduces uncharted functional and ethical complexities. Synthetic data generation, while promising in various domains (Bird et al., 2020; Giuffrè & Shung, 2023), has raised concerns specific to digital health, including privacy risks and ethical challenges stemming from the artificial but real-world nature of the data (Kern et al., 2022; Russel & Norvig, 2021; Obermeyer et al., 2019). Despite the artificiality, synthetic datasets often

reflect sensitive patterns from real-world settings, making reverse engineering and misrepresentation plausible threats (McBride, 2014; Vayena et al., 2018).

This necessitated a redefinition of the problem awareness (**RQ4**): beyond designing intuitive HCI for aMCI, there was a lack of actionable design knowledge on the effective and ethical use of synthetic data in AI-driven digital health solutions. Current IS and DSR literature provides meta-level ethical guidance (Myers & Venable, 2014; Herwix et al., 2022), but specific frameworks addressing the use of synthetic data in digital health are lacking. In general, the shift from purely usability-centered concerns (novel interaction design approach as first DSR echelon instance in this design cycle) to functional and ethical considerations in data generation (as second DSR echelon instance in this design cycle) addresses the lack of consensus on standards for synthetic data usage in healthcare AI (Panch et al., 2018; Rajkomar et al., 2019).

Thus, the problem awareness of the second design cycle builds on the evaluation results of the first cycle, which highlighted the shortcomings of wearable AR solutions for aMCI and the need for more technical and conceptual knowledge to implement the developed interaction design at a less abstract level. It pivots towards SAR-based HCI while revealing a critical gap in the functional and ethical use of synthetic data in digital health. This dual awareness – usability and ethics – now frames the research focus of this cycle, in line with the iterative and reflective principles of DSR. The absence of a sophisticated interaction design for individuals with aMCI based on SAR and deep learning, coupled with the resulting challenges of synthetic image data in digital health, emerged as the central problem to further develop the conceptual foundations of the *Cognitive Adoption Theory*.

4.2 Suggestion

In response to the identified lack of conceptual knowledge on intuitive interaction design that would presumably foster adoption of digital health technologies for individuals with aMCI in the context of the Augmented Living Spaces design theory as well as the lack of general design knowledge on synthetic image data in digital health deep learning, this second design cycle proposes the development of two interrelated conceptual and practical foundations: a **novel interaction design approach** based on the design theory and a concomitant **design theory** for the effective and ethical use of synthetic image data in digital health deep learning settings. The novel interaction design approach, termed *ConZones* (as in context-aware zones), provides indirect, location-based interaction through projected information zones designed to address disorientation, slower information processing, and reduced reasoning capabilities commonly associated with aMCI. This approach aims to create an accessible, inclusive, and cognitively easy interaction experience by minimizing the need for direct technological engagement, consistent with the overarching goal of promoting adoption and autonomy in Augmented Living Spaces.

To operationalize this, a synthetically trained deep learning model is developed that overcomes the challenges of data scarcity and error proneness in traditional datasets (e.g., sets of photographs or frames). This model serves as the technical foundation for ConZones, enabling dynamic, real-time environmental understanding and interaction management without relying on wearable or handheld devices. The synthetic data approach ensures scalability and functional viability in training AI systems for context-aware projection while reducing the logistical barriers of authentic data collection. As such, it can be seen as a means of establishing ConZone's interaction design approach by providing the basic tracking structure that allows for intuitive use without the need for wearables (Böhmer et al., 2025b).

Second, to address the functional and ethical challenges that have emerged through circumscription, this cycle further suggests the conceptualization of guiding design knowledge for the responsible use of such synthetic image data in digital health deep learning. Through a heuristic design theorizing process, this particular DSR cycle aims to develop actionable DRs and DPs that ensure ethical compliance, privacy protection, and responsible AI use in synthetic data generation and application (Böhmer et al., 2025c).

Together, these suggestions – ConZones as a novel interaction design approach and a design theory for effective/ethical synthetic data use – form a coherent response to the dual problem awareness identified in this second design cycle, targeting both usability and ethical dimensions of AI-driven SAR systems for individuals with cognitive impairments.

4.2.1 Theoretical Foundations & Lens

This section is mainly based on Böhmer et al. (2025b) and Böhmer et al. (2025c). As such, parts of the text are reused with minor edits for clarity and coherence.

Also utilizing the *analyze-with-lens* mechanism (Möller et al., 2022), the first DSR echelon instance of this second design cycle (i.e., the interaction design approach) is conceptually grounded in *Social Cognitive Theory* (Bandura, 2001), which serves as the primary theoretical lens for examining the adoption and interaction between individuals with aMCI and digital health technologies. SCT posits that human behavior is shaped by a dynamic interplay between personal, social, and environmental factors. In the context of this DSR echelon instance, it provides a framework for understanding how the cognitive abilities, beliefs, and attitudes of individuals with aMCI, as well as their physical and social environments, influence their adoption and use of technology (Petersen, 2016; Petersen et al., 2018; Yu et al., 2017). Given the cognitive challenges that individuals with aMCI face, particularly in dealing with complex instructions and multistep interactions, this lens supports the development of systems that align with their abilities and needs.

To operationalize this theoretical perspective, this DSR echelon instance integrates three sub-fundamental theories. *User-centered Design* (Abras et al., 2004) guides the participatory design of intuitive, usable, and desirable systems, ensuring that the developed ConZones interaction approach directly reflects the preferences and capabilities of the target group. *Value-sensitive Design* (Friedman et al., 2013) addresses the ethical dimension by embedding values such as privacy, autonomy, and inclusiveness into the design process, which is critical when designing for a vulnerable population such as people with aMCI. In addition, findings from HCI research with older adults (Dickinson et al., 2007) inform methodological adaptations and inclusive design strategies tailored to the aging population affected by aMCI. This framework emphasizes the consideration of sensory, cognitive, and physical changes that support the usability and accessibility of SAR-based interfaces. Complementing these lenses, the *UTAUT* (Venkatesh et al., 2003) provides a robust framework for evaluating user acceptance, particularly through constructs such as PE and EE. UTAUT supports the empirical validation of the usability and acceptance of the developed system by aMCI individuals and integrates with the primary and sub-theoretical foundations to guide both design and evaluation.

In the context of the theoretical foundations for this DSR echelon instance, the rise of intelligent systems in digital health, including deep learning and computer vision, holds promise for patient monitoring, behavioral analysis, and cognitive support (Dhiman et al., 2022; Mavropoulos et al., 2021; Gao, 2019; Preum et al., 2019). Synthetic training data provides a scalable solution to data scarcity and privacy challenges in deep learning, with studies demonstrating improved model performance through domain adaptation and transfer learning (Bird et al., 2020; Hinterstoisser et al., 2019; Krump et al., 2020; Seib et al., 2020; Valtchev & Wu, 2021). Mixed data approaches further enhance model robustness (Wan et al., 2021; Bird et al., 2020; Müller et al., 2018; Zhang et al., 2018; Scheck et al., 2020). However, its use in healthcare, particularly for ethical, high-fidelity AI systems, remains limited (Gonzales et al., 2023; Chen et al., 2021).

Moreover, overhead fisheye tracking provides a non-intrusive method for monitoring living environments, which is critical for individuals with aMCI who struggle with wearables (Anderson, 2019; Petersen et al., 2016). Synthetic datasets for omnidirectional object detection have advanced technical feasibility (Aranjuelo et al., 2021; Scheck et al., 2020), but remain focused on surveillance rather than healthcare applications. Solutions for distortion correction and person detection exist (Zorin & Barr, 1995; Tezcan et al., 2022), but lack integration into HCI for vulnerable users.

Finally, HCI research emphasizes the need for intuitive, accessible systems for aMCI, with a focus on passive interaction and AI-based assistants that reduce cognitive demands (Dickinson et al., 2007; Maedche et al., 2019; Mallas et al., 2022). While trust and usability in digital health are recognized challenges (Blass et al., 2022; Vines et al., 2015), combined SAR and synthetically trained AI approaches tailored to the needs of aMCI have yet to be developed.

	Research stream 1 **STD**	Research stream 2 **OFT**	Research stream 3 **I-HCI**
Bird et al. (2020)	X		
Chen et al. (2021)	X		
Hinterstoisser et al. (2019)	X		
Krump et al. (2020)	X		
Seib et al. (2020)	X		
Valtchev and Wu (2021)	X		
Aranjuelo et al. (2021)	X	X	
Scheck et al. (2020)	X	X	
Yang et al. (2020)		X	
Tezcan et al. (2022)		X	
Ahmed et al. (2021)		X	
Zorin and Barr (1995)		X	
Duan et al. (2020)		X	
Yu et al. (2019)		X	(X)
Colantonio et al. (2018)		X	X
Chignell et al. (2023)		X	X
Maedche et al. (2019)		X	X
Mallas et al. (2022)			X
Dickinson et al. (2007)			X
Vines et al. (2015)			X
Kriglstein et al. (2016)			X
Chen and Levkoff (2015)			X
Blass et al. (2022)			X
The ConZones approach	X	X	X

Legend
STD: Synthetic training data with transfer learning and domain adaptation for real image setting
OFT: Overhead fisheye and distorted top view object tracking
I-HCI: aMCI-suitable human-computer interaction approaches and requirements for an innovative and easy usability
(X): Implicit application

Table 9. Relevant research streams for the first DSR echelon instance of the second design cycle (Böhmer et al., 2025b).

As shown in Böhmer et al. (2025b) and Table 9, no existing approach combines SAR-based HCI with synthetically trained deep learning to support aMCI individuals. Though advances in synthetic data and fisheye tracking exist, they have not been applied to inclusive, ethical digital health systems for this group (Ahmed et al., 2021; Aranjuelo et al., 2021; Seib et al., 2020). As such, the first DSR echelon instance fills this gap by proposing an intuitive SAR-driven HCI system, grounded in synthetic data and tailored to the unique cognitive challenges of aMCI individuals (Petersen et al., 2018; Yu et al., 2017).

The second DSR echelon instance of this design cycle (i.e., the design theory for utilizing synthetic data) is also based on *Value-sensitive Design* theory (Friedman et al., 2002; 2013). Its structured approach, covering conceptual, empirical, and technical dimensions (Denning et al., 2010; Deng et al., 2016), ensures that ethical concerns such as privacy, fairness, and inclusivity are embedded throughout the heuristic design theorizing process (see Chapter 4.2.2), which is especially critical for vulnerable groups such as people with aMCI. This lens guided both the derivation and evaluation of DPs, particularly in the context of synthetic image data, where ethical risks associated with the representation and use of human-like data are significant (Mueller et al., 2018; Dadgar & Joshi, 2018). Their use ensured that general AI-driven systems are not only functional but also ethically aligned with user values. To complement this view, *Sociotechnical Systems Theory* (Trist & Bamforth, 1951; Emery & Trist, 1960) was applied to address the interaction between social dynamics and technical systems in healthcare. This theory supports the alignment of human factors with technical design, which is critical to the ethical use of synthetic data in sensitive environments. Insights from, e.g., Mumford (2006) or Baxter &

Sommerville (2011), reinforced the need to balance technical performance with social responsibility, ensuring that AI solutions in digital health are both effective and socially responsive.

In healthcare, synthetic data supports predictive analytics and privacy, but raises concerns about bias, re-identification, and regulatory gaps (Giuffrè & Shung, 2023; Gonzales et al., 2023; Murtaza et al., 2023; Chen et al., 2021). While synthetic data enables scalable, privacy-preserving AI training, their real-world fidelity may reproduce sensitive patterns, requiring strong ethical safeguards.

Despite meta-level IS ethics frameworks (Myers & Venable, 2014; Herwix et al., 2022), Böhmer et al. (2025c) showed that specific guidance for synthetic image data in healthcare is still lacking. As shown in Figure 18, issues such as bias, consent, and data misuse require tailored ethical frameworks (Obermeyer et al., 2019; Panch et al., 2019; Vayena et al., 2019; Raji et al., 2020; Rajkomar et al., 2019). Digital health is at the intersection of AI ethics, IS ethics, and value ethics and requires context-aware ethical design (Floridi & Cowls, 2019; Becker & Becker, 2001; McBride, 2014; Kern et al., 2022; Russell & Norvig, 2021).

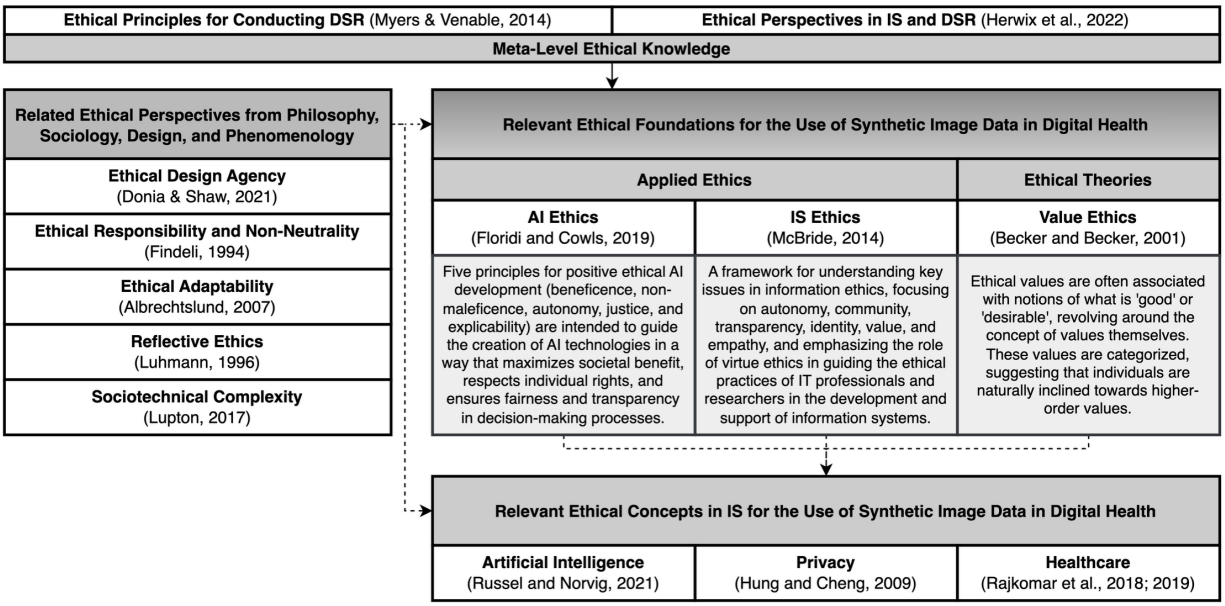


Figure 18. Relevant ethical foundations and concepts for the use of synthetic image data in digital health (Böhmer et al., 2025c).

In addition, philosophical perspectives emphasize that design decisions are morally charged (Donia & Shaw, 2021; Findeli, 1994; Albrechtslund, 2007; Luhmann, 1996; Lupton, 2017). Synthetic data, although artificial, may reflect real data, highlighting the need for ethical adaptability in design and responsible technology use.

While research supports the technical benefits of synthetic data, there is no consistent design framework to guide its ethical and effective use in digital health. As shown in Table 10, the lack of structured design knowledge hinders consistent and responsible application in high-stakes health care settings (Giuffrè & Shung, 2023; Rajkomar et al., 2018; Panch et al., 2018). Integrating ethical, technical, and social perspectives through design theory can address this gap and promote fairness, privacy, and interdisciplinary collaboration (Chandra et al., 2015; Meth et al., 2015; Gregor & Jones, 2007; Burton-Jones et al., 2021; Lukyanenko & Parsons, 2020).

Literature	**Research Stream 1:** Synthetic Image Data in Deep Learning		**Research Stream 2:** Digital Ethics in IS	
	EA-SD	*CS-SDU*	*TPF-DE*	*PAI-DH*
Lee et al. (2019)	X			
Krump et al. (2020)	X			
Aranjuelo et al. (2021)	X	X		
Valtchev and Wu (2021)	X			
Wan et al. (2021)	X			
Bird et al. (2020)				
Lahiri et al. (2018)		X		
Venkateswara et al. (2017)		X		
Kuhnke and Ostermann (2019)		X		
Seib et al. (2020)		X		
Müller et al. (2018)		X		
Zhang et al. (2018)		X		
Scheck et al. (2020)		X		
Giuffrè and Shung (2023)		X		X
Murtaza et al. (2023)	X			X
Gonzales et al. (2023)	X			X
Becker and Becker (2001)			X	
O'Neill (2004)			X	
Floridi and Taddeo (2016)			X	
Spiekermann et al. (2022)			X	
Schlagwein et al. (2019)			X	
Vayena et al. (2019)			X	
Donia and Shaw (2021)			X	
Luhmann (1996)			X	
Lupton (2017)			X	
Albrechtslund (2007)			X	X
Findeli (1994)			X	X
Obermeyer et al. (2019)			X	X
Panch et al. (2019)			X	X
Hansen and Baroody (2020)				X
Turja et al. (2020)				X
Al-Dhaen et al. (2021)				X
Floridi and Cowls (2019)				X
Russel and Norvig (2021)				X
Raji et al. (2020)				X
Rajkomar et al. (2019)				X
Hung and Cheng (2009)				X
This DSR echelon instance	X	X	X	X
Legend	• EA-SD = Effectiveness and Application of Synthetic Data • CS-SDU = Challenges and Strategies in Synthetic Data Utilization • TPF-DE = Theoretical and Philosophical Foundations of (Digital) Ethics • PAI-DH = Practical Applications and Implications in Digital Health.			

Table 10. Relevant research streams for the second DSR echelon instance of the second design cycle (Böhmer et al., 2025c).

4.2.2 Research Design

To address RQ3, the research design of the first DSR echelon instance in this cycle is based on the *DASC-PM* model (Kuehnel et al., 2023) because the novel HCI approach is centered on a deep learning model (Böhmer et al., 2025b). In general, the DASC-PM aims to overcome isolated problem-solving and focuses not only on a phase-oriented flow of a data science research project, but also includes other key areas, such as the application domain, scientific rigor (scientificity), and the required IT

infrastructure. As shown in Figure 19, the approach follows a structured data science procedure, beginning with defining the problem of limited HCI intuitiveness for aMCI individuals and outlining solution requirements, akin to setting the scope in the project order phase of the DASC-PM. The data provision phase then focuses on generating and preparing synthetic image data for the intended SAR-based projection approach and the respective context-aware zones of movement. This is followed by the analysis phase, which employs a deep learning model for movement tracking trained on synthetic image data that is evaluated using quantitative training, testing, and validation metrics. Subsequently, the deployment phase involves integrating the trained model into the HCI approach of the Augmented Living Spaces concept and implementing it in the SAR environment for continuous use by aMCI individuals. Lastly, the application phase emphasizes ongoing monitoring and user validation using methods such as usability testing, think-aloud sessions, and questionnaires to assess the cognitive impact, usability, and intuitiveness of the proposed HCI approach (Böhmer et al., 2025b).

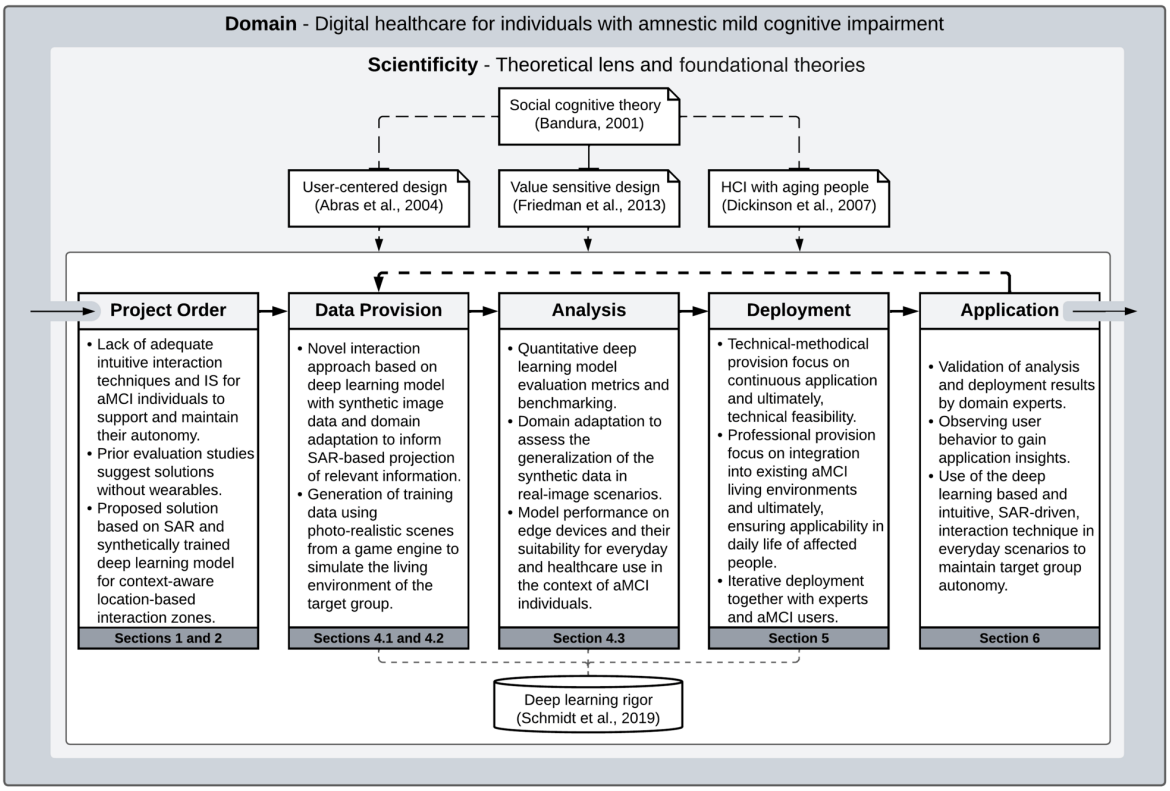


Figure 19. Data science process model approach following Kuehnel et al. (2023) for the first DSR echelon instance of the second design cycle (Böhmer et al., 2025b).

With the overarching goal of the *Cognitive Adoption Theory* in sight, this echelon instance prioritizes cognitive targets over direct emotional measurements (e.g., participants' mood), focusing on the rehabilitative potential and cognitive influence of the HCI approach. User feedback on emotional aspects, such as trust and frustration, is captured incidentally during think-aloud sessions, providing relevant yet complementary insights. As such, the research design follows a rigorous and reproducible deep learning methodology to ensure scientific rigor and traceability, as proposed by Schmidt et al. (2019). This deep learning rigor approach ensures that training data is checked and cleaned, adequate model architectures are employed, data is split into train, test, and validation sets, data is generally pre-processed, and the model is iteratively refined (e.g., hyperparameter evolution, layer freezing, or feature change). Moreover, the data collection and evaluation processes are designed to specifically assess the cognitive impact and perceived usefulness of the proposed SAR-based HCI approach for individuals with aMCI.

However, while addressing RQ3, several challenges and research gaps were identified regarding the use of synthetic image data in general deep learning, especially in the context of digital health, which led to the circumscription within this design cycle (Böhmer et al., 2025b). While synthetic image data (artificially generated images, e.g., video game engine scenes) offers scalability and feasibility for deep learning in digital health (Bird et al., 2020; Hinterstoisser et al., 2019; Krump et al., 2020), its creation, often rooted in real-world data, necessitates careful safeguarding to prevent misrepresentation, discrimination, and privacy breaches (Kern et al., 2022; McBride, 2014; Obermeyer et al., 2019; Russel & Norvig, 2021). Despite its artificial nature, synthetic data carries the risk of reverse-engineering patterns from source data and introducing unanticipated biases, particularly in sensitive domains like digital health (Vayena et al., 2018; Rajkomar et al., 2018). Therefore, rigorous anonymization, fairness metrics, and ethical guidelines are crucial to mitigate these challenges and ensure responsible use (Obermeyer et al., 2019; Panch et al., 2019; Raji et al., 2020; Rajkomar et al., 2019; Zhang et al., 2018). Thus, since the use of synthetic image data is a means to an end of the first echelon instance in this design cycle, and the novel HCI interaction design approach pioneered this kind of conceptual idea, it seemed reasonable to delve deeper into this topic by formulating RQ4 and its implications for digital health research – extensively described in Böhmer et al. (2025c).

Because these considerations in the context of the research gap addressed by RQ4 are conceptual, design, and guiding knowledge, a theory-driven configuration (Schoormann et al., 2024) and heuristic design theorizing approach (Gregory & Muntermann, 2014) were chosen, similar to the first design cycle of this dissertation. Likewise, incorporating focus group findings with AI and digital health experts as well as theoretical foundations from two distinct literature streams (i.e., synthetic image data in digital health and digital ethics in IS), the heuristic design theorizing approach was conducted over two design cycles[5] (Böhmer et al., 2025c). As shown in Figure 20, the first cycle was aimed at decomposing the wicked problem perception and developing DPs mainly based on the focus group findings. In this context, the findings from the focus groups (n=11) were analyzed using qualitative content analysis, following the methodological approach proposed by Gioia et al. (2013). Developing first-order concepts, second-order themes, and aggregate dimensions (AD), this particular content analysis methodology is used to build theory within IS (Magnani & Gioia, 2023) and provides a foundation for DR and DP development. This approach to concept development allowed the echelon instance of the second design cycle of this dissertation to balance the often-conflicting goals of developing new concepts inductively and maintaining high standards of rigor in IS research. As such, first-order coding (inductive) was used to capture informant-centered concepts, which were then interpreted into second-order themes through constant comparison and theoretical reflection (abductive).

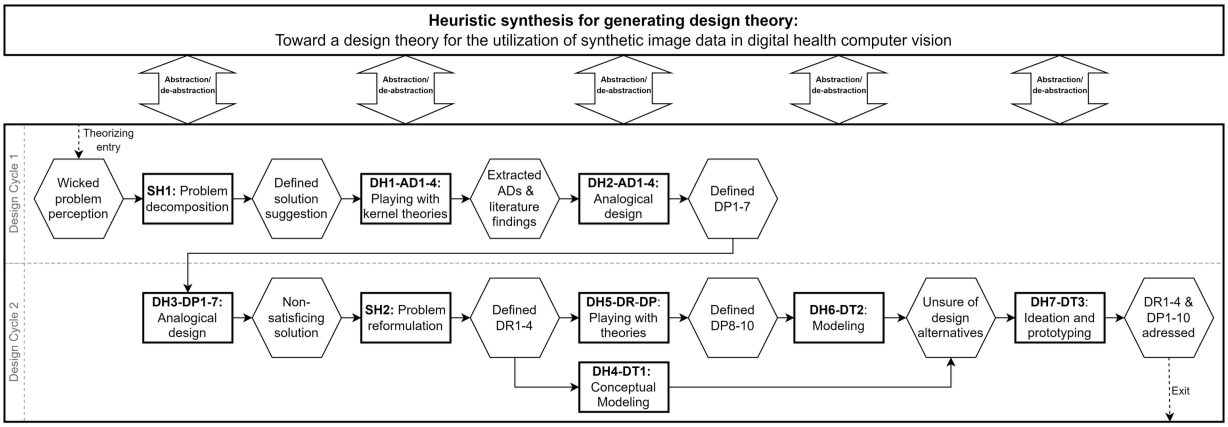


Figure 20. Heuristic design theorizing approach for the second DSR echelon instance of the second cycle, adapted from Gregory and Muntermann (2014) (Böhmer et al., 2025c).

[5] Again, these design cycles should not be confused with the overarching design cycles of this dissertation, but rather as design cycles employed within this specific DSR echelon instance.

In Böhmer et al. (2025c), these themes were then aggregated into four dimensions representing core design constructs: *Privacy and Ethical Compliance* (AD1), *Data Governance* (AD2), *Synthetic Scene Generation* (AD3), and *Robust Learning and Generalization* (AD4). These ADs, together with the literature, formed the basis of the DPs, which are prescriptive and universal in this context, specifying how an instantiation should be designed to meet the proposed requirements (Fu et al., 2016). In this context, the DPs were derived from the conceptual scheme of Gregor et al. (2020) (see Appendix J for the detailed scheme), whose a priori specification suggests a prescriptive formulation (Fu et al., 2016). Moreover, the use of the framework allowed this perspective to formulate accessible, precise, and expressive design knowledge (Gregor et al., 2020). By evaluating the reusability of the DPs in the context of digital health (Iivari et al., 2021), several areas for improvement and revision were derived, which were crucial for initiating the second design cycle (echelon instance internal). Evaluation feedback from the first cycle included suggestions for strengthening the responsible AI paradigm due to ethical and social concerns, revising ambiguous DP descriptions, addressing control mechanisms in data generation, and reevaluating the strategy for increasing complexity in synthetic scenes. Concerns were also raised about the specific applicability of these principles in the digital health domain, especially in the context of digital ethics, through potentially missing design knowledge, as their applicability may vary in different support, treatment, or diagnostic contexts, which ultimately triggered the need for a second cycle (Böhmer et al., 2025c).

4.3 Development

As briefly mentioned in Chapter 4.2.2, the whole second design cycle employed a multi-method approach (Mingers & Brocklesby, 1997) with aspects of a mixed-methods design (Venkatesh et al., 2013), containing well-known research methodologies for AI research, empirical deep learning model testing and evaluation, qualitative (design) theory building, and qualitative evaluation episodes. Given the promise of deep learning models trained on synthetic data (Alzubaidi et al., 2021), for this dissertation, they are viewed as a means to achieve the overarching goal of providing innovative and intuitive interaction designs for people with aMCI, which ultimately lays the conceptual foundations of the *Cognitive Adoption Theory*. As such, the approach employs a deep learning model trained on photorealistic synthetic living room scenes that accurately detects people in real-world environments and generates a spatial understanding of the room. This enables the projection of location-based information tailored to the specific needs of people with aMCI. Subsequently, based on the encountered challenges in the first step of this cycle and recent calls for guidance on synthetic data utilization (Murtaza et al., 2023), the proposed design theory then addresses key aspects such as ethical compliance, privacy protection, data governance, scene diversity, controlled composition, complexity management, data augmentation, and responsible AI. Hence, it provides actionable and theory-grounded guidance for researchers and practitioners in the selection, generation, and integration of synthetic image data for digital health computer vision.

Given the circumscription encountered in this design cycle, the following chapters will start by presenting the deep learning model and subsequent novel HCI approach (first DSR echelon instance of this cycle), followed by the design theory and conceptual model for utilizing synthetic image data in digital health (second DSR echelon instance of this cycle).

4.3.1 Deep Learning Model

Given the focus of this dissertation on computer vision as a means of SAR-driven assistance for people with aMCI, convolutional neural networks (CNN) were deliberately chosen as the algorithmic architecture of choice, given their widespread use and prominence in the field (Alzubaidi et al., 2021). CNNs excel in computer vision tasks, especially object detection, due to their ability to learn relevant features from local input patterns, their efficient parameter utilization through weight sharing, and their hierarchical feature learning approach, which allows for a high degree of translation invariance (Alzubaidi et al., 2021). The model developed in Böhmer et al. (2025b) is based on the well-known YOLO (v4-v8) architecture but with unique combinations of existing neural network techniques tailored for optimal performance on synthetic image data. The model incorporates anchor-free object detection,

feature extraction, and cross-stage partial connections. Figure 21 illustrates the ConZones deep learning model, which uses a *CSPDarkNet-53* (Bochkovskiy et al., 2020) backbone derived from the *EfficientNet* architecture to extract features from the input image, which is critical due to the synthetic nature of the input data. The following paragraphs incorporate passages from Böhmer et al. (2025b), with minor edits.

As shown in Böhmer et al. (2025b), the model includes shortcut links and a spatial pyramid pooling module that generates feature maps at multiple scales, which are then concatenated to capture objects of different sizes. The neck architecture processes the feature maps through convolutional layers and upsampling operations to produce detection maps, with each map predicting objects of specific scales and aspect ratios at different locations in the synthetic image. Multiple fusion blocks within the neck architecture fuse feature maps from the backbone architecture to produce more discriminative features. The head architecture performs object detection and classification on the synthetic images, using convolutional layers to generate a set of detection maps that indicate the presence of a particular class of objects. To improve performance and convergence, the ConZones model was pre-trained on the *MS COCO* dataset (Lin et al., 2014), following the consensus in deep learning research and mitigating the risk of overfitting. To fine-tune the model with synthetic data, a transfer learning strategy was adopted (Bozinovski and Fulgosi, 1976), enabling rapid retraining with novel data without the need to retrain the entire network. Furthermore, layer freezing was employed on the model backbone, a technique that keeps some layers' weights fixed during the fine-tuning process of a pre-trained neural network. This approach is particularly helpful when adapting synthetically trained models to real image data (Hinterstoisser et al., 2019), as the lower layers of the network (model backbone) capture general features that are useful across different tasks. By freezing these layers, the model utilizes the learned representations to enhance the higher layers' performance on a new task, preventing overfitting and reducing training time (Böhmer et al., 2025b).

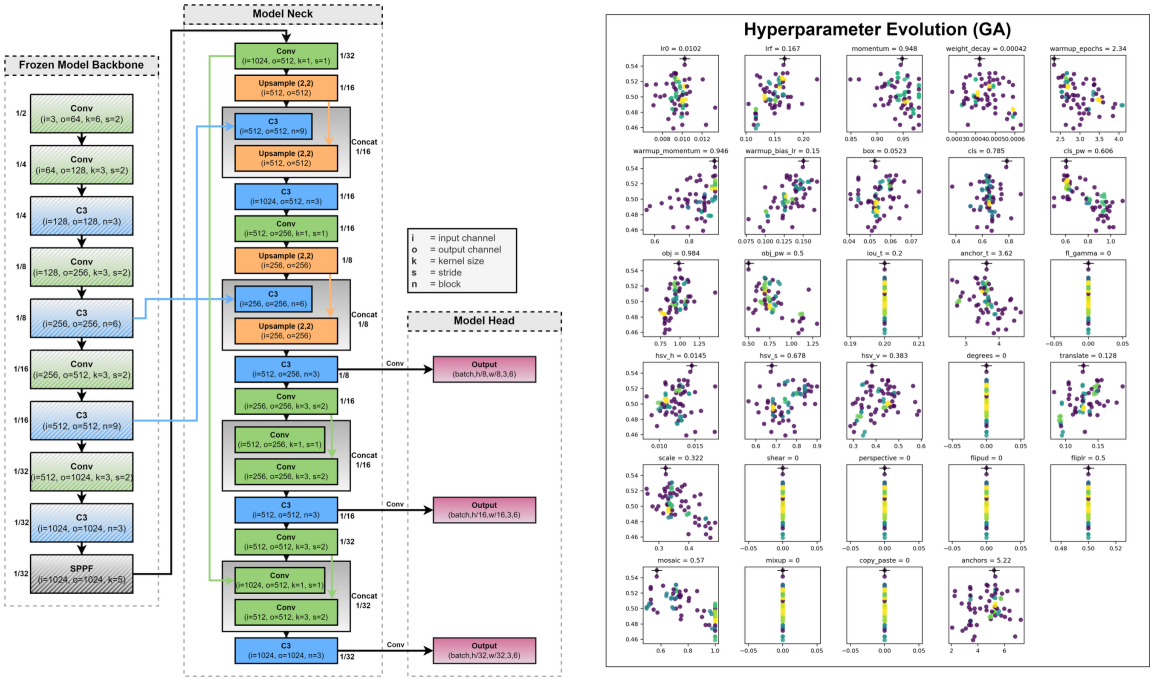


Figure 21. Deep learning model architecture and hyperparameter evolution (Böhmer et al., 2025b).

Additionally, layer freezing stabilizes the training process, mitigating catastrophic forgetting, which is particularly relevant for synthetic data by limiting gradient propagation during fine-tuning. Figure 21 further depicts the adoption of a genetic algorithm, following established deep learning procedures (Griebel et al., 2019) and the "refine model" process step (Schmidt et al., 2019) to discover optimal hyperparameter values for training the ConZones model. As such, the model employs a population-

based search strategy (mutation, crossover), where multiple neural networks evolve concurrently as potential solutions, increasing the likelihood of discovering optimal hyperparameters for the algorithm.

In general, when working with synthetic (image) data, *domain adaptation* is a critical step to ensure that the model will ultimately perform well (Böhmer et al., 2025b). It is a technique in deep learning that involves adapting a model trained on one domain of data to perform well on a different but related domain (Venkateswara et al., 2017) and is often used in synthetic data setups (Lahiri et al., 2018; Wilson and Cook, 2020). In this case, the source domain is synthetic (photorealistic game engine scenes), whereas the target domain is real (real images, video frames). In the context of synthetic image data, domain adaptation can be used to improve the performance of a deep learning model trained on synthetic data when it is applied to real-world images. Since the synthetically generated images may slightly differ in terms of features and characteristics (e.g., lighting conditions, textures, etc.), these differences can result in a performance gap when applying the model to real-world images. Nonetheless, domain adaptation techniques aim to reduce this performance gap and catastrophic forgetting by leveraging a small amount of real-world data to modify the model trained on synthetic data, which was done through the fine-tuning and transfer learning approach.

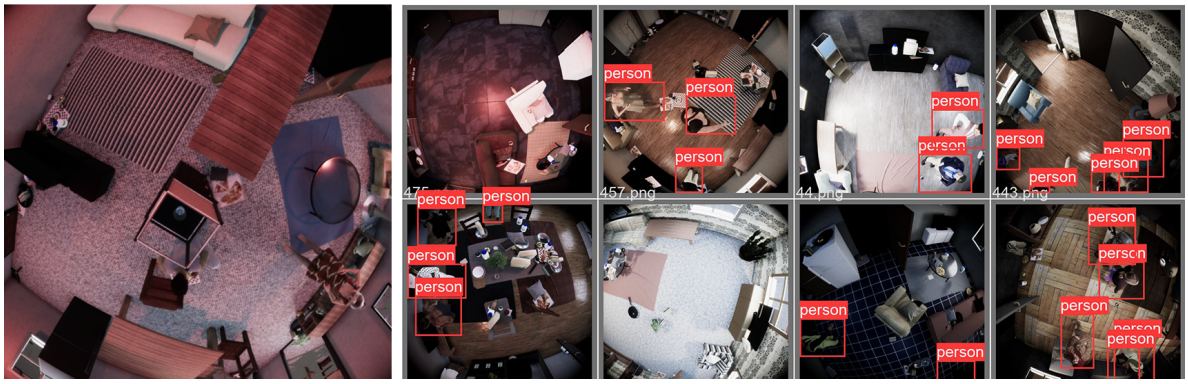


Figure 22. Synthetic, photorealistic deep learning training data generated with a video game engine (Böhmer et al., 2025b).

To achieve the best possible domain adaptation, photorealistic living room scenes were generated in Böhmer et al. (2025b) using *Unity3D*, enabling an easy omnidirectional, fisheye overhead camera setting. As shown in Figure 22, the scenes contained differing persons and objects, lighting conditions, textures, room setups, and levels of messiness, which were aimed at recreating homes of people with aMCI to the best possible scale and, thus, achieving high model generalization. In the specific context of Augmented Living Spaces, and to account for higher model generalizability, scenes were randomly and automatically modified in Unity3D as proposed by Scheck et al. (2020), opting for high domain randomization (Tobin et al., 2017; Tremblay et al., 2018). As such, image generation is infinitely scalable and can be modified according to specific environments or scene preferences, further proving that the creation of such synthetically generated datasets is fast, effortless, and economical. The often tedious process of labeling real-world image datasets becomes obsolete, as all synthetically generated images are automatically labeled with their corresponding bounding boxes, reducing labeling errors that could potentially hinder model performance. In addition, data augmentation techniques were applied to better generalize the fine-tuned ConZones model (Takahashi et al., 2018; Tobin et al., 2017).

Following the DASC-PM *Analysis* process step and the deep learning rigor procedure (Schmidt et al., 2019), experiments were conducted in Böhmer et al. (2025b) to assess the efficacy of the deep learning approach. The experiments spanned different datasets, validation settings, and evaluation metrics. The training set consisted of 6,500 scene images (similar to the ones shown in Figure 22), divided into 5,000 train and 1,500 validation images. The training was performed on an NVIDIA GeForce RTX 3080 within a virtual Python (Version 3.12.1) environment. The ConZones model was trained for 150 epochs until it was decided to conclude training due to the absence of additional gains in model performance

and to forestall potential overfitting. To evaluate the effectiveness of the deep learning approach, precision, recall, average precision, mean average precision, and corresponding model losses for class (cls), objectness (obj), and location (loc) were measured (see Table 11). Looking at the formulas, and since only one class is predicted in the specific Augmented Living Spaces use-case scenario, i describes the class 'person.' Therefore, the true positives for class i (tp_i) represent the number of individuals correctly classified as belonging to 'person,' while false positives (fp_i) indicate the number of individuals incorrectly classified as 'person.' Moreover, false negatives (fn_i) represent the number of individuals incorrectly classified as not belonging to 'person.' Based on these metrics, *Precision* determines how many individuals were correctly classified as 'person,' given all predictions of that class. *Recall* is the ratio of the number of correctly identified objects to the total number of ground truth objects in the image, measuring the proportion of all actual positive instances that were correctly identified by the model. In addition, *Average Precision* (AP) measures how well the model can precisely identify all relevant objects in an image while also minimizing the number of false positives. Subsequently, mAP as the most meaningful and current benchmark evaluation metric embodies the essential balance between precision and recall while simultaneously maximizing its impact. Evaluating the overlapping surface area between the predicted bounding box and the ground truth, which is the intersection over union, mAP provides a robust measure of the model's efficacy. Thus, the greater the intersection between the two bounding box surfaces (ground truth and prediction), the higher the mAP score, signifying a prediction that closely approximates the true object location. The classification loss penalizes the model for misclassifying an object, the objectness loss ensures that the model detects the presence of an object, and the localization loss penalizes the model for inaccurate predictions.

Metrics	Formula	Results
Precision	$\frac{1}{n}\sum_{i=1}^{l}\frac{tp_i}{tp_i+fp_i}$	0.966
Recall	$\frac{1}{n}\sum_{i=1}^{l}\frac{tp_i}{tp_i+fn_i}$	0.885
AP*	$\int_0^1 prec(rec)d(rec)$	**was only used as an intermediary for mAP calculation*
mAP 0.5	$\frac{1}{n}\sum_{i=1}^{l} AP_i$	0.937 (*mAP 0.5:0.95* = 0.607)
Loss	$Loss = \lambda_1 L_{cls} + \lambda_2 L_{obj} + \lambda_3 L_{loc}$	0.021 (*train box loss*); 0.019 (*train obj loss*); 0.030 (*val box loss*); 0.018 (*val obj loss*)

Table 11. Evaluation metrics, formulas, and train/validation results (Böhmer et al., 2025b).

Table 11 shows strong training results for the ConZones model on the 'person' class, with high precision, recall, and mAP, indicating effective learning from synthetic data and strong generalization. The high recall is especially relevant for enabling location-based, intuitive SAR projections. To address the domain gap, the model was validated on real-world fisheye data using the FES dataset from Scheck et al. (2020). Table 12 compares the mAP scores and shows that the ConZones approach slightly but significantly outperforms the approach of Scheck et al. (2020) – despite using 18.5k fewer synthetic images.

Model	mAP 0.5
ConZones	**0.921**
SSD (Scheck et al., 2020)	0.904
R-FCN (Scheck et al., 2020)	0.849
Faster R-CNN (Scheck et al., 2020)	0.873

Table 12. Model validation on the FES dataset for 'person' class (Böhmer et al., 2025b).

In Böhmer et al. (2025b), the model's performance was further tested in a specially created overhead fisheye setup. As can be seen in Figure 23, individuals are being detected and recognized consistently while also achieving considerably high detection rates for near-border and cut-off bodies. As the test scenario shows, multiple-person detection is realized swiftly in differing environments, indicating its potential to be used in a variety of settings (Böhmer et al., 2025b). Consequently, the domain adaptation and shift from synthetically generated images to a real-world imagery setting succeed well through the ConZones model. The shown scenario was deployed in real time and confirmed the proposed model architecture.



Figure 23. Domain adaptation and real-time model deployment with real image data (Böhmer et al., 2025b).

4.3.2 Novel HCI Approach for Individuals with Cognitive Impairments

As aforementioned, the synthetically trained deep learning model serves as a means to ultimately propose an intuitive, user-centered, and SAR-driven interaction approach in digital health. Hereby, the aim of this DSR echelon instance is twofold: First, to demonstrate the translation of conceptually developed deep learning approaches into real-world applications; Second, to propose a novel and SAR-driven HCI approach for digital health and provide practical implementation, thereby bridging the gap between theory and practice – building on the insights from Böhmer et al. (2025b).

Building on the foundation of the first cycle, the objective here is to provide an accessible, unobtrusive, effective, and cognitive-supporting service that addresses the lack of intuitive interaction design for individuals with aMCI – which hinders adoption. To operationalize low-threshold and accessible HCI approaches with the SAR-based widgets, the second design cycle proposes a context-aware and location-based HCI approach termed *ConZones*, which describe zones (invisible to the user) in the living environment that are monitored by an AI-driven IS for people entering them. As such, the ConZones approach, by minimizing direct interaction and embedding cues within the environment, aimed to reduce cognitive load and enhance self-efficacy, both hypothesized as critical factors for cognitive adoption. This system employs the proposed deep learning model presented in Chapter 4.3.1, which detects objects (such as people) in the room, understands their geographic location, and infers their context. Then, when a person enters a particular zone (see Figure 24), it uses this information to project useful and contextual data directly into their living space at their current location. When this happens, the widget is presented to the user, e.g., by zooming in from a minimized icon, and when all people have left the zone, the widget is minimized again. It could highlight a potential hazard in their immediate environment or guide them through a daily task without the need for wearable devices. The system is designed to be intuitive and easy to use, requiring minimal direct interaction from people with aMCI as it responds naturally to their location and actions without the need for explicit commands or complex interfaces.

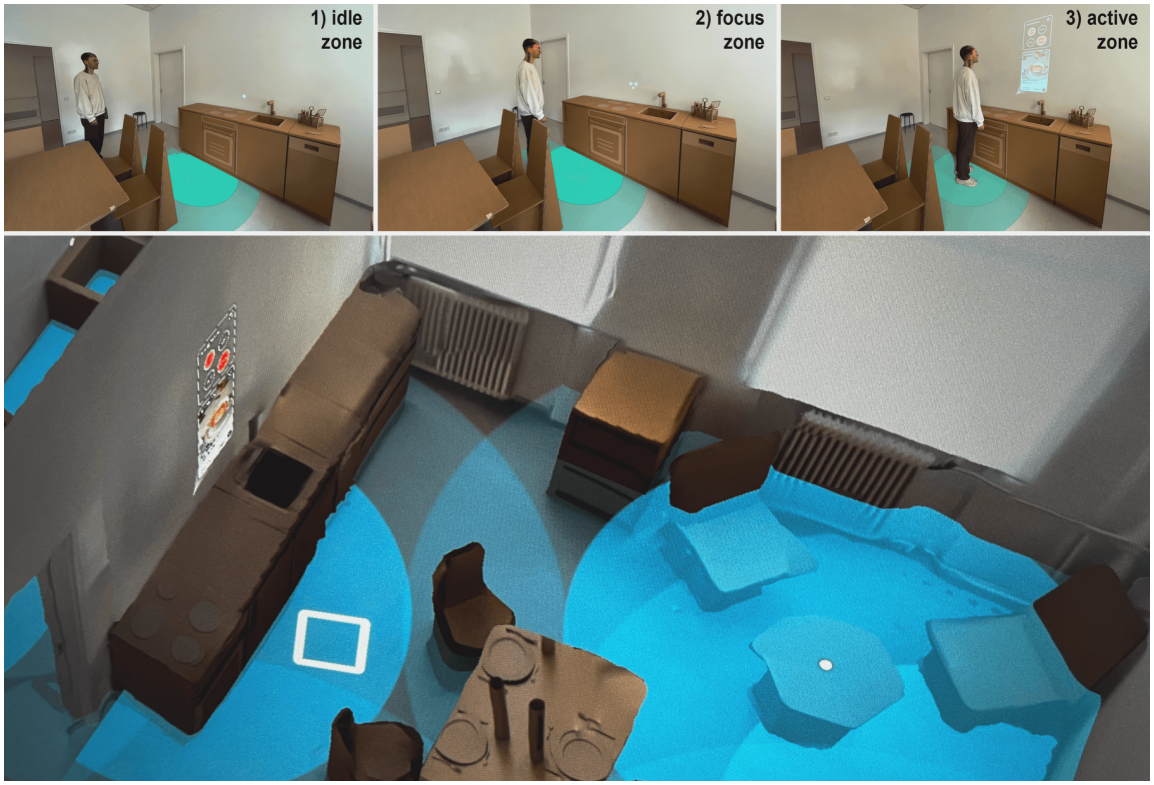


Figure 24. *ConZones approach to intuitive and accessible human-computer interaction design (Böhmer et al., 2025b).*

According to SCT (Bandura, 2001), people's cognitive processes are strongly influenced by their interactions with their environment, and they develop beliefs about their ability to perform certain daily activities, called self-efficacy beliefs. These beliefs can influence their behavior, as people are more likely to engage in activities, they believe they can perform successfully, thus maintaining or even enhancing their autonomy (Bandura, 2001). The proposed interaction approach focuses on the needs, disabilities, and preferences of people with aMCI and is tailored for accessibility and inclusivity (Abras et al., 2004) while simultaneously aiming for the most intuitive HCI approach (Dickinson et al., 2007).

As shown in Böhmer et al. (2025b), digital healthcare solutions and services have to be designed as user-friendly and intuitive in the HCI context since they otherwise hinder adoption (Blass et al., 2022), especially in the case of aMCI individuals who have to deal with reduced cognitive performance (Petersen, 2016; Petersen et al., 2018; Yu et al., 2017). By addressing these aspects of reduced cognitive performance, the proposed approach of combining synthetic deep learning with SAR has the potential to assist people with aMCI in their daily lives without requiring them to either wear head-mounted displays or directly operate complex technologies. As such, the goal is to design the adoption and use of such systems as accessible as possible, where aMCI individuals can move freely, and relevant information is projected at the right place and time to be not only visible but also helpful (Böhmer et al., 2025b). In this way, it is possible to support this vulnerable population in the areas of daily life (i.e., memory, daily life structuring, medicine, socialization) that are primarily affected by their impairments (Anderson, 2019; Gauthier et al., 2006; Jongsiriyanyong and Limpawattana, 2018; Petersen et al., 2009; Petersen, 2016), which could potentially help them achieve a higher quality of life.

Within the SAR-driven Augmented Living Space (Figure 24), each room is structured into spatial zones that are attached to the anchor points of certain objects (e.g., stove, calendar, phone). To overcome technostress and cognitive overload, it was decided not to show the whole widget presentation at all times, as the projected information is either not relevant to be projected permanently or would unnecessarily change the appearance of the living room (Böhmer et al., 2025b). Nastjuk et al. (2023) found that technostress creators are more effective in a private setting, and psychological outcomes are

often neglected. The approach presented here targeted the technostress creators of *techno-complexity*, *techno-overload*, and *techno-invasion* (Nastjuk et al., 2023) with the proposed interaction design to best address the impairments of the target group. As depicted in Figure 24, the system subdivides the spatial zones into three categories that specify the context-aware information representation of the respective widget: (1) *idle zone*, (2) *focus zone*, and (3) *active zone*. Based on the omnidirectional overhead fisheye camera and the deep learning positional reasoning module, the interaction approach is not only able to detect people in the Augmented Living Space but also to obtain precise positional data of the user calculated based on the pixels of the image. In other words, the bounding boxes described in Section 4.3.1 represent a rectangle with the corresponding pixel data (see Figure 24 and the small white rectangle that represents a bounding box). Consequently, this bounding box or positional user data can then be used to identify overlaps/intersections with the three context-aware spatial zones (idle, focus, active). A WFMS component then processes this positional data and triggers the maximization or minimization of the projected widget accordingly. The positional data can be used in other reasoning workflows and combined with other sensors in the AI- and SAR-driven IS to provide real-time, context-aware, and relevant information to an aMCI user. The mathematical foundations of this approach are shown in Table 13.

	Formula	
Top-left corner of the rectangle bounding box in image pixels	$image_x = \frac{(x \times W)}{image_{width}}$	$image_y = \frac{(y \times H)}{image_{height}}$
Width and height of the rectangle bounding box in image pixels	$image_w = \frac{(w \times W)}{image_{width}}$	$image_h = \frac{(y \times H)}{image_{height}}$

Table 13. Mathematical formulas for bounding box and pixel mapping (Böhmer et al., 2025b).
Legend: (x, y) coordinates of the top-left corner of the rectangle bounding box; Width (w) and height (h) of the rectangle bounding box; Width (W) and height (H) of the image in pixels.

Here, $image_x$ and $image_y$ represent the top-left corner of the rectangle bounding box in the image's pixel coordinates. Similarly, $image_w$ and $image_h$ represent the width and height of the rectangle in the image's pixel units. By scaling the rectangle's coordinates and dimensions with respect to the image size, the deep learning model can map the rectangle to the appropriate region within the image. These formulas assume that the rectangle's coordinates are given relative to the image size, where (0,0) represents the top-left corner of the image and ($image_{width}$, $image_{height}$) represents the bottom-right.

The following example is mainly based on Böhmer et al. (2025b), with minor edits for clarity. To illustrate an exemplary use case for ConZones, let's take *Gisela*, who is 85 years old, has aMCI, and still lives autonomously in her home, as shown in Figures 24 and 25. She was about to cook a meal, where she used the offering component of the stove widget, which gave her clear, precise, and relevant instructions on the cooking process. As all the work had to be done at the stove, she stood in the action zone with the widget and its information being ubiquitous and visually enhanced. Gisela was relieved that she no longer had to use cumbersome wearables, her complex smartphone, or fumble through her already half-decayed recipe book – the relevant information was projected directly and swiftly onto her wall behind the stove. After she finished cooking her meal, she remembered her medicine intake (which she also had a widget for) and went to another part of her apartment to get her medicine. When she came back from the living room and decided to put the medicine directly on top of the stove, the widget visually enhanced as she approached the stove and showed her that the stove places she used were still hot, thus visualizing a potential hazard warning. If Gisela had a declining vision, this information would also have been provided to accommodate individual needs, preferences, and impairments. Subsequently, if she had forgotten to turn off the hot plates, all other widgets (e.g., medication intake, social activities, memorization) would have received a warning overlay to inform her accordingly. As can be seen in Figure 25, the widgets can be placed anywhere in her living environment, addressing all possible use cases without having to sacrifice an individual's freedom in everyday life activities.



Figure 25. *'Gisela' within an exemplary AI- and SAR-driven Augmented Living Space (Böhmer et al., 2025b).*

If not already, the ethical or moral question of using computer vision techniques in digital healthcare, and specifically in this very use case, would have come up sooner or later – and rightly so. Ethical, or more precisely, privacy-intrusive approaches can not only hinder the adoption of digital health solutions (Blass et al., 2022) but also leave users with a bad and "spied on" feeling (Shak et al., 2022). Therefore, Spiekermann et al. (2022) suggest designing and developing more ethical systems, for which the foundational theories have been adopted that helped guide this research approach. In addition, Nastjuk et al. (2023) identified techno-invasion as a crucial technostress creator, which is described as invading users' personal and private space through constant connectivity, monitoring, and surveillance. Through the theoretical lens under the guise of SCT (Bandura, 2001), the target group of people with aMCI was closely involved from the beginning of this DSR echelon instance (see first design cycle). Hereby, the idea of tracking people (or rather their rectangles) circulated for longer and has been discussed in every moderated focus group, think-aloud session, and evaluation episode. As expected, it was by far the most discussed and ambiguous aspect (Böhmer et al., 2025b).

Nevertheless, the user-centered approach and close involvement of the target group in Böhmer et al. (2025b) ensured a high level of transparency to reduce bias and incorporate user feedback, thus establishing user-centered privacy controls (Chhetri and Motti, 2022). Therein, a major concern was directed at the image processing of the omnidirectional fisheye camera, which the target group of aMCI individuals felt was intrusive. However, the image processing by the ConZones deep learning model runs completely locally on an edge device, which does not store any image data and only sends the positional user data as vector coordinates of the bounding box. Any image predicted by the deep learning model is immediately deleted and not saved since pixels are being processed, not a reasoned image. The following reasoning and calculation of the context-aware image data are not based on the image itself but rather on the extracted bounding box rectangle and pixel coordinates. As can be seen in Figure 24, the person being tracked is not actually represented as a person but as a bounding box, thus ensuring privacy, anonymity, and abstraction.

Consequently, the Augmented Living Space aligns the user's positional data with the ConZones by the bounding box, effectively abstaining from tracking and monitoring additional activities. As such, the tracking can be seen as more on a higher meta-level that does not allow any conclusions about intimate and privacy aspects, where people do not have to worry about a drastic invasion of their privacy. Therefore, this approach does not use the terms *tracking* or *monitoring*, and instead assumes the use of *positional reasoning*, which not only better describes the process but also sounds less intrusive and was widely accepted in the target group evaluation.

By specifying the widget (and information) size depending on the user's position, Böhmer et al. (2025b) showed that the interaction design approach may reduce the technostress creator of *techno-overload* (Nastjuk et al., 2023), fostering adoption. As a result, users are not exposed to large amounts of information when it is not necessary in their daily lives, also targeting techno-complexity (Nastjuk et al., 2023). The goal with ConZones is to provide an environment and use of technology that aMCI individuals are comfortable with, reducing the amount of effort required to learn and understand the system. As such, the proposed SAR-based HCI approach is an intuitive application where users can move freely around, and relevant information is directly projected into their field of view, without having to actively go through complex operating processes or operate any wearables.

This approach functions as a cognitive scaffolding mechanism that informs the aspects and mechanisms of cognitive adoption into real-time interaction design. The system replaces traditional, cognitively taxing interface paradigms with spatial, gaze-sensitive, and context-aware augmentation, minimizing cognitive load while preserving user agency. The three-zone spatial structure ensures digital content enters the user's field of attention only when it is cognitively and contextually relevant. This supports temporal cognitive synchrony and situated cognitive fit mechanisms. Furthermore, the model's capability to detect and locate users via synthetic-to-real, domain-adapted object detection directly facilitates embodied cognitive anchoring, a pivotal aspect for aligning environmental cues with internal cognitive processes. Importantly, ConZones fosters social cognitive factors, such as self-efficacy, reciprocal determinism, and trust, by providing noninvasive and responsive feedback, thereby avoiding the mentioned technostress triggers. The SAR-based widget behavior (e.g., zoom-in/zoom-out interaction based on presence in spatial zones) integrates the system into the user's environment without requiring explicit commands, offering an ambient yet responsive presence that may foster digital health adoption without demanding high digital literacy or sustained attention. Finally, the system nudges users toward sustained health behavior change by reinforcing context-sensitive behaviors through repeated, embodied interaction with the environment (e.g., receiving a reminder only when entering the kitchen). These observed benefits and design choices underscore the importance of designing cognitively tailored, low-friction HCI experiences as a fundamental enabler of technology adoption. These experiences shape our understanding of how to create systems that individuals with cognitive impairments can use and integrate into their lives willingly – not because they are urged to do so by their environment.

4.3.3 Design Theory for Using Synthetic Image Data

Being the second DSR echelon instance of this design cycle, a design theory for effectively and ethically utilizing synthetic image data in digital health has been developed by the circumscription encountered in this cycle (Böhmer et al., 2025c). While it may seem counterintuitive given the artificial nature of synthetic data, the reliance on real-world references to create such data underscores the importance of proactively addressing these ethical and privacy concerns. However, even if it appears less risky due to its artificial nature, synthetic data does not eliminate privacy risks or ethical challenges; patterns from the source or reference data can be reverse-engineered or misused, and its artificiality can lead to unanticipated harms, such as skewing demographic or clinical representations.

As shown in Böhmer et al. (2025c) and Figure 26, particularly the digital health domain inherently involves sensitive information and human interactions, making it critical to design technologies that are consistent with ethical standards and user values (Vayena et al., 2018; Rajkomar et al., 2018). Therefore, it is imperative that researchers and practitioners in deep learning and digital health carefully consider these ethical implications. Effective strategies must be developed to mitigate risks, including implementing rigorous standards for data anonymization, applying fairness metrics to ensure unbiased AI models, and establishing ethical guidelines for the use and distribution of synthetic image data (Obermeyer et al., 2019; Panch et al., 2019; Raji et al., 2020; Rajkomar et al., 2019; Zhang et al., 2018).

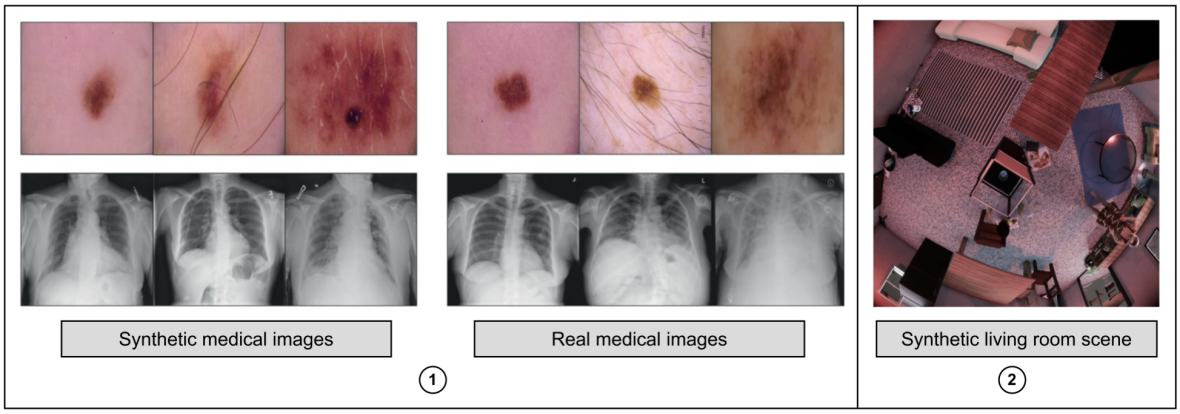


Figure 26. Exemplary applications of synthetic data with 1) a comparison of synthetic and real image data in medicine (Chen et al., 2021) and 2) synthetic living room scenes in digital health (own study) (Böhmer et al., 2025c).

Building upon initial results that have been presented in a conference format as secondary publication of this dissertation (Böhmer, 2023), the research methodology for this second design cycle (Chapter 4.2.2), and evaluation feedback throughout the development, the DRs of *Ethics & Privacy Compliance* (**DR1**), *Individuality & Generalizability* (**DR2**), *Accuracy & Precision* (**DR3**), and *Realism & Healthcare Relevance* (**DR4**) were developed. Figure 27 shows both the theory building (Gioia et al., 2013) and theory grounding (Walls et al., 1992; Schoormann et al., 2024) of those DRs, while Figure 28 shows a simplified depiction of the design theory and its core components.

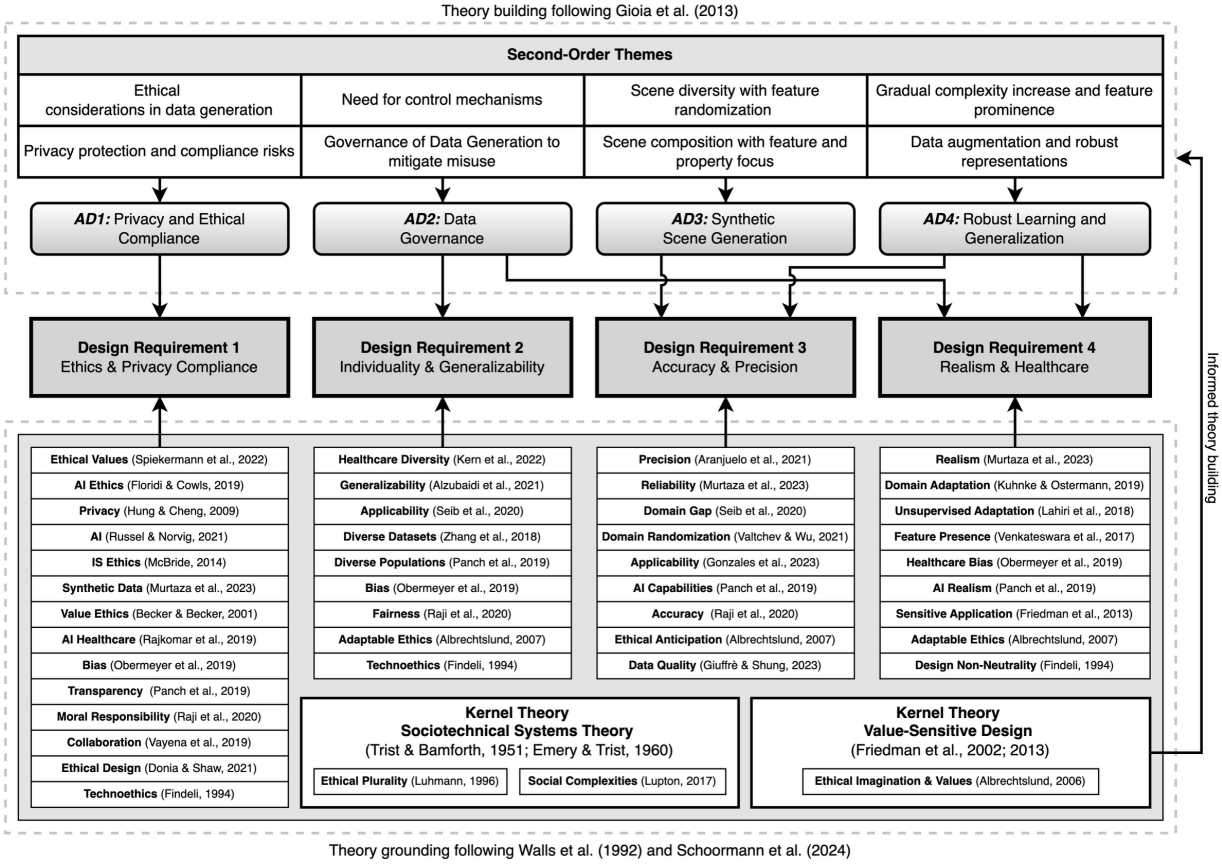


Figure 27. Theory building and theory grounding of the DRs in the second cycle (Böhmer et al., 2025c).

To provide a focused, rather than overly detailed, description of the DRs and DPs, the following concentrates on the main aspects and theoretical/practical foundations. A more thorough explanation can be found in Böhmer et al. (2025c) (Appendix J).

Based on *AD1*, **DR1** requires that synthetic data in digital health be generated and used in an ethical manner. This involves prioritizing privacy, consent, fairness, and transparency (Dadgar & Joshi, 2018; Mueller et al., 2018; Friedman et al., 2002, 2013; Floridi & Cowls, 2019). Despite being artificial, synthetic data can pose re-identification risks (Giuffrè & Shung, 2023), requiring strong governance and compliance with regulations such as the GDPR (Becker & Becker, 2001). Grounded in value-sensitive and socio-technical design (Mumford, 2006; Trist & Bamforth, 1951), DR1 emphasizes that ethical principles must not be compromised for technical efficiency (Rajkomar et al., 2019; Vayena et al., 2019; Raji et al., 2020).

DR2 (based on *AD2*) calls for synthetic data reflecting real-world healthcare diversity to ensure model generalizability and fairness (Kern et al., 2022; Alzubaidi et al., 2021). Comprehensive, demographically rich datasets prevent bias and support equitable predictive care (Zhang et al., 2018; Obermeyer et al., 2019; Raji et al., 2020). Value-sensitive and socio-technical design approaches support flexible, inclusive systems that respond to stakeholder needs (Findeli, 1994; Albrechtslund, 2007; Baxter & Sommerville, 2011).

DR3 (based on *AD3* and *AD4*) emphasizes the need for synthetic image data to enable high accuracy and precision, ensuring the safe and reliable performance of AI in healthcare (Aranjuelo et al., 2021; Seib et al., 2020). Inaccuracies risk patient harm and reflect deeper value trade-offs between performance and ethics (Panch et al., 2019; Yetim, 2011). Adhering to socio-technical design aspects (Emery & Trist, 1960), DR3 promotes AI models that are technically robust and ethically sound (Raji et al., 2020; Denning et al., 2014).

Based on *AD2* and *AD4*, **DR4** demands that synthetic image data realistically represent healthcare contexts, including conditions, demographics, and environments, to reduce bias and improve relevance (Murtaza et al., 2023; Venkateswara et al., 2017). Grounded in value-sensitive and phenomenological design (Friedman et al., 2002; Albrechtslund, 2007), DR4 acknowledges the sociotechnical necessity of aligning data with real-world complexity (Bostrom & Heinen, 1977). This approach ensures inclusivity and the practical utility of models.

Based on *AD1*, **DP1** states that synthetic image data must be generated ethically and transparently, complying with privacy laws and value-sensitive design principles (Friedman et al., 2002; Spiekermann et al., 2022; Donia & Shaw, 2021). However, synthetic data still poses re-identification risks and requires rigorous oversight and documented decision-making processes (Obermeyer et al., 2019; Panch et al., 2019). Ethical design is never neutral and must balance innovation with accountability (Mumford, 2006; Yetim, 2011). **DP2** (also based on *AD1*) emphasizes the use of robust anonymization and obfuscation techniques to prevent the exposure of identities from synthetic data derived from real sources (Giuffrè & Shung, 2023; Seib et al., 2020). Ethical practices must consider subtle identifiers and evolving norms (Albrechtslund, 2007; Luhmann, 1996) to ensure that data remains privacy-preserving and free from exploitation or bias (Deng et al., 2016). **DP3** (based on *AD2*) calls for robust governance frameworks, such as toolkits and virtual environments, to oversee the creation and use of synthetic data throughout its lifecycle (Gonzales et al., 2023; Rajkomar et al., 2018). These structures ensure ethical compliance, prevent misuse, and promote inclusion and reflexivity (Yetim, 2011; Baxter & Sommerville, 2011). **DP4** (based on *AD3*) states that synthetic scenes must include diverse, randomized elements (e.g., textures, backgrounds, and objects) to enhance robustness and avoid bias (Denning et al., 2014; Raji et al., 2020). Including sociocultural variability ensures generalizability across clinical contexts (Rajkomar et al., 2019; Seib et al., 2020). **DP5** (based on *AD3*) emphasizes balancing diversity with clarity by maintaining controlled object composition in synthetic scenes (Scheck et al., 2020). Randomization should support learning intrinsic features while preserving medical relevance and interpretability (Krump et al., 2020; Findeli, 1994).

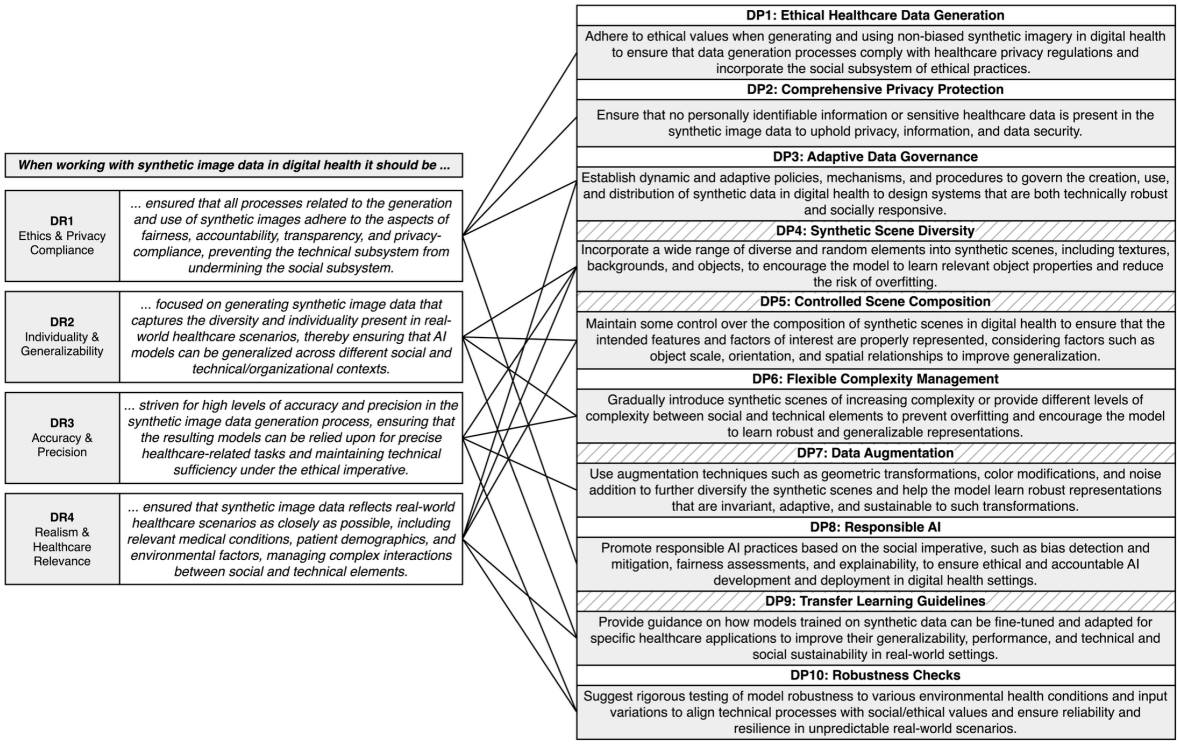


Figure 28. The core constructs and simplified representation of the synthetic image data design theory (Böhmer et al., 2025c).

Based on *AD4*, **DP6** gradually increases scene complexity to optimize learning and generalization (Bird et al., 2020; Alzubaidi et al., 2021). This varying complexity prepares models quantitatively and qualitatively for real-world unpredictability, aligning with socio-technical system design (Mumford, 2006). **DP7** (also based on *AD4*) uses data augmentation (e.g., rotation, color shifts, and noise) to improve model robustness under varied conditions (Zhang et al., 2018; Seib et al., 2020). However, the augmentation must remain realistic to avoid compromising generalizability (Alzubaidi et al., 2021; Emery & Trist, 1960). **DP8** (based on *AD1*) emphasizes the importance of detecting bias, assessing fairness, and ensuring explainability in AI systems trained on synthetic data (Floridi & Cowls, 2019; Vayena et al., 2018). Transparent outputs promote trust, and developers and users must share ethical responsibility (Herwix et al., 2022; Donia & Shaw, 2021). **DP9** (based on *AD4*) emphasizes the importance of clear domain adaptation protocols for transitioning models from synthetic to real-world healthcare data (Dadgar & Joshi, 2018; Venkateswara et al., 2017). Fine-tuning with real data ensures accuracy, context relevance, and adaptability in clinical settings (Murtaza et al., 2023). **DP10** (based on *AD1* and *AD4*) emphasizes the need for rigorous robustness testing under varied conditions (e.g., lighting, demographics, and emergencies) to prevent failures and ensure equity (Giuffrè & Shung, 2023; Obermeyer et al., 2019). Stress testing promotes resilience and ethical safety in critical healthcare scenarios (Lupton, 2017).

The design theory for synthetic image data, mainly articulated through its DRs and DPs, may implicitly inform the conceptual mechanisms of cognitive adoption by operationalizing how ethical, adaptable, and technically robust AI systems can foster trust, reduce cognitive barriers, and enhance perceived efficacy – central tenets of adoption among individuals with cognitive impairments (Böhmer et al., 2024; Flicker et al., 1991; Petersen, 2016; Yu et al., 2017. Specifically, **DP1**, **DP2**, and **DP3**, which embed ethical safeguards, privacy-respecting design, and transparent governance into the synthetic data lifecycle, reinforce cognitive adoption mechanisms of trust calibration and ethical resonance, enabling users to perceive AI-driven systems as safe, comprehensible, and aligned with their values. Furthermore, requirements for data individuality, generalizability, and realistic representation of healthcare diversity (**DR2**, **DR4**, and DPs such as **DP4** and **DP5**), coupled with requirements ensuring accuracy, precision,

and model robustness (**DR3** and DPs such as **DP6**, **DP7**, DP9, and **DP10**), contribute to the development of effective and reliable systems that are perceived as equitable. This perceived reliability and fairness may directly impact the adoption aspects/mechanisms by shaping usability and reducing the cognitive load associated with unpredictable or biased system behavior.

Following general design theory communication, justification, and cumulation, this DSR echelon instance also adopted the outlined process for design theory "anatomy" proposed by Gregor and Jones (2007). Table 14 provides a summary of this design theorizing process.

Component	Description
Purpose and Scope	The current trajectory of synthetic image data utilization in digital health computer vision settings is unguided and inconsistent due to its sudden occurrence in the rapidly evolving deep learning field. As such, this inconsistency may hinder the ethical deployment of such models and their performance in IS digital health applications. The aim is to develop a design theory that will not only alter this trajectory but also path the way for ethical, effective, and compliant synthetic image use in such settings. Therefore, the goals are: ensuring ethical and privacy compliance (**DR1**); focusing on individuality of image data and model generalizability (**DR2**); fostering model accuracy and precision through scene diversity (**DR3**); and ensuring data realism and healthcare feasibility (**DR4**).
Constructs	Guiding and framing requirements and principles for the utilization of synthetic image data in digital health computer vision are conceptualized. As such, the proposed DRs and DPs build the foundation for a conceptual model (Figure 31), encompassing the constructs of data realism, model effectiveness, data utility, data diversity, responsible privacy, and ethical compliance that are representations of the entities of interest in the design theory.
Design Principles of form and function	Features of current synthetically trained computer vision deep learning models in digital health are fundamentally epitomized by uncontrolled data generation (i.e., potential misrepresentations, privacy data breaches, or ethnical biases), insufficient data and model preparation, overfitting problems, and faulty domain adaptation. The dynamic and rapidly evolving nature of digital health deep learning hence requires novel and contemporary guidance in the form of design knowledge on how to utilize such data in these sensitive environments. Through theorizing, ten relevant DPs were developed to address this goal (Figure 28): ethical healthcare data generation (**DP1**); comprehensive privacy protection (**DP2**); adaptive data governance (**DP3**); synthetic scene diversity (**DP4**); controlled scene composition (**DP5**); flexible complexity management (**DP6**); data augmentation (**DP7**); responsible AI (**DP8**); transfer learning guidelines (**DP9**); robustness checks (**DP10**).
Testable propositions	The design theory offers guidance on how to use synthetic image data in digital health both ethically and effectively. Therefore, the DPs and DRs as the core components of the design knowledge, offer high accessibility, importance, novelty and insightfulness, actability and guidance, and effectiveness. Users can design (synthetically trained) computer vision deep learning solutions in digital health by altering conventional approaches and adhering to the design theory. The testable propositions are viewed as varying in their degree of generality and as truth statements about the design theory, meaning that these general statements describe expected outcomes (i.e., addressing the DRs) based on the application of the DPs. Thus, it is hypothesized that in the context of synthetic image data in digital health computer vision, if System A uses the design theory, it will work or be more ethical and efficient than a System B that does not. On a more granular level, the testable propositions here refer to the relationships between DRs and DPs, as shown in Figure 28, emphasizing that if someone has similar DRs in a different context, the corresponding DPs from this design theory can be applied and their effective relationship can be tested. To give a specific example, if DP4 (Synthetic Scene Diversity) is applied during synthetic image generation, the resulting data will (partially - since multiple DPs address DR3) satisfy DR3 (Accuracy & Precision), leading to improved model performance in diverse healthcare tasks, which can be tested by comparing the accuracy and precision metrics of models trained on diverse versus homogeneous datasets. Thus, the following testable propositions arise: **DR1** → *DP1/DP2/DP3/DP8*; **DR2** → *DP4/DP5/DP6/DP9*; **DR3** → *DP4/DP6/DP7/DP10*; **DR4** → *DP3/DP4/DP5/DP9/DP10*

Artifact mutability	The framing constructs for the utilization of synthetic image data in digital health are theorized as a type of guidance to change the current trajectory in digital health computer vision that works in a complementary relationship to real image-based approaches. The theorized artifact can be used in various digital health computer vision domains, such as medical imaging, diagnosis, human computer interaction, monitoring, detection, or predictive analytics. In addition, it provides general DPs that can be applied across domains of synthetic image processing, and its applicability is deep learning-model independent.
Justificatory Knowledge	Universal themes of synthetic image data use and value sensitive design theory (Friedman et al., 2002, 2013) together with an initial think aloud session and first cycle evaluation feedback serve as the theoretical and practical foundations of the design theory. The chosen kernel theories and qualitative analysis findings remain consistent across various domains, justifying the derivation of DRs and DPs.
Principles of implementation	The universally design knowledge suggests various implementation criteria to the conventional use of synthetic image data in digital health that will yield ethical and performance outcomes. Thus, the design theory can be used in computer vision project processes as a form of feasible and applicable guiding knowledge. Therefore, 20 DFs are proposed (Figure 29) that illustrate how the design theory could potentially operationalized.
Expository instantiation	A series of DRs and DPs was developed that, alongside a conceptual model for synthetic image use in digital health, show how researchers can apply the proposed constructs to develop ethical and performant computer vision models. Furthermore, it is shown how the design theory can be used to derive theoretical models or concepts in digital health.

Table 14. Components of the second cycle's design theory according to Gregor and Jones (2007) (Böhmer et al., 2025c).

As shown in Figure 29, the DPs were operationalized as DFs in Böhmer et al. (2025c) to validate their feasibility in a real-world application scenario. This iterative process ensured that the design features were not only consistent with the theoretical underpinnings of the design theory but also met the practical needs of users in a dynamic healthcare environment (i.e., the Augmented Living Spaces context). As a result, the prototype demonstrated the practicality of the DPs and bridged the gap between theory and practice. The DFs shown in Figure 29 serve as a transparent description of how the design theory was implemented in the Augmented Living Spaces scenario, where synthetic image data was used as a means to locate people with aMCI, monitor their health status, and project appropriate information at the right place and time (see Figure 30). It is meant to be an illustrative example that shows how the DPs can be operationalized by specific actions that have been taken to instantiate the design theory. These DFs can be seen as possible characteristics when using the design theory, but they are not meant to be mandatory.

DP1 Ethical Healthcare Data Generation	**Design Feature 1:** Used data privacy laws and value-sensitive design to guide data generation.
	Design Feature 2: Used non-genuine characters and a variety of ethnicities, cultures, etc. for data generation.
DP2 Comprehensive Privacy Protection	**Design Feature 3:** Used positional reasoning via bounding box coordinates rather than visual representation.
	Design Feature 4: Anonymized subtle features such as background details, specific patterns, and colour schemes.
DP3 Adaptive Data Governance	**Design Feature 5:** Automatically reviewed all generated synthetic images against a set of predefined standards.
	Design Feature 6: Developed a policy document that outlines the ethical creation and usage of that image data.
DP4 Synthetic Scene Diversity	**Design Feature 7:** Used a script for Unity3D to automatically generate random and compliant scenes.
	Design Feature 8: Used a script for Unity3D to randomly add or modify objects, backgrounds, and textures.
DP5 Controlled Scene Composition	**Design Feature 9:** Used scene balancing in Unity3D to maintain the correct scale and orientation of structures.
	Design Feature 10: Used an algorithm that maintains appropriate spatial relationships between objects in a scene.
DP6 Flexible Complexity Management	**Design Feature 11:** Used a script that introduces both quantitative and qualitative complexity changes.
	Design Feature 12: Used an algorithm to ensure that models don't become overly specialized in simpler scences.
DP7 Data Augmentation	**Design Feature 13:** Used a tool that applies geometric transformations such as scaling, rotating, and mirroring.
	Design Feature 14: Used a script that adds controlled noise at pixel level and perspective warping.
DP8 Responsible AI	**Design Feature 15:** Implemented an AI bias monitoring algorithm to ensure that it does not favor or disfavor groups.
	Design Feature 16: Used an AI model evaluation tool to ensure equitable decisions across patient demographics.
DP9 Transfer Learning Guidelines	**Design Feature 17:** Developed a protocol to guide the adaptation of synthetic models to real-world data nuances.
	Design Feature 18: Implemented a process to fine-tune models on real-image data and assessing performance.
DP10 Robustness Checks	**Design Feature 19:** Developed a testing protocol that simulates a wide range of environmental conditions.
	Design Feature 20: Conducted stress tests to evaluate model resilience against unusual or rare conditions.

Figure 29. Design features for instantiation (Böhmer et al., 2025c).

In addition, Figure 30 shows the aforementioned exemplary instantiation of the DPs, operationalized by the DFs, in the context of the proposed interaction design approach within an Augmented Living Space (Böhmer et al., 2025b; 2025c). In comparison to the examples of synthetic image data in digital health (Figure 26), i.e., cancer detection and skin conditions, this illustrative example shows a very attenuated form of application, where model errors are certainly not as drastic as in disease diagnosis.

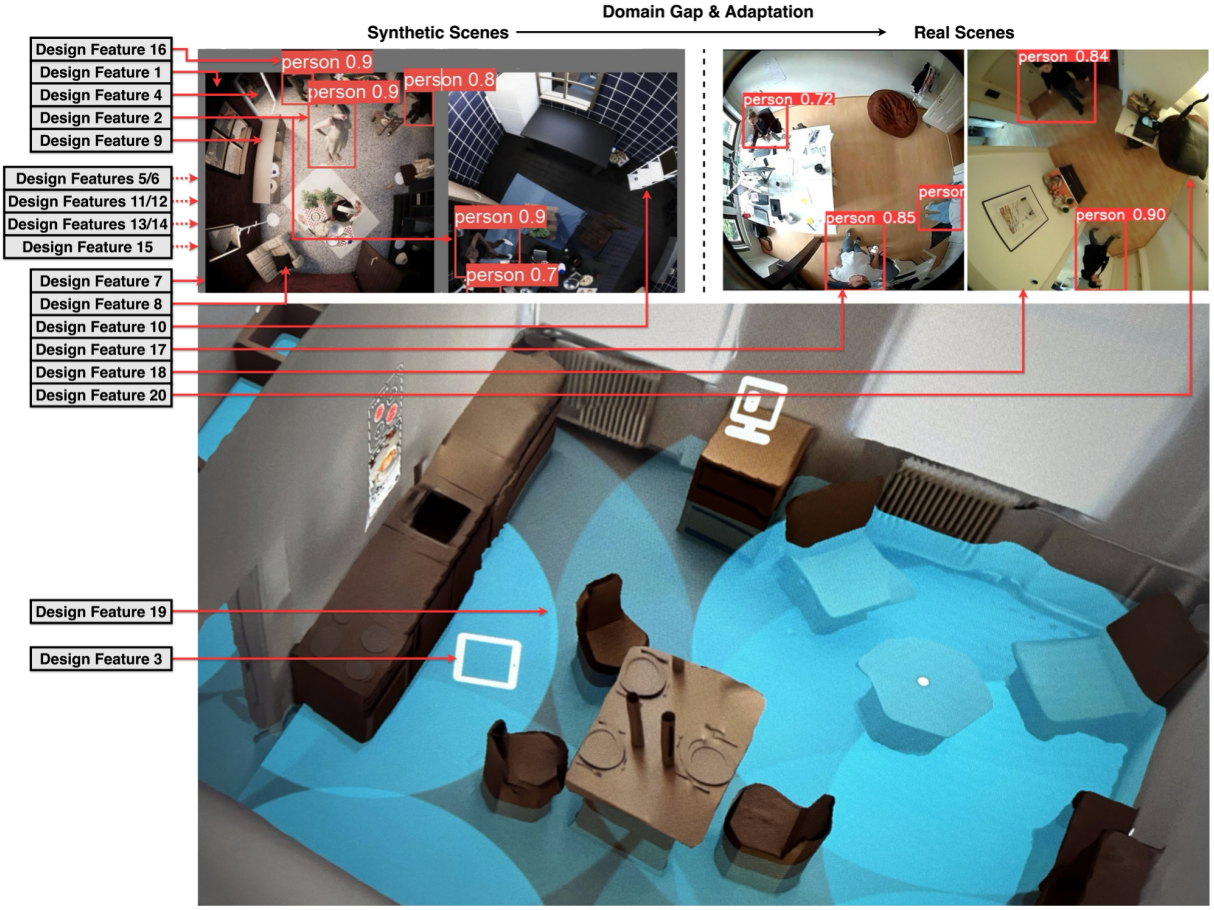


Figure 30. Instantiation of the design theory in the Augmented Living Spaces HCI approach context (Böhmer et al., 2025c).

By following value-sensitive design theory, abstract and non-genuine characters were generated for the scenes, ensuring ethical data generation (DP1) and privacy preservation (DP2). In addition, data gathering and processing for zone alignment only refers to the coordinates of the person's bounding box, not their actual appearance (see Figure 30 and the white rectangle), further ensuring that no sensitive data is displayed or actively used for processing. Using a video game engine and various mechanisms to generate the synthetic image data (DP3), a wide variety of scenes (DP4) and compositions (DP5) were achieved, significantly and intentionally varying the key features. Figure 30 shows the aforementioned domain gap and its adaptation, where the ConZones model trained on synthetic image data is applied to real scenes. In addition, several scenes contain varying complexity (DP6) to achieve better generalization and scalability, while data augmentation techniques (DP7) in the form of geometric transformations (i.e., lens distortion) were used to reduce the risk of overfitting. Prior bias detection, e.g., ethnicity or gender, was performed for data generation (DP8), and transfer learning (DP8) and robustness checking (DP10) strategies were employed. Exaggerated by this blatantly privacy-invasive example for positional reasoning in home care settings, the use of ethically generated and applied synthetic image data, properly operationalized by the design features, has the potential to mitigate these privacy-related concerns while still meeting the ethical requirements associated with digital health applications.

4.3.4 Conceptual Model

As a result of the heuristic theorizing approach, various steps of modelling were conducted (i.e., Figures 28 and 31) to visually develop different types of representations of the problem solution (Gregory & Muntermann, 2014). Following one of many approaches to graphically depict a conceptual solution schema for design theories (Müller-Wienbergen et al., 2011), a conceptual model was developed based on the design theory for the ethical use of synthetic image data in digital health (Figure 31) (Böhmer et al., 2025c). Within the theorizing process, such a conceptual model enables a more accurate expression of the underlying assumptions, thoughts, constructs, and implications, and can be seen as an abstract instantiation of the design theory (Bittmann & Thomas, 2013; Schermann et al., 2009). As such, the conceptual model represents the abstract constructs as entities of interest in the design theory (Gregor & Jones, 2007; Kane et al., 2021).

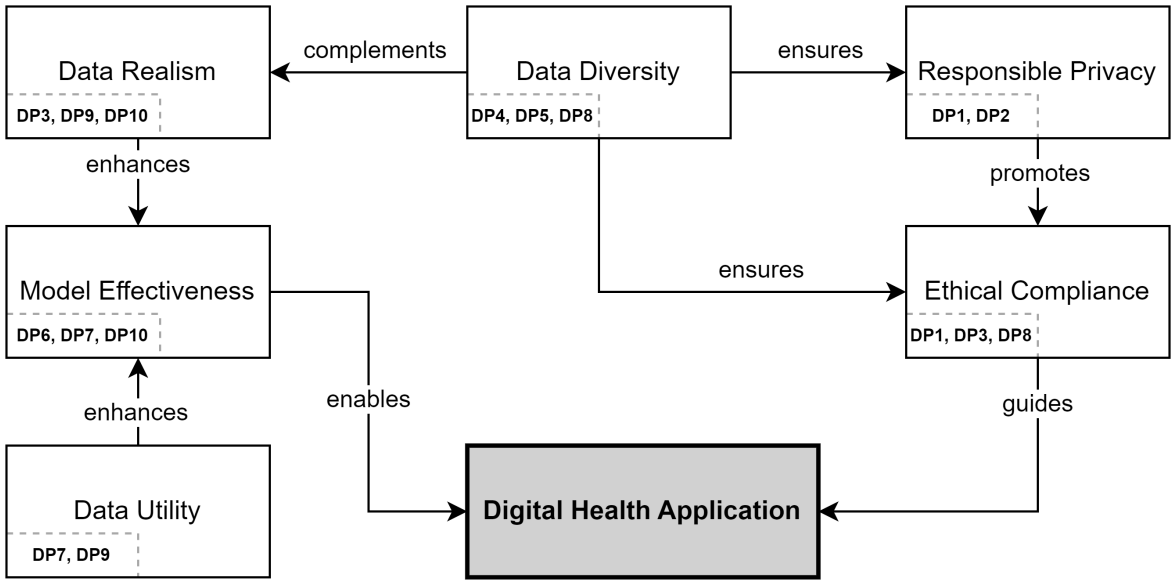


Figure 31. Conceptual model as a theorizing step (Böhmer et al., 2025c).

Based on the design theory, and in particular the DPs, the conceptual model graphically depicts how the theorized constructs ultimately affect the application of synthetically trained computer vision models in digital health (Böhmer et al., 2025c). Based on DP4, DP5, and DP8, *data diversity* complements *data realism* (DP3, DP9, and DP10) and ensures both *responsible privacy* (DP1, DP2) and *ethical compliance* (DP1, DP3, DP8). Thus, the conceptual model underscores the importance of a holistic design approach that integrates technical data and model robustness with rigorous ethical standards to promote adoption, trust, and reliability in digital health settings. In addition, *data realism* and *data utility* (DP7, DP9) both enhance *model effectiveness* (DP6, DP7, DP10) while addressing potential biases to ensure that the use of these models leads to equitable and accurate health outcomes for diverse populations. Finally, *model effectiveness* enables ethical compliance to guide digital health applications, creating a balanced framework where AI-driven solutions not only meet healthcare expectations but also align with ethical values and privacy concerns, paving the way for sustained adoption and innovation in digital health.

4.4 Evaluation

4.4.1 Evaluation of the HCI Approach

Similar to the evaluation approach in the first design cycle of this dissertation, a target-group-specific and thorough evaluation of the novel HCI approach seemed reasonable as the first step. Under the theoretical guidance of SCT (Bandura, 2001), the assessments of *self-efficacy, performance expectancy,* and *outcome expectancy* were identified as the key evaluation measures that can be measured either

quantitatively or qualitatively. To gauge the effectiveness, intuitiveness, and usability of the proposed deep learning-based HCI approach, a total of three evaluation episodes with different experimental settings, subjects, and evaluation purposes (system tests, questionnaires, think-aloud) were conducted in Böhmer et al. (2025b) as recommended by Kriglstein et al. (2016). Regarding the sample sizes, the iterative evaluation episodes and user-centered design align with the principles of meaning and theoretical saturation (e.g., via tailored sampling approaches), ensuring that all nuances and contextual meanings of HCI interactions for aMCI individuals are thoroughly captured (Wutich et al., 2024).

Evaluation episodes 1 & 2 in this second design cycle were characterized by a similar experimental setting but included different subjects and different evaluation purposes. While the first evaluation episode aimed to assess the usability and intuitiveness perceived by the target group of people with aMCI, the second evaluation episode applied the same system evaluation setting to a group of IS and digital health experts. To determine usefulness and intuitiveness as a form of *self-efficacy*, *performance expectancy*, and *outcome expectancy* (Bandura, 2001) that are not explicitly measurable, the same UTAUT items (Venkatesh et al., 2003) were used as shown in the first design cycle. Since PE4 would not be meaningful in the context of this research, it was changed to "*increased chance of receiving health insurance benefits"* for the questionnaires, which implies that using such a digital health application could yield potential healthcare benefits (e.g., reduced therapy costs, free courses, etc.).

In the first step, both the target group and experts were asked to use the system in a semi-natural setting (Abras et al., 2004) with three active widgets that offered the novel interaction approach (Böhmer et al., 2025b). In selecting the sample size for health pilot studies, the approach adhered to the minimum of n=12 subjects suggested by Julious (2005) based on feasibility rationale, precision of mean and variance, and regulatory concerns. This approach is further supported by Wutich et al. (2024), who emphasize that small but carefully chosen sample sizes are appropriate for capturing rich, meaningful data in iterative, context-specific qualitative research designs.

As shown in Böhmer et al. (2025b), in evaluation episode 1, n=12 subjects with aMCI used the system, while evaluation episode 2 consisted of n=14 domain experts. Subjects were then asked to move freely and use/test the SAR-based system by pretending to perform activities of daily living such as cooking, taking medication, and socializing via video telephony. Subsequently, the study participants were asked to complete the questionnaire, which included 1) an introductory text about the research project, 2) the description of the *ConZones* HCI approach, 3) the statements on the PE and EE, and 4) some socio-economic questions. For data collection, interval-scaled verbal-numeric 7-point Likert-style scales were used. The questionnaires were anonymized before being analyzed. Subjects of the aMCI target group were aged older than 60 years (some over 80 years old), lived autonomously or with their partners at home, and had already retired from their professional roles. Moreover, the domain expert respondents partially fulfilled multiple professional roles and included two senior IS researchers, two senior digital health researchers, 1 HCI senior researcher, 2 IS research associates, one digital health research associate, four digital health project leads, one usability engineer, and one health insurance manager, all possessing 2-19 years of experience in their respective roles.

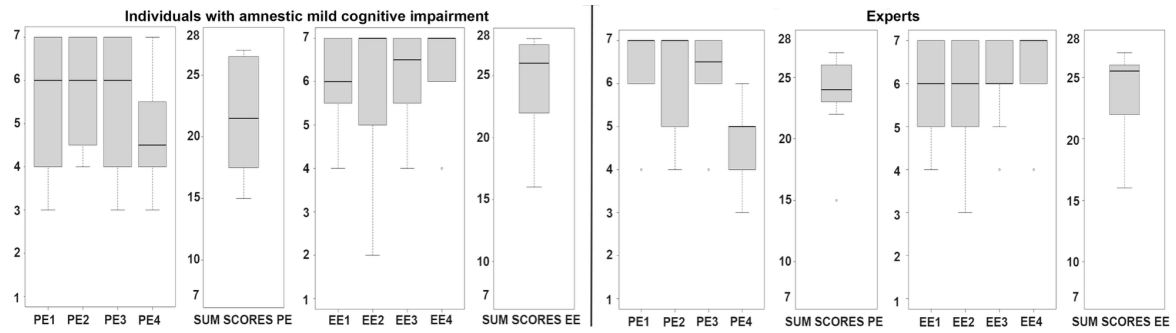


Figure 32. Boxplots for ConZones interaction evaluation with scale items (Böhmer et al., 2025b).

Figure 32 illustrates the boxplots representing the responses in Böhmer et al. (2025b), which exhibit high agreement levels across all items, displaying medians of m=6 for both the target group and field experts. Consequently, the cumulative scores of the PE and EE, with medians of m=24 for the target group and m=25 for domain experts on a 7-28 scale, effectively capture the overall positive evaluation. Subjects indicated that the novel HCI approach would enable them to accomplish tasks (e.g., cooking in an AI- and SAR-driven enhanced living environment) more quickly while increasing their overall productivity in daily activities. In particular, the high level of agreement on the EE constructs suggests a high level of user-centeredness, system usability, and learnability. To validate the quality of the PE and EE constructs, the same validation steps as described in Chapter 3.4 were applied (Table 15).

Performance Expectancy		Elderly/MCI	Experts	**Effort Expectancy**		Elderly/MCI	Experts
Loadings	Usefulness	.900	.630	Loadings	Clarity	.872	.740
	Quickness	.878	.649		Easy to Master	.423	.815
	Productivity	.906	.998		Easy to Use	.998	.695
	Chance of Raise*	.436	.743		Easy to Learn	.562	.776
	AVE	.648	.591		**AVE**	.563	.574
	CCR	.874	.848		**CCR**	.823	.843

Table 15. Construct validation for the aMCI and expert groups (Böhmer et al., 2025b).
Note: MCI = mildly cognitively impaired, AVE = average variance extracted, CCR = composite construct reliability

Despite the overall positive system use and questionnaire evaluation, a minor portion of whisker outliers was observed in Böhmer et al. (2025b) (see Figure 32), especially within the target group evaluation episode. Thus, it was decided to perform another qualitative ex-post analysis to ensure high system usability and resolve ambiguities (e.g., system use issues, cognitive load, misconceptions), which further aligns with a multi-episode evaluation strategy (Kriglstein et al., 2016). Particularly in the context of aMCI, where the assessment of technology complexity, low-threshold interaction, and intuitiveness are most relevant, it was decided to follow the techniques of *behavioral rehabilitation* for aMCI discussed by Greenaway et al. (2008), which typically focus on improving daily living skills, memory attention, and problem-solving skills. Here, computerized and AR/VR cognitive training to stimulate cognitive functions embodies interventions for people with aMCI tailored to improve specific cognitive skills that are often qualitatively evaluated (Jean et al., 2010). Hence, in pursuit of a summative and naturalistic HCI approach assessment for people with aMCI and to ensure the necessary scientific rigor, evaluation episode 3 in this second design cycle drew on the foundational theories and theoretical foundations that consider think-aloud sessions to be a valid qualitative evaluation method (Abras et al., 2004; Dickinson et al., 2007; Friedman et al., 2013; Kriglstein et al., 2016). Accordingly, the *Concurrent Think-Aloud* approach (Van Den Haak et al., 2003) was followed as a means of qualitative analysis using the "10±2 rule" for think-aloud evaluation sample size (Hwang and Salvendy, 2010) with n=12 aMCI subjects. Participants were instructed to use the system or complete a series of tasks while articulating their thoughts, allowing for evaluation of system design and implementation. To ensure qualitative rigor during and after these sessions, the well-established methodology outlined by Gioia et al. (2012) was used again based on the subjects' expressed thoughts. These details can be found in Table 16.

Overall, the results of the think-aloud sessions show promising results as the subjects felt comfortable, confident, and at ease with the novel HCI approach (Böhmer et al., 2025b). As the second-order themes show, the interaction design approach was able to effectively address the technostress creators of *techno-complexity* and *techno-overload* (Nastjuk et al., 2023), minimizing cognitive load while simultaneously increasing user-centered adoption and usability. Subjects emphasized that they felt more comfortable with the SAR-based HCI approach than with wearable or direct HCI technologies because it was more intuitive, easier to learn, and swiftly integrated into their daily lives. Participants in the think-aloud session expressed great satisfaction with the provided information, its content, and pleasantness, especially valuing the transformation and user-location dependency of widgets, as well as the division into functional and offering parts.

Aggregate Dimensions	2nd Order Themes	1st Order Concepts
Information Representation	Useful and adequate widget transformation	+ Subjects reported sufficient and pleasant content of information. + Subjects positively assessed the transformation and user-location dependency of widgets as well as their changing information content. + Subjects highlighted the widget division into a functional part and an offering part as very positive.
	Easy information access and tangibility	+ Subjects perceive the color representation as highly recognizable and could easily access and understand the communicated information. + Subjects valued the connection between a widget and its anchored augmented real-world object.
	Realistic and abstract information visualization	+ Subjects perceived the realistic representation and augmentation of the real object (e.g. number of stove plates) as highly useful. o Some subjects rather preferred text to illustrations.
Usability	Highly user-friendly and user-centric	+ Subjects highlighted the high level of user-friendliness. + Subjects highlighted the high level of user-centeredness.
	Intuitive use through indirect interaction	+ Subjects found the system and interaction process easy to use. + Subjects reported high intuitiveness and low entry barriers. + Subjects preferred the indirect interaction over wearable approaches (i.e. tablet, smartphone).
	Easy to understand and operate	+ Subjects were able to understand and use the context-aware zones quickly and without further instructions. + Subjects assessed the voice control as highly useful.
	Setup process	o Some subjects reported fears about the initial setup and instruction process.
Cognitive Relief	Information complexity and comprehensibility	+ Subjects experienced cognitive relief both from minimized complexity and from the use of easily comprehensible and object-oriented information. + Subjects reported high cognitive relief as they did not have to actively seek information and were provided with individual, relevant, and useful data. + Subjects found the different widget states to be very useful, with the idle widget showing only a small anchor point, reducing information overload.
	No need for additional devices and constant reorientation	+ Subjects were relieved to not have to reorient themselves to gather information (e.g., recipe on smartphone and cooking area in different locations). + Subjects positively assessed the information provision based on their location since it gave them relevant information at the respective object/location. + Subjects highly valued the hands-free and indirect interaction which reduces cognitive effort and the need for handling wearable devices.
Daily Routines	Holistic approach to autonomy support	+ Subjects assessed the holistic assistance approach as highly useful, expressing their need for cognitive augmentation.
	System versatility and context-awareness	+ Subjects reported high consent for having different widgets for different daily routines. + Subject positively highlighted the widget context-awareness and their real-time as well as object-dependent occurrence.

Table 16. Think-aloud evaluation results of the ConZones interaction (Böhmer et al., 2025b).
Note: + = positive aspect; o = potential for improvement

As shown in Böhmer et al. (2025b) and Table 16, the subjects found the system user-friendly, intuitive, and easy to use, with low entry barriers, where they quickly understood the context-aware zones and voice control, and considered it to be useful. Participants experienced cognitive relief from minimized complexity and easy-to-understand information, and reported the benefit of not having to actively search for information, yet receiving relevant and personalized data immediately. The different widget states, particularly the idle state, were found useful for reducing information overload, where subjects positively assessed the system's location-based information provision. Most importantly, the think-aloud session provided valuable insights into the system adoption and usage by individuals with aMCI, especially addressing the whisker outliers from the first evaluation episodes. Nonetheless, since evaluation episode 3 provided a more in-depth and detailed user experience, these outliers can be attributed to the daily form of aMCI participants, misconceptions in the task/questionnaire description, or personal reasons. It would also be presumptuous to think and expect that this rethought HCI approach with ConZones will benefit all users equally.

Overall, the three evaluation episodes for the first DSR echelon instance of the second design cycle positively assessed adoption, usability, and intuitiveness by qualitatively addressing *self-efficacy, performance expectancy,* and *outcome expectancy* of SCT (Bandura, 2001) via various methods, models, and constructs. The multi-episode evaluation strategy aimed at evaluating the proposed AI- and SAR-based HCI approach in the most naturalistic way possible, directly involving the target group of aMCI individuals as well as IS and digital health field experts, guided by the foundational theories and theoretical foundations. While the first two evaluation episodes made these positive results somewhat quantifiable (without quantitative/empirical claims), the think-aloud session allowed for a deeper understanding of the user's thoughts and feelings, where the room for improvement does not require a system or approach overhaul.

To establish the link between the evaluation results and the aspects and mechanisms of cognitive adoption, the exhibited high PE and EE scores reflect enhanced self-efficacy and outcome expectancy, core predictors of technology adoption in cognitive processing dimensions. SAR-based, gaze-sensitive interactions were found to reduce cognitive load and technostress, supporting the cognitive relief mechanism through augmented assistance. This mechanism is central to the idea that cognitively impaired users will adopt technologies that minimize the need for active control or handling multiple devices. More profoundly, the qualitative findings from the think-aloud sessions – particularly the strong themes of "cognitive relief" due to minimized complexity and hands-free interaction and "intuitive use through indirect interaction" – provided substantial initial validation of the theoretical emphasis on managing extraneous cognitive load and enhancing inherent usability as the primary drivers of successful adoption. The reported feelings of comfort, confidence, and being 'at ease' with the system also underscored the importance of bolstering (contextual) self-efficacy, a key tenet of social cognitive factors, by creating an interaction paradigm that feels supportive rather than demanding. Moreover, the expressed preference for hands-free, indirect interaction over wearable or screen-based devices validated the assumption from the first cycle that low-threshold interaction paradigms foster sustained engagement.

4.4.2 Evaluation of the Design Theory

For the second DSR echelon instance of this design cycle (Böhmer et al., 2025c), the FEDS framework proposed by Venable et al. (2016) was used similarly to the approach from the first design cycle. The evaluation phase is highly relevant in DSR (Hevner et al., 2004; Venable et al., 2016), as it is necessary to select an appropriate strategic process and determine the constructs to be evaluated. This complementary evaluation approach, while not integral or necessary to the heuristic theorizing process (Gregory & Muntermann, 2014), served to validate the reusability, practicality, and relevance of the design theory, ensuring that it "works" in real-world applications (i.e., the Augmented Living Spaces context) and resonated with stakeholder needs. Given the complexity of human factors in digital health, ethical considerations, and the practical application of technology in healthcare settings, the *Human Risk & Effectiveness* evaluation strategy (Venable et al., 2016) was again chosen to address the socio-technical and value-based imperatives of this DSR echelon instance (Figure 33).

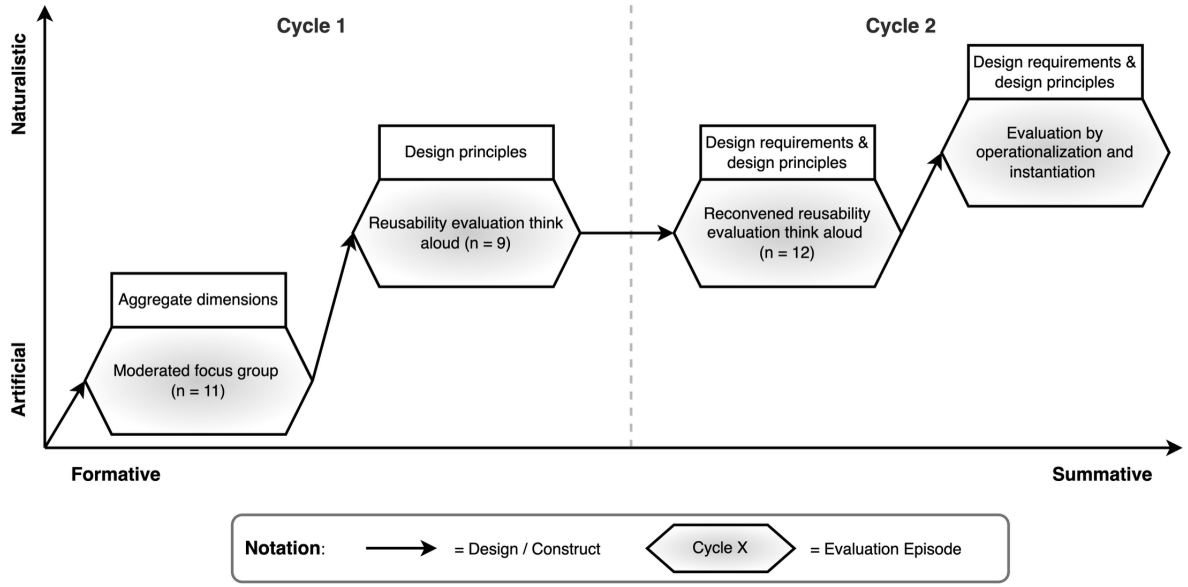


Figure 33. Evaluation strategy following the FEDS framework (Venable et al., 2016) within the second DSR echelon instance[6] of the second cycle (Böhmer et al., 2025c).

While the problem-centered research approach was theory-driven (Schoormann et al., 2024; Iivari, 2015), it sought to balance both rigor and relevance in the evaluation strategy for Böhmer et al. (2025c). Thus, the goal was to conduct an evaluation episode to complete both design cycles and to move quickly to a summative evaluation result. Despite the relatively small sample sizes of the evaluation episodes, theoretical, data, code, thematic, and meaning saturation were achieved, confirming that further data collection was unlikely to yield new insights. This saturation across multiple dimensions ensured the rigor and robustness of the findings and validated the evaluation approach as both thorough and efficient.

It is acknowledged that sample size is often questioned in qualitative research (Marshall et al., 2013; Hwang & Salvendy, 2010; Noushad et al., 2024), especially when dealing with smaller numbers of participants, who in this case were selected for their specialized expertise in synthetic (image) data, digital ethics, and AI in digital health. However, theoretical saturation was reached when no new insights emerged to further inform the design theory (Glaser & Strauss, 2017; Charmaz, 2006), while data saturation occurred when additional data collection did not yield new second-order themes or aggregate dimensions (Saunders et al., 2018), signaling that further data would not contribute new insights (Böhmer et al., 2025c). Code/thematic saturation (Bowen, 2008; Guest et al., 2020; Hennink et al., 2022) confirmed that the identified themes fully captured the essence of the cycle's focus, even after adding or subtracting experts from the sample. Finally, meaning saturation was reached, where the interpretive understanding of the themes was fully developed, and no new meaning could emerge from additional data or sessions (Hennink et al., 2017; Yang et al., 2022) (Böhmer et al., 2025c). The depth of engagement with the expert participants allowed this DSR echelon instance to make meaningful design decisions without the need for a larger participant pool, focusing on the premise that qualitative rigor comes from the richness of the data rather than the number of participants (Bryant & Charmaz, 2007; Sandelowski, 1995). The rather small sample size was used to ensure the participation of a practical and realistically recruitable subset of the target community, allowing for a focused yet meaningful evaluation of the proposed DRs and DPs by relevant practitioners outside the DSR project (Iivari et al., 2021).

The following paragraph is mainly based on Böhmer et al. (2025c) and has been minimally revised to harmonize terminology across publications and cycles for this dissertation.

[6] Note that these cycles here were performed within this second cycle's DSR echelon instance. These are not the overarching design cycles performed for this dissertation.

To ensure the objectives of feasibility, accessibility, completeness, and applicability, the framework of *Design Principle Reusability* proposed by Iivari et al. (2021) was applied. Iivari et al. (2021) actively call for adaptations of their framework, for which it has been applied to a different level of design abstraction. Thus, 3 levels of reusability for design requirements (RDR) were identified based on the items in the framework: 1) direct application (items for design principles can be directly mapped to design requirements), 2) item adoption (individual items of a construct can be mapped), and 3) non-applicability (items cannot be mapped to design requirements). Because DRs embody the objective that DPs address, their evaluation differs to some extent. To ensure content validity based on the framework and questionnaire (Iivari et al., 2021), the constructs of *accessibility* (i.e., understandability, comprehensibility, intelligibility) and *importance* (i.e., real and important problem addressing) were allocated to level 1 RDR and could be asked without tweaking them. The constructs of *actability and guidance*, and *effectiveness* were assigned a level 2 RDR with necessary adjustments. Therefore, it was decided to use "sufficient guidance," "sufficient direction," and "sufficient freedom" for *actionability and guidance*, and "usefulness," "design help," and "artifact quality" for *effectiveness*, ensuring content validity by not evaluating items that are explicitly tied to DPs and their empirical validation on these items. Finally, the construct of *novelty and insightfulness* was assigned level 3 RDR and, therefore, deemed inapplicable due to the goal-oriented formulation of the DRs. Consistent with the kernel theory of value-sensitive design and beyond the first cycle evaluation within the DSR echelon instance, a reconvened qualitative think-aloud session with n=12 AI experts was conducted to address the reusability of the proposed design theory constructs. The participants were asked to verbalize their thoughts about the DRs and DPs (to the aforementioned extent) in terms of the reusability categories proposed by Iivari et al. (2021).

A detailed description alongside a tabular representation of the qualitative think-aloud results, including the categories of the reusability framework and the manually aggregated verbalized thoughts of the participants, can be found in the respective publication (Böhmer et al., 2025c) in Appendix J.

Overall, the think-aloud subjects rated the DRs and DPs positively in terms of their theoretical and practical reusability, especially regarding accessibility, importance, novelty & insightfulness, actability & guidance, and effectiveness. Emphasizing digital ethics and precision, these evaluation results indicate a well-founded acceptance and potential for integration of the proposed design theory artifact into existing and future practices within synthetic image data and digital health. The consistent acknowledgment of the detailed and actionable nature of the DRs and DPs by the think-aloud subjects indicates a promising trajectory for the successful application of this theory, particularly in terms of construct understanding and meaning. The articulated concerns regarding the balance between guidance and design freedom, as well as a more nuanced construct description, point to an area for further refinement to ensure that the principles facilitate innovation while maintaining a clear ethical and performance-oriented framework and guiding language.

Design Theory Replication Aspects	
Replication Aspect	**Implementation**
Problem Class & Solution Space	The design theory addresses the problem of ethical and effective utilization of synthetic image data in digital health, focusing on privacy, ethical compliance, bias mitigation, domain adaptation, generalization, and accuracy. The solution space includes DRs and respective DPs for responsible AI use in digital health computer vision and enhancing model robustness for synthetic image data.
Robust & Generalizable Constructs	To ensure robust constructs, the design theory is based on value-sensitive design and sociotechnical systems theory, incorporating a multi-method (i.e., focus group, think-aloud sessions, qualitative theory building) approach and heuristic theorizing across two design cycles, presenting DRs and DPs as the main artifact and theorized constructs. These primarily apply to the use of synthetic image data in digital health computer vision but can be utilized and adapted across various deep learning domains. Moreover, the design theory contains generally applicable DPs that should be applied regardless of the specific application domain.

Explicit Methodologies & Processes	The development of the design theory followed a structured approach using a heuristic design theorizing methodology (Gregory & Muntermann, 2014) over two completed design science research cycles. In addition, the theory-driven approach of learning from abstract theoretical knowledge (i.e., kernel theories and the literature) and translating it to solve a problem (Schoormann et al., 2024) and formulating rigorous DPs (Gregor et al., 2020) for conceptualizing fewer abstract artifacts was applied.
Rationale for Design Choices	The multi-faceted study approach ensures that the DRs and DPs are not arbitrary but are grounded in conceptual and theoretical work (Schoormann et al., 2024). The rationale for design choices emphasizes that ethics and privacy are consistent with value-sensitive design and socio-technical imperatives, preventing the technical subsystem from undermining the social subsystem in digital health AI. It is argued that design decisions are never neutral, prioritizing individuality and generalizability to ensure a models' adaptability across diverse healthcare contexts. A focus on accuracy and precision in data generation underpins the reliability and effectiveness of healthcare applications. Finally, the emphasis on realism and healthcare relevance in synthetic data underscores a commitment to creating technically and ethically sound, user-centered solutions.
Variability & Adaptation	Proactively anticipating the need for variability and adaptation in the rapidly evolving nature of both digital health and synthetic image data, this DSR echelon instance provides guidelines for adapting the design theory to evolving technologies and ethical values, ensuring ongoing relevance. This approach accounts for future advances and changes in the field, both technically and ethically, and maintains the applicability of the theory in diverse and changing scenarios by not only proposing DPs that are generally applicable (e.g., DP4) regardless of the target domain, but also by choosing a wording that is invariant to future developments and maintains clarity (e.g., DP1 - ethical guidelines and laws may change, but adherence to them should not). This foresight underscores the commitment to a flexible, responsive design that can adapt to new ethical imperatives and technological developments, reinforcing the theory's robustness and longevity.
Iterative Testing & Feedback	Given the nature of DSR, the importance of iterative testing and feedback is emphasized, advocating a continuous refinement process beyond the two cycles presented. This iterative approach allows for the consistent incorporation of new insights and technological advancements, ensuring the design theory remains relevant and effective. By incorporating reconvened think-aloud sessions addressing the design theory's constructs, their reusability in terms of accessibility, importance, novelty & insightfulness, actability & guidance, and effectiveness is categorized (Iivari et al., 2021). Hence, this specifically targets design theory indeterminacy (Lukyanenko & Parsons, 2020), enabling the theory to be applied in various contexts with minimal modifications, extended to cover broader scenarios, and scaled to accommodate different levels of use.
Result Documentation & Sharing	In the design theory, the significance of meticulously documenting and sharing comprehensive data and results by grounding the design theory's constructs with their theory-grounding and theory-building foundations is underscored. Therefore, a qualitative content analysis following Gioia et al. (2013) was chosen to ensure traceability and comprehensibility throughout the design process. This commitment to transparency allows other researchers and practitioners to replicate, validate, and extend these findings. It is ensured that every aspect of the research process, from initial theory-grounding, theory-building, and formulation of DRs and DPs to iterative reusability evaluation results, is thoroughly recorded and accessible. By sharing detailed data and results, a deeper understanding of the development and application of the theory fostered, encouraging collaborative improvement.

Table 17. Design theory replication aspects according to Brendel & Muntermann (2022) (Böhmer et al., 2025c).

By adopting the heuristic theorizing approach, it was sought to reduce replication errors while maximizing transparency, reproducibility, and traceability. Following the design theory replication

framework proposed by Brendel and Muntermann (2022), this effectively addressed various critical aspects of replication in the context of the design theory for digital health computer vision using synthetic image data (Table 17). Encompassing design theory replication aspects of problem class and solution space, robust and generalizable constructs, explicit methods and processes, the rationale for design choices, variability and adaptation, and iterative testing and feedback, the proposed design theory is positioned for effective application and future development in the rapidly changing landscape of digital health and synthetic data use, while providing complementary concepts to the development of the *Cognitive Adoption Theory*. In doing so, it proved the reusability and importance of these ethical aspects, reinforcing that ethical considerations aren't just a "nice-to-have" but a fundamental prerequisite for the cognitive and emotional willingness of users to adopt health technologies.

4.5 Conclusion

The second design cycle was initiated to address the limitations of the first design cycle, which highlighted the need for a more detailed, technically operationalized, and ethically sound HCI approach for individuals with aMCI in the context of the proposed Augmented Living Spaces concept. Specifically, this cycle pursued two interrelated DSR echelon instances on the way to develop the *Cognitive Adoption Theory*: (1) **the implementation of intuitive and context-aware interaction design for digital health assistance** (e.g., in Augmented Living Spaces), and (2) the development of **design theory for the ethical and effective use of synthetic image data in digital health applications**.

In response to **RQ3**, the novel HCI approach ConZones – an indirect, location-based interaction design powered by a synthetically trained deep learning model for positional reasoning – was realized within the first DSR echelon instance of this cycle (Böhmer et al., 2025b). The model demonstrated high recognition accuracy, transferability from synthetic to real images (i.e., domain adaptation), and successful real-time deployment in the context of an Augmented Living Space. Evaluation episodes with aMCI users and domain experts confirmed the system's usability, low cognitive load, and high perceived effectiveness, which will inform the *Cognitive Adoption Theory* later on. Here, the development of the ConZones interaction design solved specific problems and uncovered crucial cognitive, behavioral, and ethical dimensions. It demonstrated how principles of cognitive accommodation, manageable cognitive load, and enhanced self-efficacy emerge from system interactions that are cognitively aligned, ethically sound, and perceptibly fair.

In parallel, and responding to **RQ4**, the second DSR echelon instance of this cycle conceptualized a design theory with ten DPs and four DRs that guide the responsible use of synthetic image data in healthcare AI (Böhmer et al., 2025c). This design theory was developed through a rigorous, heuristic design theorizing process and informed by stakeholder feedback, value-sensitive design, and socio-technical systems theory. It responds to a critical circumstance encountered in this cycle: while synthetic data enabled the technical implementation of ConZones, it raised unresolved functional and ethical concerns in the healthcare context, such as privacy, realism, bias, and lack of regulation, which might negatively impact technology adoption. Moreover, the DRs and DPs did more than enable artifact design; they encoded a design theory of cognitive accommodation. They formalize the structure that AI systems using synthetic data must have to optimize cognitive, social, and behavioral affordances for people with cognitive impairments. Therefore, they are direct theoretical antecedents to the constructs of the *Cognitive Adoption Theory*. Thus, although the design theory for synthetic image data is not aimed at dictating the structure of the Cognitive Adoption Theory, it does provide the necessary design scaffolding to observe, theorize, and validate how individuals with cognitive impairments interact with digital health technologies. As such, it revealed that conscientiously creating the underlying AI technology is a critical socio-technical determinant of cognitive adoption because it directly shapes the end-user's perception of the system's value, trustworthiness, and cognitive accessibility.

Together, these two layers (Böhmer et al., 2025b; 2025c) form a coherent response to the dual problem awareness of the cycle – addressing both the usability challenge of HCI for individuals with cognitive impairments and the ethical-operational challenge of using synthetic image data in AI-driven digital health systems.

Despite the promising evaluation results, the second design cycle is not without limitations. While the HCI approach has been successfully implemented and validated in the controlled Augmented Living Spaces environment, its long-term effectiveness, scalability across different home environments, and adaptability to changing cognitive conditions remain untested. Furthermore, the reliance of the interaction design on deep learning models requires continuous monitoring of performance in edge cases, especially as the home environment or user behavior evolves. On a theoretical level, while the design theory developed addresses significant ethical gaps in the use of synthetic data, it remains conceptual and nascent to some extent. Its prescriptive nature has been instantiated in a single system setting (i.e., ConZones) and requires broader validation across use cases, stakeholder contexts, and regulatory frameworks. Furthermore, while the theory is grounded in robust ethical and technical reasoning, it does not fully address deeper psychological or cognitive mechanisms that influence user trust, understanding, and health-related behavior in HCI contexts.

Nevertheless, this second design cycle achieved its primary goals: to develop a cognitively accessible SAR-based interaction approach, to formulate structured, theory-based design knowledge for synthetic image data in digital health, and to extract key concepts/mechanisms for the development of the *Cognitive Adoption Theory*. However, in doing so, it revealed the fundamental research gap that transcends interaction design and data ethics: the lack of explanatory kernel theories that explain **how cognitive processes in individuals with impairments affect their interaction with, acceptance of, and behavioral response to intelligent digital health systems**. This finding marks a critical transition point in the research trajectory. It signals a shift from the development of artifacts and DPs to the **development of theoretical understanding**. Specifically, it calls for a third design cycle, driven not by immediate artifact construction but by the need to theorize and model the cognitive mechanisms underlying human-AI interaction and technology adoption in health contexts. Such a cycle will seek to contribute a kernel theory that bridges cognitive science, health behavior change, and interaction design, thus enriching the theoretical foundations of both the Augmented Living Spaces concept and digital health DSR more broadly.

5 Design Cycle 3: Cognitive Adoption Theory Echelon Instance

Addressing RQ5, the third design cycle is motivated by the lack of kernel theories that explain cognitive adoption in digital health among individuals with cognitive impairments (Böhmer et al., 2024). Building upon the findings from the prior two cycles, it is specifically aligned with the theory-perspective in IS research (Leidner & Gregory, 2024) and is driven by the notion that, despite their diverse causes, all types of cognitive impairment share a commonality: the profound impact of cognitive factors on daily functioning and technology use. Previous research has shown that the technology adoption and usage behaviors of this group differ from those of the general population (Gazzaniga et al., 2018). Therefore, tailored approaches and interfaces that are more intuitive and less complex are often required (as proposed by the first two design cycles of this dissertation), as cognitive factors such as task difficulty, cognitive load, or social environment significantly influence technology adoption among people with cognitive impairments (Ienca et al., 2021). While there is growing awareness of their unique needs, research on technology adoption among this vulnerable population often neglects the specific impact of their cognitive impairments. Although research and design are beginning to address these needs, studies largely focus on older adults in general. This leaves a critical research gap in understanding the specific cognitive factors that shape adoption among people with cognitive impairments – a gap that merits further exploration (Singh & Varshney, 2020). Thus, the rapid evolution of digital health requires a comprehensive understanding of the cognitive and social factors, aspects, and mechanisms that influence its adoption, particularly on the patient side of vulnerable populations with varying cognitive impairments. As such, the third design cycle is aimed at synthesizing and abstracting insights from the first two cycles, offering an integrative theoretical model to explain these cognitive adoption mechanisms. It seeks to identify underlying causal forces (e.g., cognitive load, self-efficacy, metacognition) and articulate how they interact to influence technology acceptance and use among people with cognitive impairments.

5.1 Awareness of Problem

The third design cycle was initiated as a direct response to the reflections and conclusions of the first two cycles. Although the artifacts developed in the previous cycles successfully addressed the initially stated practical and design-oriented objectives (RQ1-RQ4), the evaluation revealed an emerging and unresolved theoretical gap encountered during the first two design cycles: existing kernel theories provided limited explanatory power regarding the cognitive mechanisms underlying technology adoption and subsequent health behavior change among individuals with cognitive impairments, such as those with aMCI. This insight highlighted that, while the solutions had proven useful in practice, the design process lacked a sufficiently robust theoretical foundation to generalize or transfer knowledge about cognitive adoption processes in this unique population. In particular, it became clear that the dominant kernel theories typically employed in digital health research, such as Bandura's SCT (1977), Sweller's CLT (1988), or the UTAUT constructs (Venkatesh et al., 2003), each captured only isolated facets of the cognitive constructs relevant to this user group.

As a consequence, a problem awareness has emerged that motivated this dissertation in general: there is a critical lack of integrative theoretical understanding of how cognitive impairment affects digital health adoption and behavior change processes. This is particularly pressing given the growing number of digital health initiatives targeting vulnerable populations with diverse forms of cognitive impairment (Gauthier et al., 2006; Gazzaniga et al., 2018). These populations often exhibit specific cognitive challenges such as reduced memory performance, altered social cognition, and slower information processing speed, all of which significantly alter how technology is perceived, learned, and used (Ienca et al., 2021). However, most existing studies either neglect these differences or subsume individuals with cognitive impairments under the broader umbrella of "older adults," thereby overlooking their unique needs (Singh & Varshney, 2020; Böhmer et al., 2022). This is of particular interest as digital health systems are increasingly being developed for individuals with neurodegenerative diseases, traumatic brain injury, or age-related decline, but whose cognitive trajectories differ from the general population, requiring targeted research and theoretical reconceptualization. As emphasized by Mathews et al. (2019) and Pak and Song (2016), the behavioral and social determinants of digital health adoption are complex, and the gap becomes particularly salient when traditional explanatory models are applied to populations for which they were not originally developed.

This problem awareness led to the framing of the initial research focus for this dissertation and its overarching goal. Rather than iterating further on artifact design per se, the third design cycle was motivated by the need to better theorize the mechanisms of cognitive adoption and behavior change in populations with cognitive impairments. The goal was to explore whether and how an integrative theoretical perspective could be developed to explain digital health adoption and its cognitive underpinnings more holistically, thereby contributing a novel mid-range theory grounded in multiple kernel theories and the practical/conceptual foundations, specifically tailored to this user group.

Following Vaishnavi and Kuechler (2015), this phase exemplifies the "emergence of a broader research challenge" as an outcome of reflection and abstraction based on the two prior cycles. It marks a clear departure from the previous artifact-centric focus and transitions the research into a more conceptual and theoretically generative domain, aligning with the notion that DSR can (and should) lead to theory creation when practical artifact design alone is insufficient to address emergent insights and scientific questions.

5.2 Suggestion

To address the theoretical gap identified in the *Awareness of the Problem* phase – namely, the insufficient explanatory power of existing kernel theories for understanding technology adoption among people with cognitive impairments – this third design cycle proposes the development of an integrative theoretical model of cognitive adoption in digital health. Specifically, it proposes to synthesize CLT, SCT, and metacognitive perspectives alongside the conceptual insights from the prior two cycles into a unified theoretical framework that captures the various cognitive, behavioral, and contextual mechanisms that shape how individuals with cognitive impairments adopt and engage with digital health

technologies (Böhmer et al., 2024). This proposal is based on the observation that, for example, neither SCT nor CLT alone adequately explains the nuanced and multidimensional adoption processes observed in previous design cycles. Drawing on theoretical constructs, practical observations, and user feedback from the first two design cycles, this approach aims to conceptualize a **Cognitive Adoption Theory** tailored to the specific characteristics of this vulnerable user population. Rather than focusing on system acceptance alone, the proposed model seeks to explain how cognitive states, such as perceived self-efficacy, information processing limitations, and reflective monitoring, interact with digital health design features to facilitate or inhibit adoption and sustained use. In doing so, this proposal lays the conceptual groundwork for developing a theory that provides a generalizable yet population-specific understanding of digital health adoption processes, thereby enriching the theoretical landscape of information systems research in health contexts.

5.2.1 Theoretical Foundations & Lens

Certain segments of this section are drawn from Böhmer et al. (2024) and have been slightly revised to improve readability and clarity.

In IS research, theory utilization is vital for developing and evaluating new interventions and technologies, as per IS theory (Gregor, 2006; Leidner & Gregory, 2024). Thus, theories focused on cognitive aspects, often from the social sciences and psychology, have been used, extended, or integrated in various IS studies (Compeau & Higgins, 1995; Ifinedo, 2012; Lin et al., 2008; Melenhorst et al., 2001; Weimann et al., 2022), informing them or shaping research perspectives. In digital health in particular, technology acceptance (the willingness to consider a technology), adoption (the integration of that technology based on endorsement), or adaptation (the ongoing adjustment of that technology) plays a pivotal role concerning people with cognitive impairments (Mostaghel, 2016). When it comes to technology adoption in digital health, cognitive aspects are highly relevant, especially in light of the cognitive impairment that often accompanies aging (Gauthier et al., 2006), as addressed by theories such as CLT or SCT. The integration of these two is particularly relevant in the context of digital health, where the design and evaluation of interventions require a comprehensive understanding of both cognitive and social factors. Subsequently, this design cycle elaborates on these theories and "borrows" their conceptual views (Jiang et al., 2022; Truex et al., 2006) to describe the need for a theorizing rationale integrating them for digital health adoption and health behavior change (Böhmer et al., 2024).

First, *Cognitive Load Theory* comes from the social sciences and is an instructional theory that is grounded in the architecture of human cognitive structures, providing insights into how information is processed and emphasizing the limitations of working memory when dealing with novel information (Sweller, 1988). Hence, cognitive load refers to the amount of mental effort used in the working memory at a given time. CLT is based on a model of human cognitive architecture that distinguishes between two types of memory: working memory and long-term memory. While working memory has a limited capacity, particularly when dealing with novel information, long-term memory's capacity is believed to be virtually limitless. Hereby, the interplay between these two types of memory is central to CLT (Baddeley, 1992). At its conceptual core, three main types of cognitive load have been identified: 1) *intrinsic cognitive load* which is inherent to the material being learned and depends on both the complexity of the information and the expertise of the learner (Paas et al., 2003); 2) *extraneous cognitive load* which is not essential for learning and is imposed by how information is presented to learners (Sweller et al., 1998); and 3) *germane cognitive load* which contributes to the construction of schemas to be effectively maximized through instructional designs (Sweller et al., 2011). The role of these schemas is central for CLT, as they are organized packets of knowledge that can be stored and retrieved as single units, allowing for efficient processing in working memory (Chi et al., 1982). With repeated exposure and understanding, these schemas can be automated, thus requiring less cognitive effort for recall and application (Ericsson et al., 1993). Recognizing the constraints of working memory and the importance of schema formation, CLT provides guidelines for instructional design, aiming at the optimization of learning by managing cognitive load and promoting the formation of schemas (Sweller et al., 1998).

Second, *Social Cognitive Theory* is rooted in the understanding of human behavior as an interplay between individual, behavioral, and environmental factors. Initially stemming from the Social Learning Theory (Bandura, 1977), SCT emphasizes the idea that learning occurs in a social context and is influenced by observing others (observational learning or modeling). Hereby, individuals can learn new behaviors and acquire new information merely by observing others (Bandura, 2001), challenging behaviorist notions that learning solely occurs via direct experiences (Bandura, 1986). From a more conceptual perspective, the four key processes for observational learning are 1) *attention* (observers must pay attention to their environment); 2) *retention* (observers must remember features of the behavior); 3) *reproduction* (observers must have the ability to reproduce the behavior); and 4) *motivation* (observers must expect to receive positive outcomes from the behavior). SCT is characterized by the concept of triadic reciprocal determinism, in which personal factors, environmental influences, and behaviors mutually interact (Bandura, 1986). It posits that behavior is shaped by, and in turn shapes, the environment and the individual. A key aspect of SCT, self-efficacy, is the belief in one's ability to achieve certain outcomes, which is influenced by past experiences, vicarious learning, encouragement, and physiological states, with high self-efficacy increasing motivation and the likelihood of completing challenging tasks (Bandura, 1997). Here, contextual self-efficacy describes the phenomenon that users' task self-efficacy is influenced by internal or external contextual factors - one might have high task self-efficacy for cycling, but low self-efficacy for doing so in the rain (Rieder et al., 2020). SCT has been further utilized and expanded to research health promotion from its initial concept (Bandura, 2013). Furthermore, the key constructs of SCT were used in the well-known UTAUT model, partly describing the social influence construct (Venkatesh et al., 2003).

In the evolving landscape of IS research, particularly in digital health, theories and theorizing provide foundational pillars upon which interventions and technologies are designed and evaluated (Burton-Jones et al., 2021; Gregor, 2006; Leidner & Gregory, 2024; Young et al., 2021). Recent next-generation theorizing in IS research underscores a transition in IS theorizing from static, desk-bound perspectives to dynamic, engaged approaches that emphasize historical context, diverse lenses, field involvement, and the real-world impacts of theories (Burton-Jones et al., 2021) – such as encompassed during the first two design cycles of this dissertation. These shifts highlight the evolving nature of IS theory in terms of complexity and fluidity, both reflecting and influencing the reality it seeks to understand while borrowing kernel concepts from other fields (Jiang et al., 2022; Truex et al., 2006). While both CLT and SCT have informed numerous studies in the social sciences and IS (Carillo, 2010; Sweller, 2023; Weimann et al., 2022), integrating and synthesizing them may offer a more comprehensive understanding of the behavioral and cognitive dimensions involved in technology adoption and health behavior change, particularly in digital health for patients with cognitive impairments. Moreover, these theories have their roots in the 1970s and 80s, when digital health applications as we know them today were a mere fantasy, and cognitive factors were difficult to facilitate. An integrative view of these theories offers a promising avenue, suggesting a more holistic approach to the design and evaluation of digital health solutions – one that simultaneously optimizes cognitive demands while harnessing the power of social learning mechanisms. Recent research advocates for incorporating and integrating kernel theories for theory extension (Sweller, 2023) or demonstrates their integration with other theories (Caprara et al., 2013; Lin et al., 2008). As such, the third design cycle recognizes a crucial gap in the existing body of technology acceptance models, as traditional models often fail to simultaneously consider the cognitive processes and the social context influencing technology use, particularly among those with cognitive impairments.

As shown in Böhmer et al. (2024), it is crucial to delimit the term 'adoption' from 'acceptance' as initially proposed by TAM (Davis, 1989) or UTAUT (Venkatesh et al., 2003). In the realm of integrating technology into daily life and professional settings, the concept of 'acceptance' has long dominated discourse and analysis (Blut et al., 2022). Traditionally, acceptance indicates a passive receipt of what is being offered, akin to someone utilizing a health app even though they have no intrinsic motivation to do so. However, as recent trends advocate for the seamless assimilation of technological tools and digital health systems, it becomes crucial to shift our vocabulary and mindset to that of 'adoption'. Adoption, as opposed to mere acceptance, is inherently voluntary and involves a conscious decision to

endorse, integrate, and incorporate technology (Karahanna et al., 1999). This nuance adds layers of complexity, suggesting a proactive engagement with the technology rather than a mere acquiescence. Therefore, emphasizing adoption over acceptance offers a richer and more comprehensive understanding of how individuals come to truly embrace technological innovations from a cognitive adoption perspective (Böhmer et al., 2024). While UTAUT provides a broad and excellent framework for explaining and predicting technology acceptance, usage intention, and behavior, the theorizing rationale for this third design cycle leans towards a deeper, more nuanced understanding and explanation (Gregor, 2006, Leidner & Gregory, 2024) of the cognitive and social aspects that influence technology adoption, use, and learning, especially among people with cognitive impairments.

Thus, the suggestion for an integrated *cognitive adoption* perspective adds an SCT focus on self-efficacy, reciprocal determinism, and observational learning, which are critical constructs for individuals with cognitive impairments. CLT, in addition, addresses the specific issue of cognitive overload and how it can be managed to improve technology adoption among people with cognitive impairments. As such, through the integration of SCT and CLT, this cycle can dive deeper into the cognitive and social intricacies that underpin digital health behaviors, offering a more holistic, granular, and user-centric lens for digital health research among individuals with cognitive impairments, where SCT's emphasis on building self-efficacy through modeling and reducing cognitive demands with CLT directly addresses the unique challenges these individuals face. By strategically selecting CLT in conjunction with SCT for their complementary strengths in examining both the cognitive demands and social influences on technology adoption, the synthesized framework may emphasize the significance of designing digital health interventions that are both cognitively accessible and socially supportive – likely enhancing adoption, health behavior change, and sustained use.

5.2.2 Research Design

To address RQ5 and realize the aforementioned suggestion, a *theorize-from-the-literature* approach (Leidner & Tona, 2021) coupled with qualitative theory-building (Gioia et al., 2013; Magnani & Gioia, 2023) was employed in Böhmer et al. (2024). In general, theorizing has a long tradition in IS research (Gregor, 2006; Leidner & Gregory, 2024), and current discussions call for rethinking, integrating, and developing new theories (Burton-Jones et al., 2021; Young et al., 2021). To address the focus of this research question on integrating and extending existing theories, this DSR echelon instance used an integrative theorizing approach to move from a single to a multi-level theory perspective (Klein & Kozlowski, 2000), combining elements of multiple theories to create a more comprehensive or coherent theoretical framework and model. Because this approach uses and borrows (Jiang et al., 2022; Truex et al., 2006) two kernel theories and literature as points of data origin, this echelon instance employs a top-down inductive theorizing approach, which is recognized for its effectiveness in generating new or synthesizing existing theories in situations characterized by tensions and discrepancies between different viewpoints and explanations of identical phenomena (Shepherd & Sutcliffe, 2011).

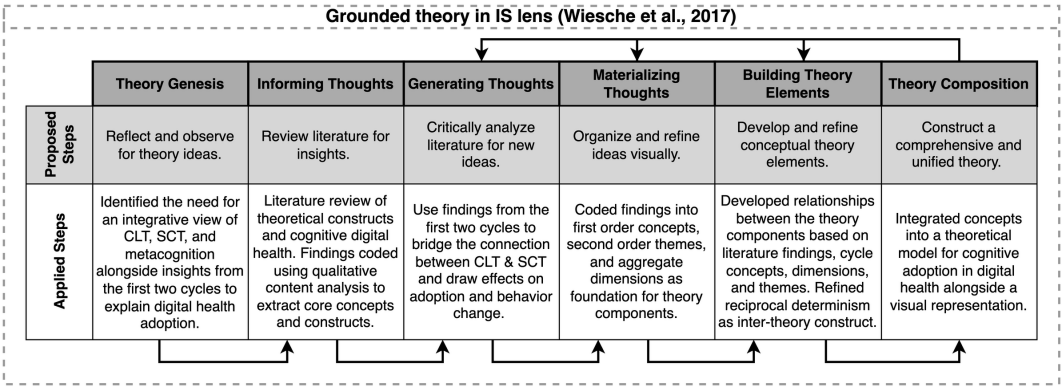


Figure 34. Theorizing-from-the-literature approach (Leidner & Tona, 2021) under the guise of grounded theory in IS for the third design cycle (Böhmer et al., 2024).
Note: CLT = Cognitive Load Theory; SCT = Social Cognitive Theory

As shown in Böhmer et al. (2024), cognitive adoption aspects have been examined across various disciplines and theoretical frameworks, reflecting diverse temporal periods and ontological practices. Using inductive top-down theorizing, this design cycle analyzes literature, especially the kernel theories of CLT, SCT, and metacognition on the phenomenon of digital health adoption among people with cognitive impairments to identify perceived theory discrepancies or synergies, from which abstract constructs and their interrelationships are derived. From a more methodological and phenomenological perspective, the *Reformulate*-strategy proposed by Burton-Jones et al. (2021) was chosen since, in general, we are witnessing a changing world (i.e., demographic change and the need for innovative digital health solutions for patients with cognitive impairments), where existing phenomena in the form of theories (i.e., CLT, SCT, metacognition) need to adapt to these circumstances and where we cannot assume that these theories will work as well as they did before – especially when they are considered individually. By modifying, synthesizing, or extending theories, this approach allows this DSR echelon instance to provide novel and potentially better insights into the field of cognitive adoption in digital health. Therefore, the research design follows the methodological framework of Leidner and Tona (2021) to theorize from the literature, as depicted in Figure 34. This iterative model encompasses initial theorizing with clear and well-defined elements, theory composition with a focus on transitioning from literature-based to theory-based insights, and the incorporation of graphical illustrations to visually represent the developmental process (Böhmer et al., 2024). Further integrating grounded theory (Corbin & Strauss, 1990) by utilizing and injecting the insights gathered from the first two cycles into the theorizing from literature methodology enriches the process of theory development by systematically grounding new theories in literature findings, practical foundations, and evaluated constructs. Grounded theory in IS, as outlined by Wiesche et al. (2017), provides a structured approach to data analysis, including open, axial, and selective coding, which aligns well with the stages of informing, generating, and materializing thoughts in the theorizing from literature model by Leidner and Tona (2021).

5.3 Development

Consequently, for the first phase of literature-based theorizing, this DSR echelon instance followed a coding procedure of the relevant literature phenomena, subject to qualitative theory building (Gioia et al., 2013; Magnani & Gioia, 2023). Here, the grounded theory approach (Wiesche et al., 2017) of developing categories (i.e., the coded dimensions) and identifying relationships between them can help to organize and structure the new theory. This allowed the theorizing approach to extract the core constructs of the selected theories and their application to digital health research (Böhmer et al., 2024). The consulted literature was systematically selected from publications addressing the cognitive and adoption concepts in the AIS Senior Scholars' List of Premier Journals, top-tier IS conference proceedings (e.g., ICIS, ECIS), and selected digital health and social sciences databases (PubMed, JSTOR, EBSCO) using Scopus's advanced search. A multidisciplinary review methodology was adopted, covering different perspectives to holistically understand "cognitive adoption" in digital health. Articles were selected that developed or used this concept, analyzing different perspectives on cognitive processes. Next, it was examined how these works defined and approached cognitive adoption, identifying key viewpoints, foundational assumptions, and areas of debate, which were synthesized in the informing thoughts step of the Leidner and Tona (2021) approach, shown in Böhmer et al. (2024).

The initial theory genesis encompassed personal reflection on cognitive aspects from the prior design cycles, which shaped the fundamental idea of an integrative perspective between CLT and SCT to provide a more holistic and adequate theoretical framework for understanding the complexities of digital health adoption among people with cognitive impairments (Böhmer et al., 2024).

Within this phase, the psychological construct of *metacognition* has been identified, acting as an overarching meta-view on cognition (i.e., the thinking about thinking or cognition about cognition) as initially defined by Flavell (1979). In other words, metacognition serves as a reflective and adaptive layer atop the constructs of SCT and CLT. An integrative view posits that effective learners are not only socially influenced and cognitively attuned but also consistently reflective and strategic in their approach, making metacognition an indirect yet central pillar in this combined theoretical perspective as outlined by Flavell (1979).

Aggregate Dimensions	2nd Order Themes (1st Order concepts)	Literature
Cognitive Load *(AD1)*	• **Intrinsic cognitive load** [task complexity; prior knowledge; mental effort; cognitive schema] • **Extraneous cognitive load** [instructional design; cognitive interference; redundancy; information overload; navigation complexity] • **Germane cognitive load** [reflective processing; schema building; mental rehearsal; metacognitive awareness] • **Cognitive load management** [chunking; scaffolding; progressive disclosure]	Antonio et al. (2023); Baddeley (1992); Chi et al. (1982); Flavell (1979); Melenhorst et al. (2001); Paas et al. (2003); Paas and Van Merriënboer (1994); Sweller (1988); Sweller et al. (1998); Sweller et al. (2011); Treiblmaier et al. (2018); Weimann et al. (2022)
Social Cognitive Factors *(AD2)*	• **Observational learning** [modeling; vicarious reinforcement; attentional processes; retention and memory] • **(Contextual) Self-efficacy** [perceived competence; outcome expectations; mastery experiences; social persuasion; emotional states] • **Reciprocal determinism** [behavior; personal factors; environmental factors; interaction and feedback loops, self-regulation]	Bandura (1977); Bandura (1986); Bandura (1997); Bandura (2001); Carillo (2010); Compeau and Higgins (1995); Compeau et al. (1999); Fallon et al. (2019); Flavell (1979); Ifinedo (2012); Kankanhalli et al. (2005); Pak and Song (2016); Rieder et al. (2020); Weimann et al. (2022)
Digital Health Adoption *(AD3)*	• **Usability** [user interface design; task efficiency; error tolerance] • **Accessibility** [universal design, interaction, user-centeredness; accessibility features; user support] • **Learning curves** [ease of onboarding; learning resources; skill development; adaptability] • **Behavioral Compensation** [psychological effects; collateral behavioral consequences; intervention efficacy]	Flavell (1979); Jozan et al. (2023); Kenei and Opiyo, 2022); Kim and Han (2021); Kyratsis et al., (2022); Melenhorst et al. (2001); Pak and Song (2016); Rieder et al. (2020); Venkatesh et al. (2003); Wolf et al. (2023)
Health Behavior Change *(AD4)*	• **Adaptive behavior modification** [personalized goal setting; progressive goal adjustment; self-monitoring; behavioral flexibility] • **Treatment adherence** [medication and treatment plan compliance; digital health tool adherence; barrier identification] • **Lifestyle modification** [dietary adjustments; physical activity integration; stress management] • **Coping mechanisms and resilience** [emotional coping strategies; social engagement; resourcing]	Fallon et al. (2019); Flavell (1979); Jozan et al. (2023); Kenei and Opiyo, 2022); Kim and Han (2021); Melenhorst et al. (2001); Pak and Song (2016), Rieder et al. (2020); Singh and Varshney (2020); Wolf et al. (2023)

Table 18. Literature coding following the qualitative content analysis by Gioia et al. (2013) (Böhmer et al., 2024).
Note: 1st order concepts are shown in square brackets.

As shown in Böhmer et al. (2024) and Table 18, first-order concepts, second-order themes, and ADs[7] were developed to embody the foundation of the integrative theory. For example, the first-order concept of task complexity is grouped under the second-order theme of intrinsic cognitive load, which in turn is part of the aggregate dimension of cognitive load. As such, the four aggregate dimensions of *cognitive load*, *social cognitive factors*, *digital health adoption*, and *health behavior change* were developed. The iterative approach of grounded theory, moving back and forth between data (i.e., literature) and analysis, is critical in this phase of theorizing. The qualitative theory-building findings can thus be viewed as the result of the first theory-building phase (Leidner & Tona, 2021), with the aggregate dimensions as its key components, further informed by the literature at a deeper and more granular level.

[7] Again, these ADs are echelon specific and do not relate directly to the ADs presented in the previous design cycles/echelons.

Besides the theoretical foundations, and as part of the *Generating Thoughts* step (Leidner & Tona, 2021), Table 19 links the qualitative findings from the first two cycles and summarizes how they informed the constructs of the *Cognitive Adoption Theory*.

Cognitive Adoption Theory Construct	**Cycle 1 Findings** (Augmented Living Spaces: Design Theory, Reference Architecture, Evaluation)	**Cycle 2 Findings** (ConZones Interaction Design, Evaluation, Design Theory Synthetic Data)
Cognitive Load	DPs for personalized, low-threshold communication (DP1, DP2) & SAR use (DP8) demonstrated tangible pathways to reduce extraneous cognitive load by aligning interfaces with user impairments and minimizing interaction friction. Reference architecture design emphasizing modularity & passive data collection minimized cognitive overhead. Evaluation confirmed SAR and augmented assistance reduced cognitive load for aMCI users. DR2 & DR5 emphasizing effort minimization and adaptive learning highlighted the need to manage intrinsic load.	The ConZones HCI approach, with its indirect, location-based interaction and three-zone structure, empirically validated methods for minimizing extraneous cognitive load and techno-complexity. Hands-free, non-wearable interaction in the ConZones interaction design provided evidence for significant cognitive relief as reported by users. Synthetic Data design theory principles ensuring AI accuracy and reliability (DR3, DPs like DP6, DP7, DP9, DP10) indirectly support cognitive load aspects/mechanisms by reducing cognitive load from unpredictable system behavior.
Social Cognitive Factors	DPs addressing socio-emotional aspects like privacy (DP6) & non-patronizing service orientation (DP7) illuminated the role of trust and self-efficacy in user empowerment. Cooperative, non-intrusive cognitive support perceived by users supported the need to foster self-efficacy, reciprocal determinism, and positive social cognitive responses. Evaluation highlighted observational learning as key factor driving adoption.	By providing non-invasive, responsive feedback and avoiding technostress triggers, the approach demonstrated how to foster (contextual) self-efficacy, reciprocal determinism, and trust. Evaluation showing user comfort and confidence, providing feedback for enhanced self-efficacy through supportive interaction design. Synthetic data principles for ethical safeguards, privacy, and fairness (DR1, DP1, DP2, DP8) create conditions for trust calibration and ethical resonance, fostering positive social cognitive aspects.
Digital Health Adoption	DRs for user satisfaction via cognitive empowerment (DR1) & general, intuitive accessibility (DR4) established foundational conditions for initial technology adoption. Reference Architecture design enabling system responsiveness and personalization highlighted architectural enablers for perceived supportiveness, crucial for adoption. Evaluation showing users found the system intuitive and comfortable confirmed adoption-related assumptions stemming from user-centered, low-barrier design.	ConZones providing an intuitive, hands-free, accessible experience demonstrated a pathway to enhanced adoption by aligning with natural behaviors and minimizing digital literacy demands. Strong PE and EE scores for the interaction design supported the link between perceived usefulness, ease of use, and adoption intention. Synthetic data design theory ensuring system reliability and fairness (DR2, DR3, DR4 & DPs) contributes to adoption by enhancing perceived usability and system value, reducing potential adoption barriers.
Health Behavior Change	DPs for adaptive, evolving functionality (DP3) & AI-driven cognitive assistance (DP12) laid groundwork for systems facilitating internalization of strategies necessary for sustained health behavior change. DR3 (dynamic scaffolding) & DR5 (adaptive learning) pointed to mechanisms supporting gradual autonomy and internalization of health-supportive behaviors.	ConZones reinforcing context-sensitive behaviors through repeated, embodied interaction (e.g., reminders, alarms) provided a model for nudging users towards sustained health beahvior change. The system's unobtrusive integration into daily life, as per ConZones, suggests pathways for making health behavior modifications feel less like an explicit effort and more like a natural part of routines, supporting long-term health behavior changes.

Table 19. Mapping of design cycle insights to cognitive adoption theory constructs.

5.3.1 Cognitive Adoption Theory Constructs

This section incorporates insights from Böhmer et al. (2024) with attribution; revisions were applied to ensure a coherent dissertation narrative.

The *Cognitive Adoption Theory* model shown in Figure 35 is a comprehensive framework that integrates key constructs from CLT, SCT, metacognition, and conceptual aspects/mechanisms from the first two cycles to elucidate the complex process of adopting digital health technologies and facilitating health behavior change among people with cognitive impairments. Their distinctive and most prevalent aspects of cognitive impairment, such as reduced information processing speed, memory loss, changes in social cognition, or impaired reasoning (Gazzaniga et al., 2018), are also depicted in Figure 35 to demonstrate how these impairments frame the adoption and effective use of digital health technologies. Classified as *explanatory* IS theory (Gregor, 2006), the theorized model can further be described as a mid-range theory as it refines knowledge in the specific field of digital health to provide measurable relationships between constructs (Leidner & Tona, 2021). It has been meticulously developed from the structured literature theorizing approach, utilizing a qualitative content analysis, which resulted in four aggregate dimensions that integrated the initial cognitive theories and form the core component (AD3) and constructional foundation (AD1, 2, 4) of the theory proposal. Moreover, following the grounded theory paradigm (Wiesche et al., 2017), the findings from the first two design cycles (particularly DRs, DPs, qualitative analysis categories and themes, and evaluation data) further informed the development of the constructs, aspects, and mechanisms (Böhmer et al., 2024).

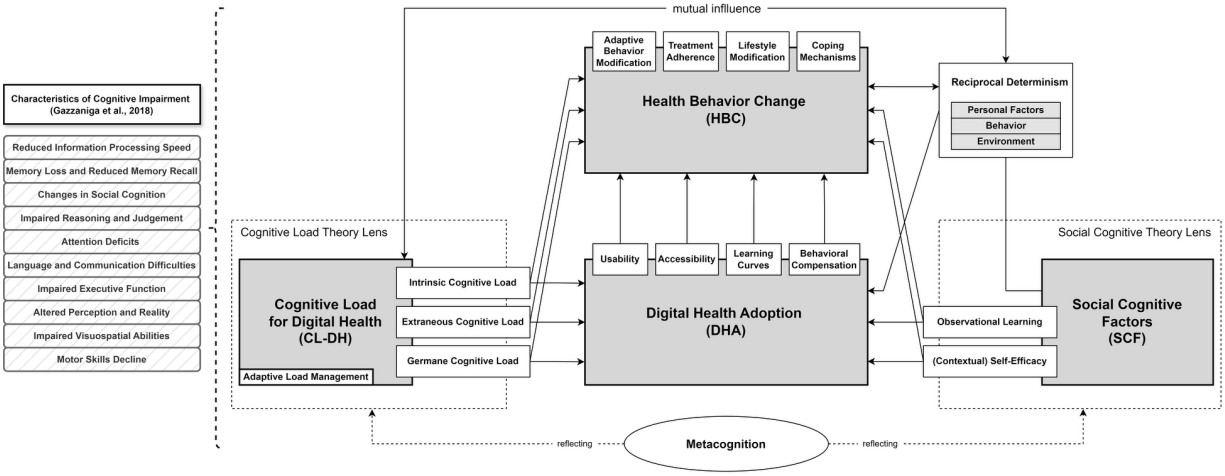


Figure 35. Proposal of a Cognitive Adoption Theory (Böhmer et al., 2024).

As shown in Böhmer et al. (2024), the first construct, **Cognitive Load for Digital Health** (CL-DH), is influenced by the principles of CLT, which stems from AD1. Therefore, it consists of three sub-dimensions that encompass cognitive load regarding digital health adoption: intrinsic cognitive load (associated with task complexity and prior knowledge), extraneous cognitive load (linked to digital interface presentation and information overload), and germane cognitive load (involving reflective processing and learning effort). Additionally, adaptive load management strategies such as chunking and scaffolding are integrated to help individuals optimize their cognitive resources while interacting with digital health tools (Antonio et al., 2023; Sweller et al., 2011; Weimann et al., 2022).

As shown in Table 19, the need to manage and reduce extraneous and intrinsic load was strongly reflected in the first cycle's DRs, particularly DR2[8] (effort minimization) and DR5 (adaptive learning), as well as in observational findings highlighting task-related overload and reduced motor and memory performance. The second cycle's ConZones approach directly targeted cognitive overload through SAR-based, low-threshold visualizations tailored to the user's location and attention, providing clear

[8] Unless otherwise stated, the DRs and DPs referenced here mainly relate to the design theory of the first design cycle.

situational cues without overburdening perception or memory. These findings deeply informed the inclusion of cognitive load dimensions in the model, highlighting the need for cognitively attuned digital health systems that accommodate limited processing capacity and scaffold mental engagement through intuitive interaction. Thus, the DPs for controlling scene complexity, ensuring perceptual clarity, and aligning synthetic realism with cognitive processing capacity (e.g., DR2, DR4, DP5, and DP6) in the synthetic image data design theory of the second cycle did not define cognitive load. However, they shaped the interactive conditions under which intrinsic and extraneous cognitive load could be reduced and observed empirically.

As shown in Böhmer et al. (2024), the second construct, **Social Cognitive Factors** (SCF), draws from SCT (AD2) and encompasses elements such as observational learning, (contextual) self-efficacy, and reciprocal determinism, representing manifestations of the individual's social learning capabilities and belief in their own effectiveness. It highlights the importance of modeling, self-perceived competence, and the dynamic interplay between individual, personal, and environmental factors in shaping technology adoption behaviors (Bandura, 2001; Compeau et al., 1999; Ifinedo, 2012; Pak & Song, 2016). In the context of *reciprocal determinism* and through the "building theory elements" step (Leidner and Tona, 2021), it was found that cognitive load is dynamically interwoven with behavioral, personal, and environmental factors, exhibiting a mutual influence among these elements. This relationship suggests that changes in cognitive load can both influence and be influenced by an individual's behavior, internal personal traits, and external environmental conditions. As defined in SCT, reciprocal determinism posits a bidirectional influence among behavior, personal factors, and environmental conditions (Bandura, 1977). This concept is consistent with the notion that cognitive load is dynamically intertwined with these elements, where it not only results from but also contributes to changes in behavior, personal characteristics, and environmental interactions (Sweller, 1988; Paas & Van Merriënboer, 1994). Thus, the theoretical model depicts it as being detached from a sole association with the SCF (Böhmer et al., 2024).

As shown in Table 19, insights from the first design cycle, particularly the focus group findings related to cognitive decline (K3) and challenges with cognitively impaired individuals (K2) and the need for sensitivity in communication (T5), underscore the importance of social support and non-intrusive reinforcement in everyday cognitive tasks. In the evaluation episodes, users responded best to subtle, supportive prompts rather than intrusive or overly directive interventions, confirming the theoretical necessity to integrate mechanisms of observational learning and contextual self-efficacy into SCF, which is consistent with its focus on self-efficacy and modeling. Positive user experiences with the SAR-based Augmented Living Spaces approach in the first cycle demonstrated increased comfort and acceptance due to low entry barriers (DP1), adaptive low-threshold (DP5), and non-patronizing assistance (DP7). These experiences further informed this construct by highlighting how user-centered design can promote self-efficacy and mitigate resistance. The second cycle's ConZones design operationalized these ideas by creating digitally responsive environments that foster trust and reduce intrusive feedback, thereby enhancing contextual self-efficacy and social learning. Furthermore, the design theory for synthetic image data from the second cycle, which emphasizes fairness, ethical transparency, and socially inclusive synthetic data (e.g., DR2, DP4, DP8), enabled interaction patterns that elicited users' self-efficacy and trust. This allowed the research to identify and theorize the socially embedded mechanisms, such as modeling and reciprocal feedback, that are now formalized in the SCF construct. Here, the DRs/DPs created the ethical-social "setting" that made self-efficacy and observational learning observable and relevant. These findings helped shape the SCF as a central construct, emphasizing that adoption is cognitively, socially, and emotionally embedded.

As shown in Böhmer et al. (2024), the third construct, **Digital Health Adoption** (DHA), is the core component of the theory, delving into the factors that determine the adoption of digital health technologies among people with cognitive impairments (AD3). Usability, accessibility, and learning curves are key sub-dimensions considered within this construct. Therefore, the sub-dimensions embody different factors that together form the concept of how individuals with cognitive impairments adopt digital health. Unlike reflective indicators, these do not necessarily have to correlate (Kyratsis et al., 2022), e.g., an application could be very accessible but not particularly usable, and still be adopted.

Usability encompasses elements like user interface design and task efficiency, while accessibility involves universal design principles and user-centeredness. Learning curves encompass the ease of onboarding, availability of learning resources, and the adaptability of digital health tools (Jozan et al., 2023; Venkatesh et al., 2003). Drawn from current literature, behavioral compensation plays a pivotal role in digital health adoption, potentially hindering or facilitating the process depending on how well the technology aligns with the users' cognitive and physical abilities, their environment, and the use of other digital health technologies (Wolf et al., 2023).

As shown in Table 19, the qualitative findings from the first design cycle clearly illustrated (T1: daily routine; T3: daily life activities) that for digital health adoption to be successful among cognitively impaired individuals, solutions must be seamlessly embedded into existing everyday routines, providing contextually relevant support without demanding deliberate cognitive effort. The development of the Augmented Living Space system in the first design cycle directly addressed usability (DR1) and general accessibility (DR4) by developing a non-wearable, intuitive system, explicitly aiming to reduce frustration and technology adoption burden for aMCI individuals (T2; T4). The emphasis on adapting to cognitive development over time (K3) and ensuring low physical effort (DR4; DP5) underscored the significance of learning curves and demonstrated that a gradual reduction in support can foster adoption and independence. These insights, particularly the preference for SAR-based approaches over wearables due to enhanced usability, changed how accessibility and usability for people with aMCI are approached to simplify interaction and actively encourage cognitive engagement through adaptive support mechanisms (DR1-DR5). Specifically, implementing modular (DP3), universally accessible (DP4), and intuitive, SAR-based (DP8) designs demonstrated that improving usability and accessibility is not just about simplifying interfaces; it's also about aligning technological interactions with familiar environmental cues and habitual tasks.

The second cycle's ConZones approach built on this by introducing real-time, context-aware feedback that minimized cognitive barriers and technostress while maximizing intuitiveness and personalization. Built on the design knowledge for synthetic image data use in the second cycle, the DRs and DPs for usability, accessibility, and adaptive realism (i.e., second cycle's design theory: DR3, DR4; DP3, DP9) did not determine adoption outcomes. However, they enabled the creation of an interaction design that was adoptable, and thus revealed how accessibility, learning curves, and interaction intuitiveness function in the lived experience of cognitive technology use. These practical applications provided concrete examples of how digital health tools can be usable and accessible without requiring explicit interaction. Ultimately, they informed the structuring of DHA as a central, distinct construct in the theory.

As shown in Böhmer et al. (2024), the fourth construct, **Health Behavior Change** (HBC), incorporates elements essential for fostering positive health-related transformations (AD4), assuming that changes in health behavior are reflective of underlying personal motivations, beliefs, and attitudes. The use of digital health technology is a means to an end, not an end in itself, as the ultimate goal is to achieve sustainable health outcomes, which is only possible if technology adoption leads to positive behavior change. Here, the various factors like usability, accessibility, learning curves, and behavioral compensation reflect changes in this latent health behavior change construct. This construct encompasses sub-dimensions such as adaptive behavior modification, treatment adherence, lifestyle modification, and coping mechanisms. These sub-dimensions are based on features that support stimulus/forethought, self-regulation, incentivizing, and social interaction to facilitate behavior change (Fallon et al., 2019) and assess their effectiveness (Singh and Varshney, 2020). These are critical in shaping how individuals set and adjust personalized health goals, adhere to treatment plans, modify their lifestyles, and employ coping mechanisms to achieve better health outcomes (Kenei & Opiyo, 2022; Kim & Han, 2021; Wolf et al., 2023). Recent research already shows phenomena like *technology-behavioral compensation effects*, where users tend to reduce preventive health behaviors after adopting a specific health application that they find useful (Wolf et al., 2023) or experience context-dependent adoption or behavior change factors (Rieder et al, 2020).

As shown in Table 19, the first design cycle highlighted how routines and cognitive anchors in people's daily lives (T1) act as stabilizing forces, underscoring the need for behavioral system interventions that

support autonomy without disrupting cognitive or social habits, such as providing timely nudges for daily activities (T3). The emphasis on scaffolding to promote autonomy and enabling adaptive learning (DR5) directly informed the behavioral change mechanisms, as the goal was to facilitate gradual internalization of cognitive strategies rather than passive task completion. Specifically, the successful instantiation of adaptive semiotic mediation (DP13) and interactive scaffolding features (DP1; DP9) illustrated how structured, context-aware prompts can progressively internalize new cognitive schemas and behavioral patterns without disrupting established routines. Moreover, the second cycle's ConZones interaction design implemented this concept by providing real-time, adaptive prompts that encourage healthy behaviors while minimizing cognitive load and preserving user autonomy. These cumulative findings from the first two cycles demonstrated how subtle, well-designed interventions rooted in users' context and capabilities can support long-term behavior change, directly informing the structuring of HBC as a theoretical construct that bridges cognitive adoption with sustainable digital health outcomes.

As such, the model addresses how digital health technologies can trigger unintended behavioral adjustments that negate intended benefits, emphasizing the need for designs that manage cognitive load, integrate social learning for reinforcement, promote metacognitive awareness, and prioritize usability to encourage sustained, positive health behavior change. Learners' self-awareness (**Metacognition**) and confidence (self-efficacy) influence their approach to tasks and technology use (Böhmer et al., 2024). Strong metacognition allows them to adapt strategies based on difficulty (cognitive load), and feedback helps calibrate these strategies for optimal learning (Flavell, 1979). In digital health design, understanding these factors provides a comprehensive perspective for user-centered tools. This includes intuitive interfaces, alignment with health goals, and consideration of user beliefs to promote adoption and integration into health routines for individuals with reduced cognitive function.

The findings from the first design cycle, particularly the observations regarding memory aids and reliance on external structures in daily routines (T1), revealed the immediate need for designs that seamlessly integrate into existing habits. This implicitly shows users' attempts to externalize cognitive regulation. The identified challenges with object location (T2) and cognitive perception (T4), as well as limited motor skills (T4), directly informed the critical importance of low-threshold interaction (DP5) and semiotic mediation (DP13) to reduce cognitive effort and facilitate smoother interaction with digital health tools. These tools effectively act as external metacognitive supports that help users monitor and adjust their engagement with the environment.

5.3.2 Cognitive Adoption Theory Mechanisms and Relationships

Since midrange theories are embodied in measurable relationships, *Cognitive Adoption Theory* postulates various relationships and mechanisms that can potentially be tested, validated, or challenged, all based on the theoretical and practical groundwork established by previous publications and discovered through the qualitative content analysis (or rather, the qualitative theory-building) (Böhmer et al., 2024). The proposed IS theory is conceptual and explanatory, and thus, unlike predictive theories, doesn't require testable relationships (Gregor, 2006). The construct relationships are based on literature and insights from the prior two design cycles, some empirically validated, focusing on concept development rather than hypothesis testing. The relationships described are therefore directional, not necessarily quantifiable or complete, and are drawn mainly from Böhmer et al. (2024) with minor edits.

From a cognitive load perspective, intrinsic cognitive load, the inherent difficulty associated with a particular instructional topic, can facilitate the adoption of digital health tools if kept manageable (Paas et al., 2003; Treiblmaier et al., 2018; Weimann et al., 2022). However, when this load becomes excessive, it can inhibit health behavior change by overwhelming users, especially those with cognitive impairments (Paas & Van Merriënboer, 1994). On the other hand, extraneous cognitive load, often resulting from confusing digital interfaces, can deter users from both adopting digital health tools and changing their health behaviors (Melenhorst et al., 2001). Yet, the germane cognitive load, which embodies the effort one invests in learning, can positively enhance both digital health adoption and health behavior change, by fostering a profound understanding of health behaviors (Antonio et al., 2023; Paas & Van Merriënboer, 1994; Sweller et al., 2011).

As shown in Table 19, the first design cycle's deliberate focus on non-wearable SAR and low-threshold interactions (DP5) was empirically driven to reduce extraneous cognitive load, as consistently confirmed by user feedback on 'cognitive relief' during think-aloud sessions (Table 8). This design choice was predicated on the assumption that minimizing processing burden would enhance technology acceptance. Furthermore, the explicit emphasis on adaptive learning and scaffolding (DR5) and intuitive interaction (DP1) within the Augmented Living Spaces design theory aimed to manage intrinsic load by dynamically adjusting interventions based on the user's evolving cognitive state, thereby fostering germane load that facilitates learning and autonomy. These insights were directly informed by observational findings highlighting task-related overload and observed reductions in motor and memory performance (T2, T4), underscoring the critical need for systems that actively manage cognitive demands rather than merely presenting information. As such, these findings suggest a nonlinear relationship: while a certain level of cognitive challenge (germane load) is necessary for growth and internalization, both excessive intrinsic and extraneous load can create friction points that undermine the adoption process. Thus, the theory assumes that the optimal cognitive zone for adoption lies between over-simplification (leading to disengagement) and cognitive overload (leading to avoidance).

Incorporating social cognitive factors, observational learning can be leveraged as a significant asset that positively impacts both digital health adoption and health behavior change (Böhmer et al., 2024). Seeing others successfully use digital health tools can inspire and guide individuals with cognitive impairments (Bandura, 2001; Kim & Han, 2021). Being a core construct within the social cognitive lens, high self-efficacy, or belief in one's ability to perform tasks, can increase confidence in adopting digital health tools and increase motivation to change health behaviors (Bandura, 1997; Compeau & Higgins, 1995, Compeau et al., 1999; Ifinedo, 2012; Pak & Song, 2016). Interestingly, contextual self-efficacy, which describes one's task self-efficacy regarding internal and external contexts, can negatively affect health compliance and, therefore, health behavior change (Rieder et al., 2020) by creating overconfidence in individuals' ability to navigate the complex environment of health interventions without the necessary resources or support. Since personal factors, environmental influences, and behaviors all interact and influence one another, the relationship of reciprocal determinism with cognitive load, digital health adoption, and health behavior constructs is complex and characterized by both reinforcing and counteracting dynamics (Bandura, 1986; Venkatesh et al., 2003).

As shown in Table 19, the first design cycle's qualitative insights, particularly from focus groups regarding interactional sensitivity (T5) and observations on how aMCI individuals respond to "patronizing or urging behavior" (Table 5, T5), directly informed the DP of service orientation (DP7). This underscored the crucial assumption that fostering user comfort and a collaborative interaction style, rather than a directive one, would enhance self-perceived competence and reduce psychological barriers to engagement. The positive evaluation of the Augmented Living Spaces' non-intrusive approach, as captured by "intuitive user interface and technology access without the need for extra devices" (Table 8, DP1), provided qualitative grounding for how design choices can positively shape self-efficacy. This also extends to how contextual self-efficacy is influenced by the 'comfort' subjects felt, as documented in the observational study (Table 5, T2) and evaluation episodes. The second design cycle's ConZones approach, with its intuitive, location-based interaction designed to avoid techno-stressors like 'techno-invasion' and 'techno-overload,' further operationalized these social cognitive principles. The aim was to create a socially and spatially responsive digital environment that fosters user trust and reduces intrusive feedback, thereby enhancing contextual self-efficacy and enabling more natural social learning within the living space, which resonated positively with the evaluation participants.

Thus, the theory assumes that socially mediated confidence and reflection (e.g., via supportive prompts and transparent system behavior) enhance engagement when self-efficacy is accurate, but may impair it when overconfidence leads to reduced behavioral regulation (Böhmer et al., 2024).

Digital health adoption impacts health behavior change through technology design and functionality. Enhanced usability and accessibility promote broader demographic adoption and intuitive use (Kim & Han, 2021; Melenhorst et al., 2001; Pak & Song, 2016; Venkatesh et al., 2003). Additionally, a manageable learning curve encourages sustained tool usage, aiding in long-term health behavior change.

Nonetheless, technology-behavioral compensation negatively affects health behavior change as users reduce other preventive health behaviors if they find one solution highly useful (Wolf et al., 2023).

The first design cycle's empirical evaluations on perceived usefulness, performance and effort expectancy in the context of the Augmented Living Spaces design theory and reference architecture directly confirmed these assumptions, indicating that artifacts designed with user satisfaction (DR1) and efficiency (DR2) in mind positively influence early adoption factors. The preference for SAR-based approaches over conventional wearables, as validated in comparative analyses (e.g., Böhmer et al., 2025d), provided strong evidence of the practical impact of accessible, low-threshold designs (DR4 and DP5) on perceived usability and adoption. The second cycle's ConZones approach, a direct instantiation of these principles, demonstrated how real-time, context-aware feedback could minimize cognitive barriers and techno-stress while maximizing intuitiveness and personalization. This approach reinforced the idea that highly usable and accessible interfaces are essential for long-term digital health adoption.

An emergent concern across both cycles was technology-behavioral compensation (Wolf et al., 2023): the assumption that the tool "takes care of it" led some users to reduce their own initiative, particularly in remembering tasks or identifying risks (T1; T3). This confirms the need for adaptive fading mechanisms that gradually reduce system dependence and promote metacognitive reflection.

Throughout both cycles, the interplay between personal cognition, environmental feedback, and observed behavior was evident, confirming the relevance of reciprocal determinism as an overarching mechanism. For instance, as users received more immediate, relevant feedback (environment), their confidence grew (personal factor), which in turn affected how they approached subsequent interactions (behavior). When environmental cues were misaligned (e.g., late prompts, poor visibility), the feedback loop broke down, leading to frustration or neglect. These patterns suggest that the mechanisms of adoption and behavior change are inherently dynamic and mediated by context-sensitive feedback loops. The theory, therefore, assumes that effective cognitive adoption is a process of calibration, requiring adaptive support that evolves alongside the user's mental model, emotional state, and learning trajectory.

Reflecting on these relationships and mechanisms, it becomes apparent that cognitive adoption (in the context of cognitive impairment) is not a one-time decision, but rather a dynamic, co-evolutionary process that unfolds between the system and the user. This process is shaped as much by subtle cognitive tensions as by design features. If we fail to design with this interplay in mind, we risk creating technologies that are merely used but never truly integrated into the lives they aim to support.

5.4 Evaluation

In the final design cycle of this dissertation, the primary goal was to develop a type-II midrange explanatory theory, as classified by Gregor (2006), which emphasizes understanding through the articulation of causal relationships and conceptual insights rather than empirical testing or artifact instantiation. As such, the focus of this cycle was conceptual and theoretical rather than practical or technological. Consistent with Gregor's (2006) view, explanatory theories - particularly those aimed at a deeper understanding of phenomena - can be considered valuable without requiring formal evaluation in the traditional DSR sense (e.g., testing of instantiated artifacts or utility measures as done in the previous cycles). This is also consistent with Leidner and Gregory (2024), who emphasize that theory papers serve different purposes – such as offering novel perspectives or integrating bodies of knowledge – and should be evaluated based on their conceptual clarity, internal consistency, and contribution to understanding, rather than on their empirical generalizability or problem-solving effectiveness. Given this epistemological and ontological orientation, a traditional DSR evaluation phase would be inappropriate and potentially misleading, since the goal is not to assess the utility or efficacy of an artifact, but to advance theoretical knowledge about a class of phenomena. Therefore, the absence of an evaluation phase in this final cycle is not a limitation, but a reflection of the scientific intent of the cycle and the nature of theory-driven inquiry. However, a categorical and conceptual classification of the developed theory artifact according to Gregor (2006) seemed reasonable.

As shown in Böhmer et al. (2024) and following Whetten's (1989) concept of theory as well as Gregor's (2006) *explanatory* type of IS theory (type II), the *Cognitive Adoption Theory* aims to explain the *what*,

how, and *why*. Through this type of theorizing, the model tries to explain the phenomenon of cognitive adoption regarding digital health applications and health behavior change of people with cognitive impairments and decreased cognitive performance (Böhmer et al., 2024). Such theories often lead to the development of process-type theories, which are essentially designed to improve the understanding of various phenomena (Gregor, 2006). They can be viewed as theories aimed at enhancing comprehension and providing insights into the world. In the specific case of this DSR echelon instance, the *Cognitive Adoption Theory* proposal analyzes the contributing load and social factors of cognitive processes to explain their effect on digital health adoption and health behavior change. These analyses provide valuable insights, especially when borrowing concepts from different fields (Jiang et al., 2022; Truex et al., 2006).

Theory Overview	
A new theoretical model was developed, the *Cognitive Adoption Theory*, which claims that both cognitive load and social cognitive factors simultaneously influence digital health adoption and health behavior change.	
Theory Component	**Instantiation**
Means of representation	Words (Chapter 5.3), diagram (Figure 35), tables (Tables 18, 19 and 20).
Primary constructs	Cognitive load theory and social cognitive theory as main lenses. Conceptual features of intrinsic, extraneous, and germane cognitive load as well as observational learning, self-efficacy, and reciprocal determinism including metacognition as an overarching construct. The theory's primary constructs encompass DHA, HBC, CL-DH, and SCF.
Statements of relationship	Derived from literature (Chapter 4.2), depicted as a model (Fig. 2). An example: "[…] intrinsic cognitive load, the inherent difficulty associated with a particular instructional topic, can facilitate adaptation to digital health tools if kept manageable […]. However, when this load becomes excessive, it can inhibit health behavior change by overwhelming users, especially those with cognitive impairments […]".
Scope	The statements of relationships include modal qualifiers to draw boundaries to the digital health domain and cognitive impairment. Still, a high level of generality ensures applicability in general healthcare environments.
Causal Explanations	The statements of relationship (Chapter 5.3.2) include causal explanations, for example: "Enhanced usability and accessibility can both significantly promote health behavior change, catering to a broader demographic and making the adoption process more intuitive […]".
Testable propositions	Not present. The theory is explanatory in nature, and the model should be applied conceptually, but provides a basis for deductive, hypothesis-driven research.
Prescriptive statements	Not present.

Table 20. Taxonomic theory perspective according to Gregor (2006) (Böhmer et al., 2024).

As shown in Böhmer et al. (2024) and Table 20, the theory aims to shift the perspective of the observer, offering a new way to see and understand digital health adoption, its actionable effects, and its phenomena, rather than predicting future occurrences or testing propositions (Gregor, 2006; Leidner & Gregory, 2024). Such a theory closely corresponds to some views of interpretivist theory as the artifact can be seen as a preliminary end product of the theorizing process and is not expected to lead to deterministic and predictive theory, aligning with the interpretivist paradigm by emphasizing meaning, understanding, and context rather than prediction and control (Klein & Myers, 1999). This approach is particularly beneficial in digital health, where complex human behaviors and technology interactions converge, as it allows for a more nuanced and empathetic understanding of vulnerable populations and their dynamic interactions with technology, providing a fresh lens through which to examine and understand digital health adoption and behavior (Böhmer et al., 2024).

5.5 Conclusion

The third design cycle marked the culminating shift in this cumulative dissertation – from an artifact-centric focus to a theory-oriented contribution – by addressing the theoretical gap identified in the previous design cycles. While the first and second cycles developed and evaluated IS artifacts that successfully supported the adoption and use of digital health by individuals with cognitive impairments, the lack of an integrative theoretical explanation for these adoption processes revealed a deeper, unresolved challenge. Answering **RQ5** and addressing the overarching goal of this dissertation, the final design cycle followed a theory-generative approach to construct an explanatory mid-range theory, called **Cognitive Adoption Theory**, that synthesizes constructs from CLT, SCT, metacognition, and findings from the first two cycles.

Using a structured theorizing-from-the-literature method (Leidner & Tona, 2021) grounded in qualitative theory-building techniques (Gioia et al., 2013; Wiesche et al., 2017), the third design cycle produced three distinct DSR echelon instance outputs (Böhmer et al., 2024): (1) a conceptual model of cognitive adoption in digital health, (2) an integrated framework that incorporates cognitive, social, and behavioral dimensions, and (3) a generalizable theoretical artifact classified as a type II explanatory theory (Gregor, 2006). Thus, this cycle bridges theoretical and practical domains by translating insights from the previous artifact development in the context of Augmented Living Spaces into a conceptual structure that accounts for the specific cognitive characteristics of individuals with impairments and their influence on digital health adoption and health behavior change.

Despite the theoretical richness of this cycle, a few limitations remain. First, while the theory has been rigorously developed by synthesizing multiple streams of literature and informed by empirical findings from the previous design cycles, it has not yet been empirically validated. This is consistent with the nature of explanatory theories (Gregor, 2006; Leidner & Gregory, 2024), which emphasize understanding over prediction, but it also invites future work to test and refine the proposed relationships. Second, while this model specifically targets individuals with cognitive impairments, cognitive impairments are heterogeneous in their manifestations and progression. Thus, further refinement may be needed to adapt the model to more specific subpopulations or clinical contexts. Finally, although the model strives for generalizability within digital health contexts, it was developed in the limited domain of IS for cognitively impaired users; extending its applicability to other domains or user groups should be undertaken with theoretical and empirical caution.

The third design cycle not only responded to a theoretical shortcoming but also fulfilled the scientific obligation of DSR to contribute to knowledge beyond problem-solving artifacts. As emphasized by Vaishnavi and Kuechler (2015), DSR cycles can lead to new research questions and conceptual generalizations. This third design cycle embodies this transition. It responds to the emerging understanding that digital health adoption by cognitively impaired users is shaped by intersecting cognitive loads, social learning mechanisms, and reflective monitoring capacities – factors not adequately captured by existing models such as TAM or UTAUT. Through its theoretical integration of SCT, CLT, and metacognition, this DSR echelon instance provides a theoretical artifact that both explains and reframes cognitive technology adoption aspects in digital health contexts, providing a foundation for future IS theorizing and empirical validation.

Moreover, the cycle exemplifies the growing call in IS research for "next generation" theories that move beyond static representations toward dynamic, contextually sensitive frameworks (Burton-Jones et al., 2021). The proposed *Cognitive Adoption Theory* contributes to this agenda by offering a lens that is sensitive to the realities of aging, cognitive decline, and digital transformation in healthcare. It invites scholars and practitioners to consider how IS artifacts interact with the cognitive limitations of vulnerable users, and to design with these complexities in mind.

With the successful development of a comprehensive theory that addresses cognitive adoption processes in digital health, no further design cycle was deemed necessary. The third cycle concludes this dissertation by satisfying the overarching goal and both the practical imperatives of DSR and the theoretical ambitions of IS research. While previous cycles solved domain-specific problems through artifact instantiations (i.e., in the context of Augmented Living Spaces), this final cycle abstracted from

those solutions to develop a theory capable of explaining the broader phenomenon. Consistent with the goals of DSR and Vaishnavi and Kuechler's (2015) process model, this final cycle represents the culmination of reflective iteration, where practical insights sparked theoretical innovation, and the theory, in turn, equips the field to address future challenges. No further iteration was necessary, as the research problem had been addressed both practically and conceptually.

6 Discussion

Building on the notion of Gregor and Hevner (2013), the findings of this dissertation contribute to both the theoretical understanding of digital health adoption by individuals with cognitive impairments and the practical design of assistive technologies tailored to their needs – ultimately addressing the design theoretical indeterminacy often encountered in such approaches (Lukyanenko & Parsons, 2020). By integrating insights from cognitive psychology and IS, HCI, and DSR, this dissertation provides a novel theoretical model (i.e., the *Cognitive Adoption Theory*) as a useful product of IS theorizing (Hassan et al., 2022), which captures the cognitive mechanisms that influence technology adoption in this vulnerable population. At the same time, throughout multiple design cycles, it provides actionable DPs and guidelines for the development of cognitively inclusive digital health solutions, addressing both fundamental and applied aspects of the research problem (Brendel et al., 2022; Gregor & Hevner, 2013; Lukyanenko & Parsons, 2020). This dual contribution underscores the importance of bridging theory and practice, and aligning abstract theoretical models with the tangible realities of technology use in real-world contexts. As a product/artifact that emerged as a result of the findings from the first two design cycles, the *Cognitive Adoption Theory* developed as an overarching goal of this dissertation extends the theoretical discourse by addressing gaps in existing technology acceptance models and incorporating constructs that account for the unique cognitive, emotional, and social challenges faced by individuals with cognitive impairments. In simpler terms, the first cycle taught us *what matters*. The second cycle showed us *what happens*. The third cycle explained *why it matters* and *happens that way*.

Driven by the research questions, which had a theoretical focus, this dissertation followed the *envision*-strategy proposed by Burton-Jones et al. (2021) for next-generation theorizing in IS. In doing so, the proposed artifacts helped to study new phenomena (i.e., SAR and AI coupled with context-aware components in digital health) emerging in a changing world (i.e., demographic change and increased occurrence of neurodegenerative diseases), which effectively led to new theoretical insights and concepts culminating in the *Cognitive Adoption Theory*. As such, the dissertation aimed to contribute to the field by developing generalizable (design) knowledge and a novel theoretical framework for cognitive adoption, offering significance beyond the specific cases of aMCI and SAR.

The research approach taken in this dissertation may not only enrich the academic understanding of digital health adoption but also provide practical implications for developers, practitioners, and policymakers, highlighting the need for cognitively responsive design, context-aware interventions, and user-centered innovation. In the following sections, validity claims of the DSR artifacts, the knowledge contribution assessment, and the theoretical and practical contributions of this dissertation are discussed in more detail, reflecting on how the findings can inform both future research and the ongoing development of digital health technologies that benefit vulnerable populations.

6.1 Design Science Validity Claims

Reflecting on the research questions and findings from this dissertation, it seemed reasonable to consider the validity of DSR claims for the first two design cycles and their artifacts. Here, the *Design Science Validity Framework* proposed by Larsen et al. (2025) provides a systematic structure for understanding and establishing the validity of knowledge claims about artifacts developed in DSR. It defines design science validity as the extent to which knowledge claims about a focal artifact are supported by evidence, organizing validity into three main types based on the nature of the knowledge claim: *criterion validity* (comparing the effectiveness or characteristics of an artifact to a standard reference entity), *causal validity* (assessing the effects of specific parts of an artifact by comparing them to a manipulated version), and *contextual validity* (assessing the extent to which claims hold in specific or multiple

settings, including real-world environments). Thus, this dissertation explicitly used the framework to account for the specific knowledge claims made about the DSR artifacts developed in the first two design cycles. As detailed in Table 21, the framework was used to systematically assess and articulate how different evaluation activities (such as expert focus groups, prototypical scenarios, usability evaluations, methods, and theoretical grounding) provided evidence to support specific criterion, causal, and contextual validity claims for the design theories, reference architecture, conceptual model, and prototype instantiations developed within these cycles. As such, it demonstrates the robustness of the foundational work of the first two cycles that led to the *Cognitive Adoption Theory*. It is about showing that the building blocks were sound, and less about the validity of the final theory itself, which is assessed differently as an explanatory theory (see Chapter 5).

Validity Aspect	**First Design Cycle**	**Second Design Cycle**
Knowledge Claim Type	**Design Theory & Reference Architecture**: Prescriptive, guiding ALiS development for aMCI support. Emancipatory design and general IS midrange theory.	**Design Theory & Conceptual Model:** Prescriptive, guiding ethical/effective synthetic image data use in digital health CV. Emancipatory design and general IS midrange theory. Includes heuristically theorized conceptual model.
Criterion Validity		
Efficacy Validity	**Concurrent Validity:** Evaluated prototype efficacy (user satisfaction, efficiency via PE/EE, task performance via think-aloud) compared to reference outputs (baseline performance) existing concurrently with the evaluation data.	**Concurrent Validity:** Assessed perceived usefulness/effectiveness of DT via reusability framework compared to concurrent standards/expectations. Prototype demonstration implies efficacy compared to baseline expectations.
Instance Validity	*Supported*: Prototype characteristics (e.g., intuitiveness, feature usefulness) compared via think-aloud sessions and questionnaires to abstract characteristics representing the standard (defined by DPs derived from theory/data).	*Supported*: Prototype operationalization (design features) characteristics compared to abstract characteristics representing the standard (defined by DPs derived from theory/data).
Theory Validity	*Supported*: Design theory characteristics compared to characteristics of theory reference entities (kernel theories, literature, empirical data); grounding & justification provided; heuristic design theorizing. Evaluation strategy compared design theory characteristics to theoretical framework standards.	*Supported*: Design theory characteristics compared to characteristics of theory reference entities (kernel theories, literature, focus group); grounding & justification provided; heuristic design theorizing. Reusability evaluation compared design theory characteristics to theoretical framework standards.
Model Validity	*Supported*: Reference architecture characteristics compared implicitly to characteristics of model reference entities (e.g., baseline RA standards in IS). Expert evaluation (UTAUT constructs) compared RA characteristics to implicit models of good and rigorous RAs.	*Supported*: Conceptual model characteristics (structure, relationships) implicitly compared to characteristics of model reference entities (theoretical standards via derivation from DPs) as well as baseline model characteristics in IS research.
Method Validity	*Supported*: Employed rigorous DSR methods (heuristic design theorizing, theory-driven DSR configuration, FEDS strategy, etc.) compared implicitly to characteristics of method reference entities (i.e., established DSR procedures in IS).	*Supported*: Employed rigorous DSR methods (heuristic design theorizing, theory-driven configuration, qualitative theory-building, etc.) compared implicitly to characteristics of method reference entities (i.e., established DSR procedures in IS).

Causal Validity		
Causal Efficacy Validity	*Supported*: Evaluation comparing efficacy with/without a specific part of the design theory and system (e.g., wearable AR against spatial AR assistance).	*Not explicitly supported*: No evaluation comparing efficacy with/without a specific part. Implicitly supported through prototypical instantiation and operationalization.
Causal Characteristic Validity	*Supported*: Iterative refinement suggests belief in causal link between design choices (e.g., adding kernel theories such as ZPD) and characteristics (e.g., actionability. Explicit comparison to manipulated artifact (e.g., wearable AR) missing a part (i.e., spatial projections).	*Implicit Support*: Iterative refinement suggests belief in causal link between design choices (e.g., adding DPs) and characteristics (e.g., ethical focus). No explicit comparison to manipulated artifact missing a part.
Context Validity		
External Validity	*Supported*: Evaluation occurred across contexts represented by diverse experts and target group. Design assessment addressed applicability in other socio-technical systems. Discusses potential use in more than one system or area (e.g., smart homes, human-AI collaboration).	*Supported*: Evaluation occurred across contexts represented by diverse experts and target group. Reusability assessment addressed applicability in other socio-technical systems. Discusses DPs applicable to more than one system and addresses replication aspects.
Ecological Validity	*Supported*: Data gathering and evaluations (observation study, focus group, prototype think-alouds) conducted in socio-technical systems (care facility, simulated home environment with target users) corresponding to the real-world systems for which the artifact is intended.	*Partially Supported*: Prototypical demonstration and operationalization in a relevant context. Expert evaluations used imagined scenarios corresponding to practice. Lacks evaluation within a full real-world socio-technical system involving end-users.

Table 21. Application of the design science validity framework following Larsen et al. (2025).

As shown in Table 21, both perspectives strongly establish criterion validity. They both evidence *concurrent validity* (via *efficacy validity*) through evaluations comparing efficacy against baseline standards or expectations existing at the time. Furthermore, both perspectives strongly support *theory validity* by explicitly grounding their respective design theories in kernel theories, literature, and design theorizing heuristics, comparing their characteristics against these theoretical standards/procedures. They also support *model validity* (e.g., by comparing the RA or conceptual model characteristics against baseline standards), *method validity* (by using established DSR methods), and *instance validity* (by evaluating prototype characteristics against the standards defined by their DRs and DPs).

In terms of *causal validity*, the first design cycle explicitly supports *causal efficacy validity* and *causal characteristic validity* by evaluating the artifact compared to a manipulated version (i.e., wearable AR vs. spatial AR – explicitly shown in Böhmer et al. (2025d)). On the other hand, the second design cycle, while offering implicit support for *causal characteristic validity* through iterative refinement, does not claim explicit support for either causal subtype via manipulation testing in the application of the framework. Moreover, both perspectives support *external validity* through evaluations involving diverse experts/target groups and assessments addressing applicability across multiple socio-technical systems or contexts. However, the Augmented Living Spaces IS evaluation alongside the novel HCI approach demonstrates stronger *ecological validity* with evaluations conducted in settings (care facility, simulated home with target users) corresponding closely to the intended real-world system. In contrast, the second design cycle's circumscription with the design theory for the effective and ethical use of synthetic image data offers partial support through demonstrations and expert evaluations in relevant/imagined contexts but lacks evaluation in a full real-world end-user system, which still is supported by the notion of the design science validity framework (Larsen et al., 2025).

6.2 Knowledge Contribution Assessment

The methodological and theoretical foundation discussing the positioning of this dissertation draws on the DSR *Knowledge Contribution Framework* proposed by Gregor and Hevner (2013). This framework categorizes research contributions based on two central dimensions: (1) the maturity of the problem domain, indicating the extent to which the issues addressed by the research are recognized, understood, and articulated within existing knowledge; and (2) the maturity of the solution domain, referring to the degree to which effective and reliable solutions already exist. Thus, the framework delineates four quadrants – *Invention*, *Improvement*, *Exaptation*, and *Routine Design* – each representing different knowledge contribution types and levels.

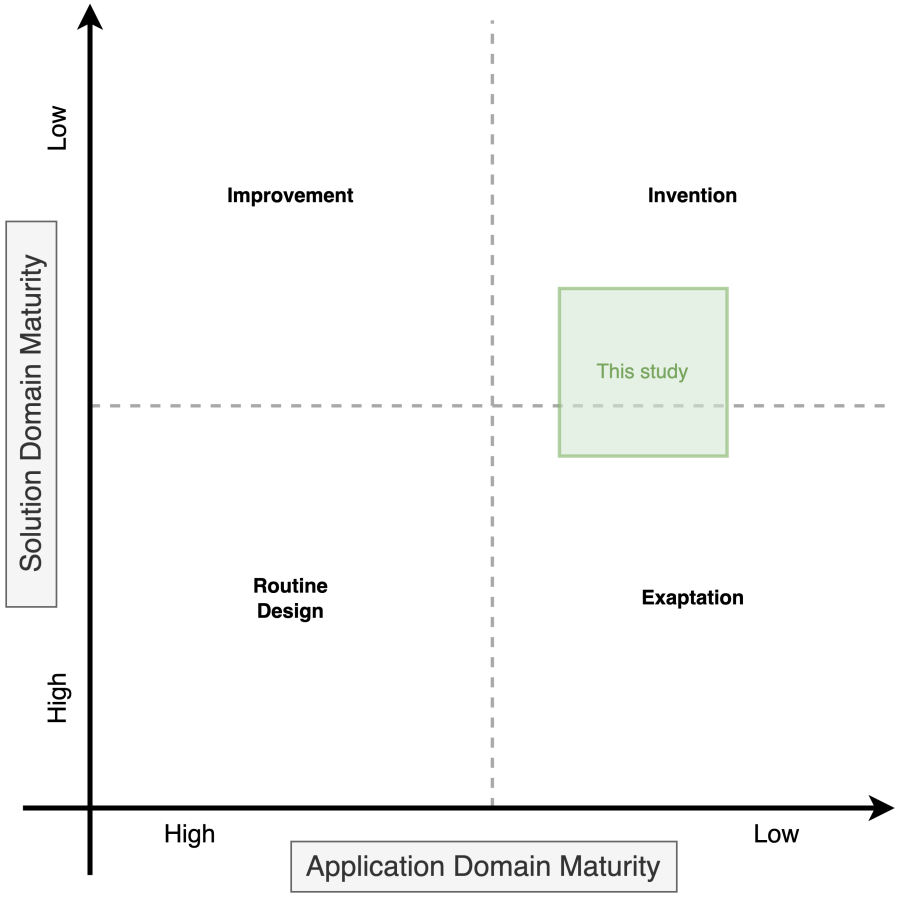


Figure 36. Knowledge contribution assessment across all three design cycles of this dissertation, mapped to the matrix proposed by Gregor and Hevner (2013).

As shown in Figure 36, the research presented here over the three design cycles predominantly resides within the *Invention* quadrant, characterized by exploring and generating novel solutions addressing emerging and previously unexplored problems. Specifically, the first design cycle, which presents a design theory and reference architecture for the Augmented Living Spaces concept employing SAR-based digital assistance, clearly fits within this quadrant due to the low maturity of both the problem domain (newly emerging needs stemming from the increased prevalence of cognitive impairments) and the solution domain (novelty of the SAR-based intervention approach). Similarly, the second cycle, proposing a novel interaction design for people with aMCI, leveraging synthetic image data for digital health applications, also primarily aligns with the *Invention* quadrant due to its originality in addressing conceptual and practical gaps within digital health and synthetic image data application contexts. Nonetheless, elements of this second cycle, due to the encountered circumscription (Vaishnavi & Kuechler, 2015), also partially intersect with the *Exaptation* quadrant as it draws upon and extends

existing techniques, concepts, and theories from emancipatory design and synthetic data generation to this novel problem context.

Finally, the third design cycle aligns predominantly with the *Exaptation* quadrant, explicitly extending established cognitive theories (CLT, SCT, and metacognition) and findings from the prior two cycles, to systematically explain and foster digital health technology adoption among individuals with cognitive impairments – a previously unexplored application domain. Thus, through carefully delineating these positions, the dissertation demonstrates a thoughtful combination of predominantly inventive contributions, enriched by significant theoretical exaptations, complementing the chosen focus (Figure 3) for this study.

6.3 Core Contributions of the Dissertation

In general, the findings of this dissertation correspond to four core publications, which are based on the three design cycles, addressing the aforementioned research questions:

- **Böhmer, Martin** / Kuehnel, Stephan / Damarowsky, Johannes (2025): *Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health*. Submitted to: Decision Support Systems (awaiting decision) – (Böhmer et al., 2025a).
    - VHB-Rating 2024: **B**
- **Böhmer, Martin** / Massler, Philip / Kuehnel, Stephan / Damarowsky, Johannes / Sackmann, Stefan (2025): *Too Hard to Handle: Empowering People with Amnestic Mild Cognitive Impairment through Innovative Human-Computer Interaction and Innovative Interfaces*. In: Behaviour & Information Technology – (Böhmer et al., 2025b).
    - VHB-Rating 2024: **B**
- **Böhmer, Martin** / Kuehnel, Stephan / Damarowsky, Johannes / Brendel, Alfred Benedikt (2025): *SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning*. In: The DATA BASE for Advances in Information Systems, In Press (Pre-Print) – (Böhmer et al., 2025c).
    - VHB-Rating 2024: **B**
- **Böhmer, Martin** / Kendziorra, Jennifer / Kuehnel, Stephan (2024): *A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Cognitive Impairments*. In: 32nd European Conference on Information Systems (ECIS 2024) – (Böhmer et al., 2024).
    - VHB-Rating 2024: **A**

In general, the first publication (Böhmer et al., 2025a) presents the conceptual foundations, design heuristics, reference architecture, and initial prototypical instantiations and evaluations of the Augmented Living Spaces IS. This journal article, submitted to the Senior Scholars' List of Premier Journals outlet, *Decision Support Systems,* thus addresses and answers RQ1 and RQ2. This publication is currently still under review and awaits a decision.

The second publication (Böhmer et al., 2025b), published in the renowned journal *Behaviour & Information Technology*, addresses the second design cycle and proposes the novel HCI approach based on the developed deep learning model, thus answering RQ3. Presenting the circumscription encountered in design cycle 3, the third publication (Böhmer et al., 2025c), published in the renowned journal *The DATA BASE for Advances in Information Systems*, proposes the theorized design heuristics for the ethical and effective use of synthetic image data in digital health deep learning, thus answering RQ4.

Finally, the fourth core contribution of this dissertation (Böhmer et al., 2024), published in the proceedings of the prestigious *European Conference on Information Systems* (ECIS), presents the proposal of the *Cognitive Adoption Theory*, thus answering RQ5.

An overview of how these publications address the design cycles and research questions of this dissertation is provided in Table 22:

Publication	Design Cycle 1		Design Cycle 2		Design Cycle 3
	RQ1	RQ2	RQ3	RQ4	RQ5
Böhmer et al. (2025a) *"Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health"*	**X**	**X**			
Böhmer et al. (2025b) *"Too Hard to Handle: Empowering People with Amnestic Mild Cognitive Impairment through Innovative Human-Computer Interaction and Innovative Interfaces"*	**X**		**X**		
Böhmer et al. (2025c) *"SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning"*				**X**	
Böhmer et al. (2024) *"A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Cognitive Impairments"*					**X**

Table 22. Core contributions of the dissertation and their design cycle, and research question alignment.

6.3.1 Theoretical Implications

The developed artifacts of the first design cycle make several theoretical contributions to the field of IS and digital health. First, this cycle demonstrates the efficacy of design theory as a forward-looking approach to guide the development of practical and replicable technologies for the future (Young et al., 2021). The design theory developed in the first DSR echelon instance provides a framework for rethinking systems design methodologies by explicitly considering the societal implications of technological advances (Burton-Jones et al., 2021; Kane et al., 2021; Mandviwalla, 2015; Young & Zhu, 2021). Based on the established knowledge frameworks of Gregor and Hevner (2013) and Woo et al. (2014), the first design cycle positions these artifacts within the prescriptive IS knowledge base and categorizes the resulting design theory as a *Level 3*, well-developed inter-field design theory according to Gregor and Jones (2013) and Darden and Maull (1977), where the reference architecture may be seen as instantiation and conceptual *Model* according to Gregor & Hevner (2013). Furthermore, the first cycle contributes to next-generation theorizing by introducing a heuristically developed IS theory focused on supporting the autonomy of elderly and aMCI individuals through the proposed Augmented Living Spaces concept (Burton-Jones et al., 2021). By addressing the specific needs of individuals with neurodegenerative diseases and developing DRs and DPs based on the multi-method approach, this design cycle highlights the importance of integrating socio-technical perspectives in future innovations. As such, it extends the application of Vygotsky's (1978) zone of proximal development from human facilitators to AI-driven adaptive systems, reframing digital assistance systems as adaptive cognitive scaffolds and demonstrating that digital assistance technologies can serve as "more knowledgeable others" by modulating their level of intervention based on users' cognitive development. This implies that assistive systems must be designed to dynamically fade out their support, allowing users to progressively take ownership of cognitive processes rather than perpetuating technological dependence, which this dissertation would argue, challenges the traditional notion of assistive health systems only being "easy-to-use."

Reflecting on the first cycle, the core argument is straightforward: if assistance information systems in digital health, especially in the context of cognitive impairments, fail to address the adequate interaction design and cognitive mechanisms necessary, the resulting solutions won't benefit affected individuals and undermine the very goals they are intended to serve. This dissertation argues that the developed DRs and DPs not only add to the body of IS knowledge but also have the potential to change the way we approach the design and implementation of such systems for individuals with cognitive impairments. For a more detailed discussion of the theoretical implications of the first design cycle, see the related publication (Böhmer et al., 2025a) in Appendix B.

The second design cycle then provides several important theoretical contributions. Primarily, it demonstrates how the AI- and SAR-driven HCI approach can positively influence the self-efficacy of individuals with aMCI by empowering them through intuitive and low-threshold access to digital health solutions (Bandura, 2001; Böhmer et al., 2024). The first DSR echelon instance of the second design cycle also applies the concept of reciprocal determinism, illustrating how the developed interaction design can structure the environment to support desired behaviors and create a positive feedback loop between technology, user capabilities, and environmental affordances (Bandura, 2001). This aligns with and builds upon the first cycle's application of Vygotsky's zone of proximal development, emphasizing adaptive cognitive scaffolding. In addition, this echelon instance emphasizes the interplay between cognitive and emotional dimensions, suggesting that intuitive and low-threshold interactions may indirectly promote positive emotional outcomes such as increased self-confidence and reduced frustration, thereby expanding the theoretical scope of SCT and reciprocal determinism (Bandura, 2001; Siepmann & Kowalczuk, 2021; Steinert & Dennis, 2022; Zoccarato et al., 2024). As such, the first DSR echelon instance of the second design cycle extends the theoretical discourse on cognitive interventions for individuals with aMCI by incorporating synthetic, data-driven deep learning and SAR to bring new dimensions to the field. Unlike traditional cognitive interventions using VR (Jean et al., 2010; Kim et al., 2019; Migo et al., 2016), ConZones leverages SAR to create an intuitive, accessible, and low-threshold interaction environment. This approach moves SAR from entertainment and industrial applications to a therapeutic context, providing novel cognitive support in areas such as memory, structuring, and participation (Petersen, 2016; Petersen et al., 2018; Yu et al., 2017). For a more detailed discussion of the theoretical implications of the first DSR echelon instance in the second design cycle, see the related publication (Böhmer et al., 2025b) in Appendix F.

This second design cycle further enriches theoretical discourse by developing a mid-range IS design theory that emphasizes projectability over traditional generalizability (Baskerville & Pries-Heje, 2019; Offermann et al., 2011). By addressing the methodological challenge of design theory indeterminacy (Lukyanenko & Parsons, 2020), the framework clearly articulates actionable and adaptable DPs, particularly DP4, DP5, DP7, and DP9, that are robust enough to be applied beyond their initial digital health context to broader domains such as autonomous driving and robotics (Alzubaidi et al., 2021; Giuffrè & Shung, 2023; Murtaza et al., 2023). This second DSR echelon instance of the second design cycle also enhances theoretical evaluation approaches within DSR by proposing three levels of reusability to evaluate DRs, promoting a more nuanced assessment of design theories (Iivari et al., 2021). Finally, it contributes to mitigating "theory fetishism" by grounding the design theory in practical applications (Iivari, 2020), which is the context of the proposed Augmented Living Spaces from the first design cycle.

From the perspective of applied kernel theories, the second cycle artifacts contribute to value-sensitive design theory by operationalizing ethical values such as privacy, fairness, and accountability in the design of synthetic image data systems, in line with the principles of responsible innovation (Friedman et al., 2002, 2013; Owen et al., 2013; Stilgoe et al., 2013). They also extend the theoretical discourse by emphasizing the need to capture diversity and individuality in healthcare scenarios and provide practical steps for implementing ethical principles in synthetic image generation, addressing the ethical risks associated with AI in healthcare (Donia & Shaw, 2021; Mueller et al., 2018). From a socio-technical systems perspective, this design cycle contributes to understanding the interplay between social and technical systems in the context of synthetic image data. It highlights the importance of joint optimization, where ethical considerations and technical requirements are balanced to ensure robust and

ethical AI applications (Mumford, 2006; Trist & Bamforth, 1951). Thus, the design theory developed as a second DSR echelon instance extends the application of *Socio-Technical Systems Theory* to AI in digital health, advocating for the integration of ethical values and social responsibility throughout the design process and promoting a user-centered approach that prioritizes social and ethical considerations alongside technical requirements (Baxter & Sommerville, 2011; Bostrom & Heinen, 1977). As such, this second design cycle argues that ethical integration is not simply a matter of adding ethical safeguards; it requires a fundamental rethinking of how we approach the design of digital health systems, especially when the generation of synthetic data is just a click away. For a more detailed discussion of the theoretical implications of the second DSR echelon instance in the second design cycle, see the related publication (Böhmer et al., 2025c) in Appendix J.

The third design cycle, with the culminating artifact of the *Cognitive Adoption Theory* proposal, contributes to IS theory by viewing it as a dynamic conversation that evolves with emerging trends and technologies rather than a static product (Burton-Jones et al., 2021; Whetten, 1989). Building upon the findings and artifacts from the prior design cycles, this final DSR echelon instance of the dissertation emphasizes the need to understand the psychological, cognitive, and sociocultural aspects of technology adoption in digital health, advocating a multifaceted approach to address complex issues. The developed theoretical model goes beyond mere description, fulfilling Whetten's (1989) requirement for theories that explain phenomena by demonstrating the intricate interactions between cognitive abilities, social influences, and environmental factors. As such, this design cycle argues that the theory developed is consistent with Sutton and Staw's (1995) perspective that robust theory requires an understanding of underlying dynamics rather than isolated variables, thus advocating for comprehensive, context-sensitive adoption strategies. By integrating psychological concepts from social sciences into IS research, the third design cycle illustrates the importance of interdisciplinary concept-borrowing (Jiang et al., 2022; Truex et al., 2006) to gain comprehensive insights into digital health adoption, extending the conversation on cognitive IS research and contributing to the intersection of social and behavioral sciences (Fallon et al., 2019; Kim & Han, 2021; Wolf et al., 2023). In addition, this design cycle advocates a shift from traditional adoption models (Venkatesh et al., 2003) to comprehensive adoption strategies that recognize the importance of cognitive fit, environmental context, and personalized interventions in improving technology use among people with cognitive impairments. Thus, it may broaden the lens through which adoption challenges are viewed, shifting the paradigm from mere technology acceptance to a more holistic understanding of adoption. Ultimately, the integrative *Cognitive Adoption Theory* is not merely representational, but performative (Burton-Jones et al., 2021), with the potential to actively influence real-world outcomes by informing effective digital health adoption practices. This theoretical framework provides a foundational platform for future research and practical applications aimed at improving the lives of cognitively impaired individuals through thoughtfully designed, cognitively accessible digital health solutions. For a more detailed discussion of the theoretical implications of the third design cycle, see the related publication (Böhmer et al., 2024) in Appendix L.

The theoretical implications of the three design cycles of this dissertation collectively advance the IS discourse by establishing a cohesive and iterative theoretical narrative. In the first cycle, the focus on adaptive cognitive scaffolding and UTAUT concepts provided foundational insights into cognitively inclusive technology adoption, interaction design, and autonomy-enhancing digital solutions for individuals with cognitive impairments. The second cycle built on these foundations by integrating socio-technical systems theory and value-sensitive design to address the ethical and practical complexities of synthetic image data and intuitive interaction design in digital health. This broadened the theoretical scope by emphasizing ethical integration, human values, and the dynamic interactions between technology, users, and the environment. The culminating third cycle synthesized these findings into a comprehensive theory of cognitive adoption that integrates CLT, SCT, and metacognition. As such, it not only captures the complex dynamics of cognitive, emotional, and social factors that influence technology adoption but also positions itself as a dynamic, evolving intellectual conversation that actively informs practical adoption strategies. Taken together, the three design cycles illustrate how iterative design and theoretical pluralism can yield robust theoretical frameworks that are both

practically relevant and rigorous, potentially advancing our understanding of technology adoption among cognitively impaired populations.

6.3.2 Practical Implications

Digital healthcare solutions for aging people with aMCI are becoming increasingly important due to ongoing demographic shifts and the increasing prevalence of cognitive impairments (Bloom & Canning, 2008; Flicker et al., 1991). In contrast, health authorities, in particular, face several challenges when introducing or implementing digital solutions for such vulnerable populations, including communication with diverse stakeholders like policymakers, caregivers, and developers (Thakur et al., 2012). The developed design theory and reference architecture for Augmented Living Spaces in the first cycle may support this process by providing the vocabulary, concepts, and design knowledge necessary to bridge the gap between abstract theory and practical implementation. This is particularly important when introducing such systems in nursing or care facilities, as it ensures a shared understanding among all involved parties. The findings from the first design cycle emphasize that digital healthcare solutions for aMCI individuals must go beyond static assistive functions, serving as adaptive scaffolding mechanisms that align with users' cognitive abilities and their zone of proximal development (Vygotsky, 1978; Wertsch, 1984). This approach requires systems like the proposed Augmented Living Spaces to dynamically adjust their level of intervention based on the user's cognitive state, ensuring a gradual transition from dependency to autonomy, rather than merely compensating for impairments (Böhmer et al., 2024). This insight is particularly relevant for health authorities, developers, and decision-makers, as it highlights the need to design assistive decision support systems that promote cognitive adaptation and long-term autonomy, rather than imposing rigid system logic.

From a user perspective, innovative digital health solutions like Augmented Living Spaces can initially appear complex or intrusive, potentially leading to user resistance (Tacken et al., 2005). However, the development and evaluation episodes highlighted the importance of transparency, communication, and user involvement in the design process, aligning with user-centered (Abras et al., 2004) and value-sensitive design principles (Friedman et al., 2013). Early engagement with both healthcare experts and the target user group allowed this design cycle to identify critical usability factors, such as customizable widget sizes, color schemes, and interaction designs that better match user preferences and cognitive abilities. This iterative, user-centered approach potentially resulted in a more intuitive and acceptable system, reducing cognitive load and promoting long-term adoption (Friedman et al., 2013; Abras et al., 2004), which was confirmed in a secondary publication of the first design cycle (Böhmer et al., 2025d). For a more detailed discussion of the practical implications of the first design cycle, see the related publication (Böhmer et al., 2025a) in Appendix B.

The artifacts of the second design cycle offer significant practical implications that advance the development and ethical use of digital health technologies, directly addressing real-world challenges while building on the theoretical and practical foundations established in the first design cycle. Concerning the first DSR echelon instance of the second design cycle, the development of the ConZones approach provides a practical solution to mitigate cognitive overload and foster autonomy in individuals with aMCI, demonstrating the potential of AI and SAR-driven systems to provide more intuitive and accessible digital health tools. This has direct implications for improving activities of daily living, promoting independence, and enhancing quality of life for individuals affected by neurodegenerative diseases, and suggests broader applications of such systems within hospitals, nursing homes, and care facilities. As such, the first DSR echelon instance of this cycle contributes to research on AI-based assistants (Maedche et al., 2019), HCI combined with personal factors (Chignell et al., 2023), computer vision in assisted living (Colantonio et al., 2018), and future HCI strategies for aging populations (Vines et al., 2015), providing both theoretical insights and practical application. For a more detailed discussion of the practical implications of the first DSR echelon instance in the second design cycle, see the related publication (Böhmer et al., 2025b) in Appendix F.

Simultaneously, the design theory for synthetic image data in digital health addresses a critical practical need for robust ethical guidelines in the development and deployment of AI-driven digital health solutions. It equips practitioners with a framework to navigate the complex ethical landscape of synthetic

data, ensuring responsible innovation and mitigating potential risks related to privacy, bias, and data misuse. As such, both the design theory and conceptual model allow developers to overcome the scarcity of real patient data while maintaining user privacy, supporting the broader goals of this dissertation by ensuring secure, scalable, and context-aware digital health solutions. For a more detailed discussion of the practical implications of the second DSR echelon instance in the second design cycle, see the related publication (Böhmer et al., 2025c) in Appendix J.

Finally, the *Cognitive Adoption Theory* proposed in the third design cycle provides a model and framework to inform the design of user-centered digital health tools that are tailored to the cognitive profiles and needs of vulnerable populations, such as those with neurodegenerative diseases or the elderly experiencing cognitive decline. From a practical perspective, this theory provides a foundational lens for developers, healthcare providers, and policymakers aiming to design intuitive, patient-centered digital health solutions. It highlights the critical importance of reducing cognitive load, enhancing self-efficacy, and promoting positive feedback loops to facilitate sustained technology use, which is particularly relevant for vulnerable populations like those with neurodegenerative diseases or the elderly with cognitive decline (Gazzaniga et al., 2018; Ienca et al., 2021). By focusing on the cognitive and social dimensions of technology adoption, the theoretical model provides practical guidance for designing digital health systems that better match the cognitive profiles of their users. For example, by incorporating observational learning and self-regulation principles from SCT, developers can design digital interfaces that are less intimidating, more intuitive, and better tailored to the needs of cognitively impaired users. This approach can significantly improve patient engagement, reduce technology-related anxiety, and promote long-term adherence to digital interventions (Venkatesh et al., 2003; Bandura, 2001). In addition, by explicitly addressing cognitive load, the theoretical model ensures that digital health tools do not overwhelm users with excessive information or complex navigation, but instead provide just-in-time support that matches the user's current cognitive capacity (Sweller, 2011). Ultimately, for healthcare organizations and policymakers, this theory provides a clear framework for integrating cognitive insights into digital health strategies to ensure that interventions are not only technologically sophisticated but also psychologically and socially appropriate for their target populations. This patient-centered approach is essential to address the ongoing demographic shift and the growing demand for digital health solutions that support the autonomy, quality of life, and cognitive well-being of an aging population.

6.3.3 Limitations and Research Desiderata

In order to adequately assess the approaches and results of this work, it is necessary to consider their limitations. While the artifact-specific limitations are discussed in detail in the individual core publications, this chapter primarily serves to discuss central methodological and conceptual limitations of this dissertation. These limitations, while not detracting from the contributions of this dissertation, may provide avenues for future scholarly inquiry and development.

A key methodological consideration is the inherent subjectivity in the creation of design artifacts in DSR. As emphasized primarily in the first two design cycles, the formulation of DRs, DPs, and ultimately design theory itself is influenced by the subjective creativity of the researcher, even when grounded in rigorous literature review, theory, and qualitative analysis (e.g., observational studies, focus groups, or think-aloud sessions). While some level of creative ideation is recognized as essential to the development of novel and impactful design artifacts (Hevner & Chatterjee, 2010; Baskerville et al., 2016), this inherent subjectivity introduces a level of researcher bias. This degree of interpretive flexibility might affect the rigor and consistency of the resulting design theories (Gregor & Hevner, 2013). Different researchers, even when provided with the same foundational knowledge or data, may conceive of alternative design constructs and theoretical relationships. This is particularly relevant in the context of heuristic design theorizing (Gregory & Muntermann, 2014), which was employed in two of the three design cycles, where the researcher's insights play a significant role in shaping the theoretical output.

In addition, the iterative nature of DSR itself can lead to a divergence between initial theoretical intentions and final artifact design, as refinements often arise from practical insights rather than strict

adherence to theoretical constructs (Brendel et al., 2022; Vaishnavi & Kuechler, 2015). This divergence is not necessarily a limitation per se, but rather a feature of DSR as a flexible, adaptive approach to problem solving (Gregor & Hevner, 2013; Hevner et al., 2004). However, it can challenge the theoretical coherence of the resulting design theory, especially when attempting to bridge the gap between nascent and more mature design theories (Gregor & Jones, 2007; Schoormann et al., 2024). Future research should consider strategies for optimizing the conciseness and specificity of DPs to enhance both theoretical clarity and practical applicability. Moreover, replicating the design theory or its constructs (Brendel & Muntermann, 2022) could be a reasonable way to not only validate the design theory's assumptions but potentially refine and revise parts of it.

Furthermore, the iterative nature of the DSR process over the three cycles employed in this dissertation is itself a potential limitation. While the cyclical approach allows for refinement and evolution of the artifact based on evaluation feedback (Meth et al., 2015; Schoormann et al., 2024), this iterative process may result in a departure from the initial theoretical underpinnings or practical assumptions/feedback gathered during development. As noted in the second cycle, the final artifact is often the result of multiple refinements, which could potentially limit the extent to which it fully embodies the initial theoretical constructs. Maintaining a balance between theoretical fidelity and practical utility remains a critical challenge in DSR, and while this dissertation has striven to achieve this balance, the inherent tension warrants consideration.

Another notable methodological limitation relates to the scope and nature of the evaluation episodes. While the multi-episode evaluation strategy, guided by the CCP (Andargoli et al., 2016) and FEDS (Venable et al., 2016) frameworks, allowed for a nuanced understanding of the impact of the respective artifact on the target population of people with cognitive impairments, the sample sizes in individual evaluation episodes were intentionally kept relatively small to facilitate in-depth qualitative insights (as discussed in cycles 1 and 2) that would inform artifact design and the culminating *Cognitive Adoption Theory*. While the aggregate sample size across all cycles is justifiable for an iterative and qualitative DSR study, findings from these smaller, often topic-specific evaluations may not be directly generalizable to a broader population of individuals with aMCI or other contexts. As acknowledged in design cycles 1 and 2, evaluations with different sample compositions and sizes could yield richer and potentially different results. In particular, the indicative evidence-based data collected through questionnaires in design cycle 2, while complemented by rich qualitative data from think-aloud sessions, did not constitute a large-scale empirical validation using the full range of instruments such as the UTAUT. The practical challenges and costs associated with recruiting a large sample of individuals with aMCI compounded this limitation. Hence, this could be a promising avenue for future research as well.

The contextual limitations of the artifacts developed in this dissertation must also be considered. For example, the ConZones approach has demonstrated potential in controlled environments, but lacks extensive testing in real-world healthcare settings, where diverse user needs, physical constraints, and technological limitations can significantly impact performance. Similarly, the use of synthetic data, while practical for early-stage prototyping, raises questions about ecological validity and transferability to real-world scenarios. These limitations underscore the importance of iterative, contextualized testing and the integration of organizational change theories (e.g., Armenakis & Bedeian, 1999; Kotter, 1996) to support broader adoption.

Picking up on the contextual perspective, the exemplary context of *Augmented Living Spaces* that frames this dissertation towards the *Cognitive Adoption Theory* can also be seen as a limitation. While this context provides a specific and relevant scenario for addressing the everyday cognitive challenges of individuals with aMCI, this framing inherently focuses the design and evaluation efforts on a particular type of environment. The DRs, DPs, and resulting design theory from the first design cycle, as well as the interaction design approach from the second design cycle, are thus situated in the context of a technology-enabled everyday aid. This focus may limit the direct transferability or applicability of certain aspects of the developed artifacts and design theory to other relevant contexts where people with aMCI navigate, such as public spaces, healthcare facilities outside the home, or during mobile activities. In addition, the subjective assumptions in the concept development may have influenced the experience-based knowledge injection in the subsequent artifact development of the second DSR echelon instance

in the second design cycle (i.e., the design theory for using synthetic image data) and the subsequent theorizing in the third design cycle. Future research could explore the adaptability and generalizability of the proposed design knowledge and theoretical constructs to different environments, possibly requiring modifications or extensions to account for the unique characteristics and interaction dynamics of these alternative settings. Investigating the underlying core needs and translating the design knowledge to these diverse contexts would be a valuable next step in broadening the impact of this research. As such, it would be interesting to see whether the theoretical assumptions and concepts of the *Cognitive Adoption Theory* would be similar or replicable if the Augmented Living Spaces framing was neglected.

Finally, the theoretical foundations developed in this dissertation, particularly the *Cognitive Adoption Theory* proposed in the third design cycle, naturally remain at an early stage (Leidner & Gregory, 2024). While this theory provides a structured framework for understanding the cognitive processes involved in the adoption of digital health technologies, it requires further theoretical discourse and empirical validation to ensure its robustness across different healthcare contexts. Future research should focus on testing these theoretical propositions in diverse real-world settings to refine their practical relevance and theoretical precision. In this context, the theoretical grounding of this dissertation, particularly in the third design cycle with the explicit adoption of CLT and SCT, while providing a robust lens for understanding the IS phenomenon under investigation, inherently represents one perspective among many – which is relevant for all theoretical foundations and kernel theories applied in this dissertation. As highlighted in the third design cycle, shifting from "theory as truth" to "theory as a lens" (Burton-Jones et al., 2021) underscores that alternative theoretical frameworks could offer different, yet equally valid, insights into the design and adoption of digital health interventions for individuals with aMCI. The focus on conceptual development in the later stages of this research, while crucial for building a strong theoretical foundation, means that the potentially testable propositions derived from the theory have not been extensively validated within this dissertation. In this regard, while the *theoretical-pluralism* employed in this dissertation seemed appropriate to answer the research questions (Hirschheim & Klein, 2012; Gioia & Pitre, 1990; Lee et al., 1991; Leidner & Gregory, 2024; Mingers, 2001), this may have led to an overreliance and overprioritization of theory, culminating in what Iivari (2020) called a "theory-fetish" in DSR.

In summary, while this dissertation aimed at making significant strides in advancing the design, evaluation, and theorizing of digital health technologies for individuals with aMCI, it also highlights the inherent challenges of balancing creative design with theoretical rigor, managing methodological constraints, and addressing context-specific limitations. These reflections are not meant to be seen as fixed limitations per se, but as starting points from which future research can be guided towards more comprehensive, empirically grounded, and contextually adaptable (design) theories for digital health interventions.

7 Concluding Remarks

This dissertation aimed to theorize and validate design knowledge, including artifacts and mid-range theories, that would support IS researchers, designers, and developers in conceptualizing digital health information systems for individuals with cognitive impairments. The goal was to enable everyday assistance, foster sustained technology adoption, and promote long-term health behavior change through a multi-cyclical DSR approach and theoretical pluralism – culminating in the *Cognitive Adoption Theory* proposal. This overarching goal was articulated through a series of focused research questions, each corresponding to one of the three design cycles undertaken in this dissertation. Reflecting on the cumulative insights gained from these cycles, this dissertation argues that the development of digital health technologies for people with cognitive impairments must be understood as an inherently complex, socio-technical, and context-sensitive endeavor. Rather than presenting a single, definitive solution, this dissertation positions its artifacts and theoretical contributions as a set of possible responses to the multifaceted challenges faced by this vulnerable population. In doing so, it intentionally rejects the notion of a singular "one-size-fits-all" solution and instead advocates for a more nuanced, flexible, and

human-centered approach to technology design and theorizing in digital health. While prior work has largely treated adoption as a rational, attitudinal, or behavioral issue, this dissertation foregrounds cognitive mechanisms as central to understanding and designing for digital health adoption in cognitively vulnerable populations.

The three design cycles formed the core of this exploration, each addressing specific research questions that together sought to lead to and answer the overarching goal of developing a theory of cognitive adoption in digital health IS. The first cycle laid a conceptual and practical foundation by asking how SAR could be effectively integrated into an assistance information system for individuals with aMCI (**RQ1**), and what design heuristics and reference architecture would underpin such an *Augmented Living Space* concept (**RQ2**). The resulting design theory and reference architecture for Augmented Living Spaces provided initial answers based on user-centered research and established psychological principles. This phase highlighted the potential of SAR, but also underscored the need for a more nuanced understanding of interaction design and adoption mechanisms in this specific context.

The second cycle delved deeper, addressing how synthetic image data and deep learning could forge a novel, intuitive SAR-based HCI approach (**RQ3**), and critically, what design heuristics could ethically and effectively guide the use of such synthetic data in digital health computer vision (**RQ4**). The development of the *ConZones* interaction design approach and a corresponding design theory for synthetic data use marked significant steps in operationalizing intuitive interaction and adoption mechanisms. However, this cycle also revealed a deeper theoretical gap: the lack of an integrative explanatory theory for how cognitive aspects themselves shape technology adoption and interaction among people with cognitive impairments.

This finding directly inspired the third cycle, which shifted to a more abstract, theory-generating attempt. It sought to answer how the influence of cognitive aspects and mechanisms on digital health adoption and health behavior change could be theoretically modeled by integrating cognitive load, social cognitive factors, metacognition, and the findings from the first two cycles (**RQ5**). The culmination was the proposal of a *Cognitive Adoption Theory*, which offers a new conceptual lens to understand these complex dynamics in digital health IS, thereby moving beyond artifact creation to theoretical abstraction and contribution.

Looking across these design cycles, it becomes clear that the artifacts and theories developed in this dissertation should be viewed as stepping stones rather than endpoints. The design theories, reference architectures, interaction designs, and theoretical models presented here are intended to inspire further exploration, adaptation, and refinement. Just as each design cycle builds on the lessons learned from its predecessor, future work can extend these contributions by exploring new theoretical perspectives, integrating new technologies, and addressing the evolving needs of cognitively impaired populations. As such, the culminating *Cognitive Adoption Theory* does not close the door on cognitive adoption – it opens it.

Reflecting on this multi-cycle DSR journey, its true value lies not only in the individual artifacts or theoretical propositions, but in the evolutionary process towards the *Cognitive Adoption Theory* itself. Each cycle served as a critical "heuristic lens," where practical challenges and insights stimulated theoretical refinement, and theoretical understanding in turn guided subsequent design efforts. The deliberate embrace of *theoretical pluralism* throughout this journey was instrumental in allowing different facets of this multifaceted problem – spanning human cognition, technological design, ethical considerations, and social context – to be examined through appropriately tailored theoretical lenses. Thus, no single design theory, reference architecture, or interaction model can claim to be the definitive solution to the complex, context-dependent challenges of digital health adoption for people with cognitive impairments. Instead, this dissertation argues for a more pluralistic, adaptive, and inclusive approach to technology design, one that embraces uncertainty, learns from practice, and remains responsive to the changing realities of its users.

Acknowledging the inherent limitations discussed earlier – from methodological considerations in DSR, to the contextual specificity of the artifacts developed, to the relatively nascent stage of the proposed *Cognitive Adoption Theory* – is critical. These limitations are not flaws to be glossed over, but are

integral to the scientific process and highlight fertile ground for future research and development. They invite further empirical validation, exploration across contexts, and continued theoretical discourse.

In essence, this dissertation aimed to contribute to both the theoretical discourse in IS and the practical development of digital health technologies. It advocates a research approach that embraces complexity, acknowledges the limits of our current understanding, and remains open to the possibility of continuous improvement. In doing so, it hopes to inspire a new generation of IS researchers, designers, and practitioners to address the critical and often overlooked challenges of assisting cognitively impaired individuals through innovative digital health technologies. Picking up the catchy title, this dissertation advocates for moving "beyond the sticky note", from simplistic, superficial aids to a more digital, profound, and theoretically grounded approach to supporting this vulnerable population.

The journey of this dissertation has sought to demonstrate how IS research, through creative design and reflective theorizing, can meaningfully contribute to this critical societal challenge. The path forward requires continued collaboration, innovation, and a relentless commitment to developing solutions that are not only technologically sophisticated but also deeply empathetic to the human experience, especially for our most vulnerable populations. While the road to truly intuitive, ethically sound, and cognitively inclusive, adoptable digital health solutions remains long, this dissertation may mark an aspirational milestone on that journey – one that emphasizes not just the artifacts we build, but how we think about and engage with the complex, human-centered challenges of digital health. As such, I would like to close this dissertation with a quote from economist Peter Drucker:

"The greatest danger in times of turbulence is not the turbulence itself, but to act with yesterday's logic."

References

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered Design. Bainbridge, W. *Encyclopedia of Human-Computer Interaction*. Thousand Oaks: Sage Publications, 37(4), 445-456.

Ahmed, I., Jeon, G., Chehri, A., & Hassan, M.M. (2021). Adapting Gaussian YOLOv3 with transfer learning for overhead view human detection in smart cities and societies. *Sustainable Cities and Society* 70, 102908.

Al-Dhaen, F. et al. (2021). Advancing the Understanding of the Role of Responsible AI in the Continued Use of IoMT in Healthcare. *Information Systems Frontiers*, 1-20.

Albrechtslund, A. (2007). Ethics and technology design. *Ethics and Information Technology*, 9, 63-72.

Alegre, U., Augusto, J. C., & Clark, T. (2016). Engineering context-aware systems and applications: A survey. *Journal of Systems and Software*, 117, 55-83.

Alzubaidi, L., Zhang, J. et al. (2021). Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions. *Journal of Big Data*, 8.

Anderson, N.D. (2019). State of the science on mild cognitive impairment (MCI). *CNS Spectrums*, 24(1), 78-87.

Ando, T., Yamaguchi, T., Giovannetti, T., & Sakamoto, M. (2022). A Recognition Model of Motion Primitives in VR-IADL Based on the Characteristics of MCI Patients and Elderly Adults. HCI International 2022, HCI for Health, Well-being, Universal Access and Healthy Aging. *Lecture Notes in Computer Science*, 13521. doi: 10.1007/978-3-031-17902-0_1.

Angelov, S., Grefen, P., & Greefhorst, D. (2009). A classification of software reference architectures: Analyzing their success and effectiveness. In *2009 Joint Working IEEE/IFIP Conference on Software Architecture & European Conference on Software Architecture*, 141-150.

Antonino, P. O., Schneider, D., Hofmann, C., & Nakagawa, E. Y. (2011). Evaluation of AAL platforms according to architecture-based quality attributes, *Proceedings of AmI 2011*, 264-274.

Aranjuelo, N., García, S., Loyo, E., Unzueta, L., & Otaegui, O. (2021). Key strategies for synthetic data generation for training intelligent systems based on people detection from omnidirectional cameras. *Computers & Electrical Engineering*, 92, 107105.

Armbrust, M., Ghodsi, A., Xin, R., &Zaharia, M. (2021). Lakehouse: A New Generation of Open Platforms that Unify Data Warehousing and Advanced Analytics. *Proceedings of CIDR 2021*.

Armenakis, A. A., & Bedeian, A. G. (1999). Organizational change: A review of theory and research in the 1990s. *Journal of Management*, 25(3), 293-315.

Avison, D. E., & Fitzgerald, G. (1998). *Information systems development: methodologies, techniques, and tools* (2nd ed.). McGraw-Hill Higher Education.

Avison, D. E., & Wood-Harper, A. T. (1990). *Multiview: an exploration in information systems development*. Wiley-Blackwell.

Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.

Bai, W., Chen, P., Cai, H., Zhang, Q. et al. (2022). Worldwide prevalence of mild cognitive impairment among community dwellers aged 50 years and older: a meta-analysis and systematic review of epidemiology studies. *Age and Ageing*, 51(8).

Baig, M.M., Afifi, S., Gholam, H., & Mirza, F. (2019). A Systematic Review of Wearable Sensors and IoT-Based Monitoring Applications for Older Adults - a Focus on Ageing Population and Independent Living. *Journal of Medical Systems*, 43(8).

Bala, M. Y., & Damla, K. (2021). A review of human-computer interaction design approaches towards information systems development. BRAIN. B*road Research in Artificial Intelligence and Neuroscience*, 12(1), 229-250.

Bandura, A., & Walters, R. H. (1977). *Social learning theory*, Vol. 1. Englewood Cliffs, NJ: Prentice hall.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control.* New York: Freeman.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, 52(1), 1-26.

Bandura, A. (2013). Health promotion from the perspective of social cognitive theory. In *Understanding and Changing Health Behaviour,* 299-339. Psychology Press.

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design science research contributions: Finding a balance between artifact and theory. *Journal of the Association for Information Systems*, 19(5), 3.

Baskerville, R., & Pries-Heje, J. (2010). Explanatory design theory. *Business & Information Systems Engineering*, 2, 271-282.

Baskerville, R., Kaul, M., Pries-Heje, J., Storey, V. C. & Kristiansen, E. (2016). Bounded creativity in design science research. *Proceedings of ICIS 2016*, Dublin.

Baskerville, R., & Pries-Heje, J. (2019). Projectability in design science research. J*ournal of Information Technology Theory and Application*, 20(1), 3.

Baumeister, J., Ssin, S.Y., El Sayed, N.A.M., Dorrian, J., Webb, D.P., Walsh, J.A., Simon, T.M., Irlitti, A., Smith, R.T., Kohler, M., & Thomas B.H. (2017). Cognitive Cost of Using Augmented Reality Displays. *IEEE Transactions on Visualization and Computer Graphics,* 23(11), 2378-2388.

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with Computers*, 23(1), 4-17.

Becker, L. C., & Becker, C. B. (2001). *Encyclopedia of Ethics*, Vol. 2. New York, NY: Routledge.

Bederson, B. (2003). *The craft of information visualization: readings and reflections*. Morgan Kaufmann.

Bharati, S., Mondal, M. R. H., & Podder, P. (2023). A review on explainable artificial intelligence for healthcare: Why, how, and when?. *IEEE Transactions on Artificial Intelligence,* 5(4), 1429-1442.

Bhaskar, R. (2013). *A realist theory of science*. Routledge.

Bhaskar, R., & Hartwig, M. (2016). *Enlightened common sense: The philosophy of critical realism*. Routledge.

Bider, I., Perjons, E., & Johannesson, P. (2020). Just Finished a Cycle of a Design Science Research Project: What's Next?. *Complex Systems Informatics and Modeling Quarterly*, (22), 60-86.

Biocca, F., Owen, C., Tang, A., & Bohil, C. (2007). Attention issues in spatial information systems: Directing mobile users' visual attention using augmented reality. *Journal of Management Information Systems*, 23(4), 163-184.

Bird, J. J., Faria, D. R., Ekárt, A., & Ayrosa, P. P. (2020, August). From simulation to reality: CNN transfer learning for scene classification. *Proceedings of IEEE 10th International Conference on Intelligent Systems*, 619-625.

Bittmann, S., & Thomas, O. (2013). An argumentative approach of conceptual modelling and model validation through theory building. *Proceedings of DESRIST 2013*, 242-257.

Blackler, A., Chen, L.H., Desai, S., & Astell, A. 2020. Intuitive Interaction Framework in User-Product Interaction for People Living with Dementia, HCI and Design in the Context of Dementia. *Human–Computer Interaction Series,* Springer, Cham.

Blass, M., Gimpel, H., Regal, C., & Waldmann, D. (2022). Individuals' Concerns Associated with Digital Healthcare: Professionals' and Patients' Hindrances to Adopt Digital Healthcare Services. *Proceedings of ECIS 2022*, 16.

Block, L., Gilmore-Bykovskyi, A., Jolliff, A., Mullen, S., & Werner, N.E. (2020). Exploring dementia family caregivers' everyday use and appraisal of technological supports. *Geriatric Nursing*, 41(6), 909-915.

Bloom, D., & Canning, D. (2008). Global Demographic Change: Dimensions and Economic Significance. *Population and Development Review*, 34, 17–51.

Blut, M. et al. (2022). Meta-analysis of the unified theory of acceptance and use of technology (UTAUT): challenging its validity and charting A research agenda in the red ocean. *Journal of the Association of Information Systems*.

Bochkovskiy, A., Wang, C.Y., & Liao, H.Y.M. (2020). Yolov4: Optimal speed and accuracy of object detection. arXiv:2004.10934.

Böhmer, M., Damarowsky, J., Kühnel, S., Parschat, S., & Mahn, V. A. (2022). Preserve Autonomy–Developing and Implementing a Design Theory for Augmented Living Spaces. *Proceedings of PACIS 2022*, Taipeh and Sydney (online).

Böhmer, M., Damarowsky, J., & Kuehnel, S. (2023). Implementing ALiS: Towards a Reference Architecture for Augmented Living Spaces. Proceedings of 56th Hawaii International Conference on System Sciences (HICSS), Maui, Hawaii, USA.

Böhmer, M. (2023). From Pixels to Generalization: Ensuring Information Security and Model Performance with Design Principles for Synthetic Image Data in Deep Learning. In *CIISR@ Wirtschaftsinformatik 2023*, 49-61.

Böhmer, M., Kendziorra, J., & Kuehnel, S. (2024). A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Cognitive Impairments. *Proceedings of ECIS 2024*, Paphos, Cyprus.

Böhmer, M., Kuehnel, S. & Damarowsky, J. (2025a). Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health. *Decision Support Systems* (awaiting decision).

Böhmer, M., Massler, P., Kuehnel, S., Damarowsky, J., & Sackmann, S. (2025b). Too hard to handle: empowering people with amnestic mild cognitive impairment through innovative human–computer interaction and innovative interfaces. *Behaviour & Information Technology*, 1-29.

Böhmer, M., Kuehnel, S., Damarowsky, J., & Brendel, A. B. (2025c). SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning. *The DATA BASE for Advances in Information Systems* (forthcoming).

Böhmer, M., Kuehnel, S., & Damarowsky, J. (2025d). Bridging the Gap Between Augmentation and Cognition: A Comparative Analysis of Wearable and Spatial Augmented Reality for People With aMCI. In *Impact of Digital Solutions for Improved Healthcare Delivery*, 409-444. IGI Global.

Bostrom, R. P., & Heinen, J. S. (1977). MIS problems and failures: A socio-technical perspective. Part I: The causes. *MIS Quarterly*, 17-32.

Bowen, G. A. (2008). Naturalistic inquiry and the saturation concept: a research note. Q*ualitative Research,* 8(1), 137-152.

Bozinovski, S., & Fulgosi, A. (1976). The influence of pattern similarity and transfer of learning upon training of a base perceptron B2. *Proceedings of Symposium Informatica*.

Brendel, A. B., Lembcke, T. B., & Kolbe, L. M. (2022). Towards an integrative view on design science research genres, strategies, and pivotal concepts in information systems research. *The DATA BASE for Advances in Information Systems*, 53(4), 9-23.

Brendel, A. B., & Muntermann, J. (2022). Replication of design theories: Reflections on function, outcome, and impact. *Information Systems Journal*, 32(6), 1158-1176.

Bryant, A., & Charmaz, K. (2007). Grounded theory in historical perspective: An epistemological account. *The SAGE Handbook of Grounded Theory*, 31-57

Burrell, G., & Morgan, G. (2019). *Sociological paradigms and organisational analysis: Elements of the sociology of corporate life*. Routledge.

Burton-Jones, A., Butler, B. S., Scott, S. V., & Xu, S. X. (2021). Next-Generation Information Systems Theorizing: A Call to Action. *MIS Quarterly*, 45(1).

Caprara, G., Vecchione, M., Barbaranelli, C. & Alessandri, G. (2013). Emotional stability and affective self–regulatory efficacy beliefs: Proofs of integration between trait theory and social cognitive theory. *European Journal of Personality*, 27(2), 145-154.

Cardoso, L.F., Mariano, F.C., & Zorzal, E.R. (2020). A survey of industrial augmented reality. *Computers & Industrial Engineering*, 139(1), 1-12.

Carillo, K. D. (2010). Social cognitive theory in is research–literature review, criticism, and research agenda. *Proceedings of ICISTM 2010*, 20-31.

Center for Universal Design (eds.) (2008). College of Design, North Carolina State University, https://projects.ncsu.edu/ncsu/design/cud/about_ud/udprinciples.htm.

Chandra, L., Seidel, S., & Gregor, S. (2015). Prescriptive knowledge in IS research: Conceptualizing design principles in terms of materiality, action, and boundary conditions. *Proceedings of HICSS 2015*, 4039-4048.

Chandra Kruse, L., Purao, S., & Seidel, S. (2022). How designers use design principles: design behaviors and application modes. *Journal of the Association for Information Systems*, 23(5), 1235-1270.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage Publications.

Chen, R.J., Lu, M.Y., Chen, T.Y., Williamson, D.F., & Mahmood, F. (2021). Synthetic data in machine learning for medicine and healthcare. *Nature Biomedical Engineering,* 5(6), 493-497.

Chen, H., & Levkoff, S.E. (2015). Delivering Telemonitoring Care to Digitally Disadvantaged Older Adults: Human-Computer Interaction (HCI) Design Recommendations. *Proceedings of ITAP 2015*. doi: 10.1007/978-3-319-20913-5_5.

Chhetri, C., & Genaro Motti, V. (2022). User-Centric Privacy Controls for Smart Homes. *Proceedings of the ACM on Human-Computer Interaction 6*, 1-36.

Chi, M. T., Glaser, R. & Rees, E. (1982). Expertise in problem solving. Learning Research and Development Center, University of Pittsburgh.

Chignell, M., Wang, L., Zare, A., & Li, J. (2023). The evolution of HCI and human factors: Integrating human and artificial intelligence. *ACM Transactions on Compututer-Human Interaction*, 30(2), 1-30. doi: 10.1145/3557891.

Chung, J. C., & Man, D. W. (2009). Self-appraised, informant-reported, and objective memory and cognitive function in mild cognitive impairment. *Dementia and Geriatric Cognitive Disorders*, 27(2), 187-193.

Churchman, C. W. (1971). *The design of inquiring system*. NY: Basic Books.

Cloutier, R., Muller, G., Verma, D., Nilchiani, R., Hole, E., & Bone, M. (2009). The concept of reference architectures. *Systems Engineering*, 13(1), 14-27.

Colantonio, S., Coppini, G., Giorgi, D., Morales, M.A., & Pascali, M.A. (2018). Computer vision for ambient assisted living: Monitoring systems for personalized healthcare and wellness that are robust in the real world and accepted by users, carers, and society. *Computer Vision for Assistive Healthcare*.

Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: Development of a measure and initial test. *MIS Quarterly*, 189-211.

Compeau, D., Higgins, C. A., & Huff, S. (1999). Social cognitive theory and individual reactions to computing technology: A longitudinal study. *MIS Quarterly*, 145-158.

Connell, B. R. (1997). The principles of universal design, version 2.0. http://www.design.ncsu.edu/cud/univ_design/princ_overview.htm.

Corbin, J. M. & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria, *Qualitative Sociology*, 13(1), 3-21.

Costa, P. D., Pires, L. F., & Van Sinderen, M. (2005). Architectural Patterns for Context-Aware Services Platforms. *Proceedings of IWUC 2005*, 3-18.

Dadgar, M., & Joshi, K. D. (2018). The role of information and communication technology in self-management of chronic diseases: an empirical investigation through value sensitive design. *Journal of the Association for Information Systems*, 19(2), 2.

Darden, L. & Maull, N. (1977). Interfield theories. *Philosophy of Science*, 44(1).

Davis, F.D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-340.

Dehling, T., & Sunyaev, A. (2024). A design theory for transparency of information privacy practices. *Information Systems Research*, 35(3), 956-977.

Deng, X., Joshi, K. D., & Galliers, R. D. (2016). The duality of empowerment and marginalization in microtask crowdsourcing. *MIS Quarterly*, 40(2), 279-302.

Denning, T., Borning, A., Friedman, B., Gill, B. T., Kohno, T., & Maisel, W. H. (2010). Patients, pacemakers, and implantable defibrillators: Human values and security for wireless implantable medical devices. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems 2010*, 917-926.

Denning, T., Kramer, D. B., Friedman, B., Reynolds, M. R., Gill, B., & Kohno, T. (2014). CPS: Beyond usability: Applying value sensitive design based methods to investigate domain characteristics for security for implantable cardiac devices. *Proceedings of the 30th Annual Computer Security Applications Conference 2014*, 426-435.

Dhiman, H., Wächter, C., Fellmann, M. et al. (2022). Intelligent Assistants. *Business Information Systems and Engineering*, 64, 645–665. doi: 10.1007/s12599-022-00743-1.

Di Donato, M., Fiorentino, M., Uva, A.E., Gattullo, M., & Monno, G. (2015). Text legibility for projected Augmented Reality on industrial workbenches. *Computers in Industry*, 70(1), 70–78.

Dickinson, A., Arnott, J., & Prior, S. (2007). Methods for human–computer interaction research with older people. *Behaviour & Information Technology*, 26(4), 343-352.

Donia, J., & Shaw, J. A. (2021). Ethics and values in design: A structured review and theoretical critique. *Science and Engineering Ethics*, 27(5).

Duan, Z., Tezcan, O., Nakamura, H., Ishwar, P., & Konrad, J. (2020). Rapid: rotation-aware people detection in overhead fisheye images. P*roceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition 2020*, 636-637.

Duggan, M., Torkzaban, B., Ahooyi, T. M., Khalili, K., & Gordon, J. (2020). Age-related neurodegenerative diseases. *Journal of Cellular Physiology*, 235(4), 3131-3141.

Easton, G. (2010). Critical realism in case study research. *Industrial Marketing Management*, 39(1), 118-128.

Emery, F. E., & Trist, E. L. (1960). *Socio-technical systems. Management science, models and techniques*, Vol. 2, 83-97.

Ericsson, K. A., Krampe, R. T. & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, 100(3), 363.

Fallon, M., Spohrer, K., & Heinzl, A. (2019). Deep structure use of mHealth: a social cognitive theory perspective. *Proceedings of ECIS 2019*.

Ferrari, V., Klinker, G., & Cutolo, F. (2019). Augmented reality in healthcare. *Journal of Healthcare Engineering*, doi: 10.1155/2019/9321535.

Findeli, A. (1994). Ethics, Aesthetics, and Design. *Design Issues*, 10(2), 49-68.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, 34(10), 906.

Flicker, C., Ferris, S.H., & Reisberg, B. (1991). Mild cognitive impairment in the elderly: predictors of dementia. *Neurology*, 41(7), 1006-1006.

Floridi, L., & Taddeo, M. (2016). What Is Data Ethics? Philosophical transactions. *Series A, Mathematical, Physical, and Engineering Sciences*.

Floridi, L., & Cowls, J. (2019). A Unified Framework of Five Principles for AI in Society. *Harvard Data Science Review*.

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, 18(1), 39-50.

Friedman, B., Kahn, P., & Borning, A. (2002). Value sensitive design: Theory and methods. *University of Washington Technical Report*, 2(8).

Friedman, B., Kahn, P. H., Borning, A., & Huldtgren, A. (2013). Value sensitive design and information systems. *Early engagement and new technologies: Opening up the laboratory*, 55-95.

Fu, K. K., Yang, M. C., & Wood, K. L. (2016). Design Principles: Literature Review, Analysis, and Future Directions. *Journal of Mechanical Design*, 138(10).

Gao, Y. (2019). Cognitive guidance and improvement of Alzheimer's disease patients based on human-computer interaction design. *Cognitive Systems Research*, 56, 192-202.

Garcés, L., Oquendo, F., & Nakagawa, E. Y. (2020). Assessment of reference architectures and reference models for ambient assisted living systems: Results of a systematic literature review, *International Journal of E-Health and Medical Communications*, 11(1), 17-36.

Gauthier, S. et al. (2006). Mild cognitive impairment. *The Lancet*, 367(9518), 1262-1270.

Gazzaniga, M., Ivry, R. & Mangun, G. (2018). *Cognitive Neuroscience: The Biology of the Mind*. WW Norton & Co, 5th Edition.

Gioia, D. A., & Pitre, E. (1990). Multiparadigm perspectives on theory building. *Academy of Management Review*, 15(4), 584-602.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, 16(1), 15–31.

Giuffrè, M., & Shung, D. L. (2023). Harnessing the power of synthetic data in healthcare: innovation, application, and privacy. *npj Digital Medicine*, 6(1), 186.

Glaser, B., & Strauss, A. (2017). *Discovery of grounded theory: Strategies for qualitative research*. Routledge.

Goldkuhl, G. (2004). Design theories in information systems-a need for multi-grounding. J*ournal of Information Technology Theory and Application*, 6(2), 7.

Gomes, A., Fernandes, K., & Wang, D. (2021). Surface Prediction for Spatial Augmented Reality Applications. *Virtual Reality*, 25(9), 1-11.

Gonzales, A., Guruswamy, G., & Smith, S. R. (2023). Synthetic data in health care: a narrative review. P*LoS Digital Health*, 2(1).

Graf, R., Benawri, P., Whitesall, A.E., Carichner, D., Li, Z., Nebeling, M., & Kim, H.S. (2019). IGYM: An Interactive Floor Projection System for Inclusive Exergame Environments. *Proceedings of CHI PLAY '19*, 31–43.

Greenaway, M.C., Hanna, S.M., Lepore, S.W., & Smith, G.E. (2008). A behavioral rehabilitation intervention for amnestic mild cognitive impairment. *American Journal of Alzheimer's Disease & Other Dementias*, 23(5), 451-461.

Grefen, P., & Vries, R. R. de (1998). A reference architecture for workflow management systems. *Data & Knowledge Engineering*, 27(1), 31-57.

Gregor, S. (2006). The nature of theory in information systems. *MIS Quarterly*, 611-642.

Gregor, S. & Jones, D. (2007). The Anatomy of a Design Theory. *Journal of the Association for Information Systems*, 8(5), 312-335.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly*, 337-355.

Gregor, S., Chandra Kruse, L., & Seidel, S. (2020). Research perspectives: the anatomy of a design principle. *Journal of the Association for Information Systems,* 21(6).

Gregory, R. W., & Muntermann, J. (2014). Research note—Heuristic theorizing: Proactively generating design theories. I*nformation Systems Research*, 25(3), 639-653.

Griebel, M., Dürr, A., & Stein, N. (2019). Applied image recognition: guidelines for using deep learning models in practice. *Proceedings of Wirtschaftsinformatik 2019*.

Grubert, J., Langlotz, T., Zollmann, S., & Regenbrecht, H. (2016). Towards pervasive augmented reality: Context-awareness in augmented reality. *IEEE Transactions on Visualization and Computer Graphics*, 23(6), 1706-1724.

Grundhöfer, A. & Iwai, D. (2018). Recent Advances in Projection Mapping Algorithms, Hardware and Applications. *Computer Graphics Forum*, 37(2), 653-675.

Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PloS one*, 15(5).

Hassan, N. R., Lowry, P. B., & Mathiassen, L. (2022). Useful products in information systems theorizing: A discursive formation perspective. J*ournal of the Association for Information Systems*, 23(2), 418-446.

Hansen, S., & Baroody, A. J. (2020). Electronic Health Records and the Logics of Care: Complementarity and Conflict in the U.S. Healthcare System. *Information Systems Research*, 31(1).

Haynes, S. N., Richard, D., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. P*sychological Assessment,* 7(3), 238.

Hennink, M. M., Kaiser, B. N., & Marconi, V. C. (2017). Code saturation versus meaning saturation: how many interviews are enough?. *Qualitative Health Research*, 27(4), 591-608.

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, 292, 114523.

Herwix, A., Haj-Bolouri, A., Rossi, M., Tremblay, M. C., Purao, S., & Gregor, S. (2022). Ethics in information systems and design science research: Five perspectives. *Communications of the Association for Information Systems*, 50(1), 589-616.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, 75-105.

Hevner, A. & Chatterjee, S. (2010). *Design Science Research in Information Systems: Theory and Practice*. Springer.

Hinterstoisser, S., Pauly, O., Heibel, H., Martina, M., & Bokeloh, M. (2019). An annotation saved is an annotation earned: Using fully synthetic training for object detection. In P*roceedings of the IEEE/CVF International Conference on Computer Vision Workshops 2019*.

Hirschheim, R., & Klein, H. K. (2012). A glorious and not-so-short history of the information systems field. *Journal of the Association for Information Systems*, 13(4), 5.

Hoque, Z., Covaleski, M. A., & Gooneratne, T. N. (2013). Theoretical triangulation and pluralism in research methods in organizational and accounting research. *Accounting, Auditing & Accountability Journal*, 26(7), 1170-1198.

Huang, B., Sun, T., & Ling, H. (2021). End-to-end Full Projector Compensation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1-16.

Hung, P. C. K., & Cheng, V. S. Y. (2009). Privacy. *Encyclopedia of Database Systems*. Boston, MA, Springer US, 2136-2137.

Hulland, J. (1999). Use of partial least squares (PLS) in strategic management research: A review of four recent studies. *Strategic Management Journal*, 20(2), 195-204.

Hwang, W. & Salvendy, G. (2010). Number of people required for usability evaluation: the 10+-2 rule. *Communications of the ACM*, 53(5), 130-133.

Ienca, M., Schneble, C., Kressig, R. W., & Wangmo, T. (2021). Digital health interventions for healthy ageing: a qualitative user evaluation and ethical assessment. *BMC Geriatrics*, 21, 1-10.

Ifinedo, P. (2012). Understanding information systems security policy compliance: An integration of the theory of planned behavior and the protection motivation theory. *Computers & Security*, 31(1).

Iivari, J. (2015). Distinguishing and contrasting two strategies for design science research. *European Journal of Information Systems*, 24(1), 107-115.

Iivari, J. (2020). A critical look at theories in design science research. *Journal of the Association for Information Systems*, 21(3), 10.

Iivari, J., Rotvit Perlt Hansen, M., & Haj-Bolouri, A. (2021). A proposal for minimum reusability evaluation of design principles. *European Journal of Information Systems*, 30(3), 286-303.

Iversen, T.R., & Joshi, S.G. (2015). Exploring spatial interaction in assistive technology through prototyping. *Procedia Manufacturing*, 3, 158-165.

Jamieson, S. (2004). Likert scales: How to (ab) use them?. *Medical Education*, 38(12), 1217-1218.

Jean, L., Bergeron, M.È., Thivierge, S., & Simard, M. (2010). Cognitive intervention programs for individuals with mild cognitive impairment: systematic review of the literature. *The American Journal of Geriatric Psychiatry*, 18(4), 281-296.

Jiang, L., London, J., Grover, V., & Sun, H. (2022). Everything old can be new again: Reinvigorating theory borrowing for the digital age. *MIS Quarterly*, 46(4): 1833-1850.

Jones, D., & Gregor, S. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, 8(5), 1.

Jongsiriyanyong, S., & Limpawattana, P. (2018). Mild cognitive impairment in clinical practice: a review article. *American Journal of Alzheimer's Disease & Other Dementias*, 33(8), 500-507.

Jozan, M. M. B., Ghorbani, B. D., Khalid, M. S., Lotfata, A. & Tabesh, H. (2023). Impact assessment of e-trainings in occupational safety and health: a literature review. *BMC Public Health,* 23.

Julious, S.A. (2005). Sample size of 12 per group rule of thumb for a pilot study. *Pharmaceutical Statistics: The Journal of Applied Statistics in the Pharmaceutical Industry*, 4(4): 287-291.

Kane, G. C., Young, A. G., Majchrzak, A., & Ransbotham, S. (2021). Avoiding an oppressive future of machine learning: A design theory for emancipatory assistants. *MIS Quarterly*, 45(1), 371-396.

Kankanhalli, A., Tan, B. C. & Wei, K. K. (2005). Contributing knowledge to electronic knowledge repositories: An empirical investigation. *MIS Quarterly*, 113-143.

Karahanna, E., Straub, D. W. & Chervany, N. L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quaterly*, 23(2).

Kenei, J. K. & Opiyo, E. (2022). Using classification and visualization to support clinical texts review in electronic clinical documentation. *Proceedings of ICMHI 2022*, 78-84.

Kern, C. J., Noeltner, M., & Kroenung, J. S. (2022). The case of digital ethics in IS research – A literature review. *Proceedings of ICIS 2022*.

Kim, E. & Han, S. (2021). Determinants of continuance intention to use health apps among users over 60: A test of social cognitive model. *International Journal of Environmental Research and Public Health*, 18(19), 10367.

Klein, K. J., & Kozlowski, S. W. (2000). From micro to meso: Critical steps in conceptualizing and conducting multilevel research. *Organizational Research Methods*, 3(3), 211-236.

Klein, K. J. & Kozlowski, S. W. (2000). From micro to meso: Critical steps in conceptualizing and conducting multilevel research. *Organizational Research Methods*, 3(3), 211-236.

Kobayashi, D., Hashimoto, N. et al. (2014). Spatial augmented reality by using depth-based object tracking. *Proceedings of ACM SIGGRAPH '14*. ACM, New York, Article 33.

Kosch, T., Wennrich, K., Topp, D., Muntzinger, M., & Schmidt, A. (2019). The digital cooking coach: using visual and auditory in-situ instructions to assist cognitively impaired during cooking. *Proceedings of PETRA '19*. ACM, New York, USA, 156–163.

Kotter, J. P. (1996). *Leading Change*. Harvard Business Review Press.

Kriglstein, S., Leitner, M., Kabicher-Fuchs, S., & Rinderle-Ma, S. (2016). Evaluation methods in process-aware information systems research with a perspective on human orientation. *Business Information Systems and Engineering*, 58, 397-414. doi: 10.1007/s12599-016-0427-3.

Krump, M., Ruß, M., & Stütz, P. (2020), Deep learning algorithms for vehicle detection on UAV platforms: First investigations on the effects of synthetic training. *Proceedings of MESAS 2019*, Palermo, 50–70.

Kucharski, A., & Fabijańska, A. (2023). Corneal endothelial image segmentation training data generation using GANs. Do experts need to annotate? *Biomedical Signal Processing and Control*, 85, 104985.

Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: anatomy of a research project. *European Journal of Information Systems*, 17(5), 489-504.

Kuehnel, S., Neuhaus, U., Kaufmann, J., Schulz, M., & Alekozai, E. M. (2023). Using the Data Science Process Model Version 1.1 (DASC-PM v1. 1) for Executing Data Science Projects: Procedures, Competencies, and Roles. In *Apply Data Science: Introduction, Applications and Projects,* 119-134. Wiesbaden: Springer Fachmedien Wiesbaden.

Kuhnke, F., & Ostermann, J. (2019). Deep head pose estimation using synthetic images and partial adversarial domain adaption for continuous label spaces. *Proceedings of IEEE/CVF International Conference on Computer Vision 2019*, 10164-10173.

Kyratsis, Y., Scarbrough, H., Begley, A. & Denis, J. L. (2022). Digital health adoption: Looking beyond the role of technology. *Frontiers in Digital Health*, 4, 989003.

Lahiri, A., Agarwalla, A., & Biswas, P. K. (2018). Unsupervised domain adaptation for learning eye gaze from a million synthetic images: An adversarial approach. *Proceedings of Indian Conference on Computer Vision, Graphics and Image Processing*, 1-9.

Larsen, K., Lukyanenko, R., Muller, R., Storey, V., Parsons, J., Vander Meer, D., & Hovorka, D. (2025). Validity in Design Science. *MIS Quarterly* (Pre-Print), arXiv preprint arXiv:2503.09466.

Lee, A. S. (1991). Integrating positivist and interpretive approaches to organizational research. *Organization Science*, 2(4), 342-365.

Lee, J. S., Pries-Heje, J., & Baskerville, R. (2011). Theorizing in design science research. *Proceedings of DESRIST 2011,* Milwaukee, WI, USA, Springer.

Lee, Y.Y., Lee, J.H., Ahmed, B., Son, M.G., & Lee, K.H. (2019). A New Projection-based Exhibition System for a Museum. *Journal on Computing and Cultural Heritage*, 12(2), 1-17.

Leidner, D. E., & Gregory, R. W. (2024). About theory and theorizing. *Journal of the Association for Information Systems*, 25(3), 501-521.

Li, X., et al. (2015). Design theory for market surveillance systems. *Journal of Management Information Systems*, 32(2), 278-313.

Lin, C., Lu, S., Lai, Z., Chebotko, A., Fei, X., Hua, J., & Fotouhi, F. (2008). Service-Oriented Architecture for VIEW: a visual scientific workflow management. *Proceedings of SCC 2008*, 335-342.

Lin, T.Y., Maire, M., et al. (2014). Microsoft coco: Common objects in context. *Proceedings of the 13th Computer Vision Conference ECCV 2014*, 740-755.

Lindlbauer, D., Mueller, J., & Alexa, M. 2017. Changing the Appearance of Real-World Objects By Modifying Their Surroundings. *Proceedings of CHI 2017*, 3954–3965.

Linstone, H. A. (1981). The multiple perspective concept: With applications to technology assessment and other decision areas. *Technological Forecasting and Social Change*, 20(4), 275-325.

Linstone, H. A. (1999). *Decision making for technology executives: using multiple perspectives to improved performance*. Artech House Publishers.

Lönngren, J., & Van Poeck, K. (2021). Wicked problems: A mapping review of the literature. *International Journal of Sustainable Development & World Ecology*, 28(6), 481-502.

Luhmann, N. (1996). The sociology of the moral and ethics. *International Sociology*, 11(1), 27-36.

Luís-Ferreira, F., Zamiri, M., Sarraipa, J., McManus, G., O'Brien, P., & Gonçalves, R. (2019). Survey on assistive technologies for people with Dementia. I*EEE Instrumentation & Measurement Magazine*, 22(6), 45-52.

Lukyanenko, R., & Parsons, J. (2020). Research perspectives: design theory indeterminacy: what is it, how can it be reduced, and why did the polar bear drown? *Journal of the Association for Information Systems*, 21(5).

Lupton, D. (2017). Towards Design Sociology. *Sociology Compass*, 12(1).

Maedche, A., Legner, C., Benlian, A. et al. (2019). AI-Based Digital Assistants. *Business Information Systems and Engineering*, 61, 535–544. doi: 10.1007/s12599-019-00600-8.

Magnani, G., & Gioia, D. (2023). Using the Gioia Methodology in international business and entrepreneurship research. *International Business Review*, 32(2), 102097.

Mallas, A., Xenos, M., & Katsanos, C. (2022). A Descriptive Model of Passive and Natural Passive Human-Computer Interaction. Human-Computer Interaction: Theoretical Approaches and Design Methods. *Proceedings of the 24th HCI International Conference*, 104-116.

Mandviwalla, M. (2015). Generating and justifying design theory. J*ournal of the Association for Information Systems*, 16(5), 3.

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, 15(4), 251-266.

Margrett, J.A., Ouverson, K.M., Gilbert, S.B., Phillips, L.A., & Charness, N. (2022). Older adults' use of extended reality: A systematic review. *Frontiers in Virtual Reality,* 2, 760064.

Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in qualitative research? A review of qualitative interviews in IS research. *Journal of Computer Information Systems*, 54(1), 11-22.

Mathews, S.C., McShea, M.J., Hanley, C.L. et al. (2019). Digital health: a path to validation. *npj Digitial Medicine*, 2(38). doi: 10.1038/s41746-019-0111-3.

Mavropoulos, T., Symeonidis, S. et al. (2021). Smart integration of sensors, computer vision and knowledge representation for intelligent monitoring and verbal human-computer interaction. *Journal of Intelligent Information Systems*, 57(2), 321-345. doi: 10.1007/s10844-021-00648-7.

Mayring, P., & Fenzl, T. (2019). *Qualitative Inhaltsanalyse.* Springer Fachmedien Wiesbaden.

McBride, N. (2014). Active ethics: An information systems ethics for the internet age. *Journal of Information Communication and Ethics in Society*, 12.

Melenhorst, A. S., Rogers, W. A., & Caylor, E. C. (2001). The use of communication technologies by older adults: exploring the benefits from the user's perspective. In P*roceedings of the Human Factors and Ergonomics Society Annual Meeting*, 45(3), 221-225.

Memon, M., Wagner, S. R., Pedersen, C. F., Beevi, F. H. A. & Hansen, F. O. (2014). Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. *Sensors*, 14(3), 4312-4341.

Meth, H., Mueller, B., & Maedche, A. (2015). Designing a requirement mining system. *Journal of the Association for Information Systems*, 16(9).

Migo, E.M., O'daly, O., Mitterschiffthaler, M. et al. (2016). Investigating virtual reality navigation in amnestic mild cognitive impairment using fMRI. *Aging, Neuropsychology, and Cognition,* 23(2), 196-217.

Mingers, J., & Brocklesby, J. (1997). Multimethodology: Towards a framework for mixing methodologies. *Omega*, 25(5), 489-509.

Mingers, J. (2001). Combining IS research methods: towards a pluralist methodology. *Information Systems Research*, 12(3), 240-259.

Mingers, J. (2004). Real-izing information systems: critical realism as an underpinning philosophy for information systems. *Information and Organization*, 14(2), 87-103.

Mingers, J., Mutch, A., & Willcocks, L. (2013). Critical realism in information systems research. *MIS Quarterly*, 37(3), 795-802.

Mitroff, I. I., & Linstone, H. A. (1995). *The unbounded mind: Breaking the chains of traditional business thinking*. Oxford University Press.

Miyamoto, J., Koike, H., & Amano, T. (2018). Gaze navigation in the real world by changing visual appearance of objects using projector-camera system. *Proceedings of VRST 2018*, 1–5.

Möller, F., Schoormann, T., Strobel, G., & Hansen, M. R. P. (2022). Unveiling the Cloak: Kernel Theory Use in Design Science Research. *Proceedings of ICIS 2022*.

Möller, F., Guggenberger, T. M., & Otto, B. (2020). Towards a method for design principle development in information systems. *Proceedings of DESRIST 2020.* Cham: Springer Nature Switzerland.

Möller, F., Schoormann, T., Ciriello, R., & Hansen, M. R. P. (2024). Dialectical Tensions in Design Theorizing: Exploring the Selection, Use, and Development of Kernel Theory. *Proceedings of DESRIST 2024*, 197-212. Cham: Springer Nature Switzerland.

Morgan, D. L. (1997). *Focus groups as qualitative research*, Vol. 16. Sage.

Morgan, S. J., Pullon, S. R., Macdonald, L. M., McKinlay, E. M., & Gray, B. V. (2017). Case study observational research: A framework for conducting case study research where observation data are the focus. *Qualitative Health Research*, 27(7), 1060-1068.

Morris, J.M. (1994). User interface design for older adults. *Interacting with Computers,* 6(4), 373-393.

Mostaghel, R. (2016). Innovation and technology for the elderly: Systematic literature review. *Journal of Business Research*, 69(11), 4896-4900.

Mousavi Hondori, H., Khademi, M., Dodakian, L. et al. (2013) A spatial augmented reality rehab system for post-stroke hand rehabilitation. *Proceedings of Medicine Meets Virtual Reality 20*, IOS Press.

Mueller, M. & Heger, O. (2018). Health at Any Cost? Investigating Ethical Dimensions and Potential Conflicts of an Ambulatory Therapeutic Assistance System through Value Sensitive Design. *Proceedings of ICIS 2018*, 17.

Mueller, M., Heger, O., & Niehaves, B. (2018). Exploring Ethical Design Dimensions of a Physiotherapeutic mHealth Solution through Value Sensitive Design. P*roceedings of Americas Conference on Information Systems 2018*.

Müller, M., Casser, V., Lahoud, J., Smith, N., & Ghanem, B. (2018), Sim4cv: A photo-realistic simulator for computer vision applications. *International Journal of Computer Vision*, 126, 902-919.

Müller-Wienbergen, F., Müller, O., Seidel, S., & Becker, J. (2011). Leaving the beaten tracks in creative work–A design theory for systems that support convergent and divergent thinking. *Journal of the Association for Information Systems*, 12(11), 2.

Mumford, E. (2006). The story of socio-technical design: Reflections on its successes, failures and potential. *Information Systems Journal*, 16(4), 317-342.

Murtaza, H., Ahmed, M., Khan, N. F., Murtaza, G., Zafar, S., & Bano, A. (2023). Synthetic data generation: State of the art in health care domain. *Computer Science Review*, 48, 100546.

Myers, M. D., & Venable, J. R. (2014). A set of ethical principles for design science research in information systems. *Information & Management*, 51(6), 801-809.

Nakagawa, E. Y., Oliveira Antonino, P., & Becker, M. (2011). Reference architecture and product line architecture: A subtle but critical difference. *Proceedings of European Conference on Software Architecture 2011*, 207-211. Berlin, Heidelberg: Springer.

Nastjuk, I., Trang, S., Grummeck-Braamt, J.V., Adam, M.T., & Tarafdar, M. (2023). Integrating and Synthesising Technostress Research: A Meta-Analysis on Technostress Creators, Outcomes, and IS Usage Contexts. *European Journal of Information Systems*. doi: 10.1080/0960085X.2022.2154712.

Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems*, 22(3), 336-359.

Niederman, F., & March, S. (2019). The "theoretical lens" concept: We all know what it means, but do we all know the same thing?. *Communications of the Association for Information Systems*, 44(1), 1.

Nielsen, J. (1994). *Usability engineering*. Morgan Kaufmann.

Noushad, B., Van Gerven, P. W., & De Bruin, A. B. (2024). Twelve tips for applying the think-aloud method to capture cognitive processes. *Medical Teacher*, 46(7), 892-897.

Nunnally, J. C. (1978). *Psychometric Theory*, 2. McGraw-Hill, New York.

Obermeyer, Z., Powers, B., Vogeli, C., & Mullainathan, S. (2019). Dissecting racial bias in an algorithm used to manage the health of populations. *Science*, 366(6464), 447–453.

Offermann, P., Blom, S., Schönherr, M., & Bub, U. (2011). Design range and research strategies in design science publications. *Proceedings of DESRIST 2011*, 77-91.

Oussalah, M. C. (2023). *Software Architecture 2.* Wiley.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. (2013). A framework for responsible innovation. In *Responsible innovation: managing the responsible emergence of science and innovation in society*, 27-50.

O'Neil, P. M. (2004). Ethics. In *Ethics* J.K. Roth (ed.). California, Salem Press.

Paas, F. & Van Merriënboer, J. J. (1994). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review*, 6(4), 351-371.

Paas, F., Renkl, A. & Sweller, J. (2003). Cognitive Load Theory and instructional design: Recent developments. *Educational Psychologist,* 38(1), 1-4.

Pak, J., & Song, Y. T. (2016). Health capability maturity model: person-centered approach in personal health record system. *Proceedongs of AMCIS 2016*.

Panch, T., Szolovits, P., & Atun, R. (2018). Artificial intelligence, machine learning and health systems. *npj Digital Medicine*, 1(1), 1–3.

Petersen, R.C., Roberts, R.O., Knopman, D.S. et al. (2009). Mild cognitive impairment: ten years later. *Archives of Neurology,* 66(12), 1447-1455.

Petersen, R.C. (2016). Mild cognitive impairment. *CONTINUUM: Lifelong Learning in Neurology,* 22(2), 404-418.

Petersen, R.C., Lopez, O., Armstrong, M.J. et al. (2018). Practice guideline update summary: Mild cognitive impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. *Neurology*, 90(3), 126-135.

Pourmirza, S., Peters, S., Dijkman, R., & Grefen, P. (2019). BPMS-RA: a novel Reference Architecture for Business Process Management Systems. *ACM Transactions on Internet Technology*, 19(1), 1-23.

Prakash, A.V. & Das, S. (2020). Intelligent conversational agents in mental healthcare services: A thematic analysis of user perceptions. *Pacific Asia Journal of the Association for Information Systems*, 12(2), 1.

Preum, S.M., Munir, S. et al. (2021). A review of cognitive assistants for healthcare: Trends, prospects, and future directions. *ACM Computing Surveys,* 53(6), 1-37.

Rai, A., Burton-Jones, A., Chen, H., Gupta, A., Hevner, A. R. et al. (2017). Editor's comments: Diversity of design science research. *MIS Quarterly,* 41(1).

Raji, I. D., Gebru, T., Mitchell, M., Buolamwini, J., Lee, J., & Denton, E. (2020). Saving face: Investigating the ethical concerns of facial recognition auditing. *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society 2020*, 145–151.

Rajkomar, A., Hardt, M., Howell, M. D., Corrado, G., & Chin, M. H. (2018). Ensuring fairness in machine learning to advance health equity. *Annals of Internal Medicine*, 169(12), 866–872.

Rajkomar, A., Dean, J., & Kohane, I. (2019). Machine learning in medicine. *New England Journal of Medicine*, 380(14), 1347–1358.

Raskar, R., Welch, G., &Fuchs, H. (1998). Spatially Augmented Reality. *First International Workshop on Augmented Reality*, San Francisco.

Rieder, A., Lehrer, C., Eseryel, U. Y., & Jung, R. (2020). The Generative Mechanisms Behind Technology-Enabled Changes in Health Behavior. *Proceedings of ECIS 2020*.

Ro, H., Park, Y.J., Byun, J.H., & Han, T.D. (2019). Display methods of projection augmented reality based on deep learning pose estimation. *Proceedings of ACM SIGGRAPH 2019*, ACM, New York.

Robey, D. (1996). Research commentary: diversity in information systems research: threat, promise, and responsibility. *Information Systems Research*, 7(4), 400-408.

Rodriguez, M. A., & Buyya, R. (2017). Scientific Workflow Management System for Clouds. In *Software architecture for big data and the cloud*, I. Mistrik, R. Bahsoon, N. Ali, M. Heisel & B. R. Maxim (Eds.), Cambridge, MA: Elsevier, 367-387.

Rowe P.G. (1987). *Design Thinking*, MIT Press, Cambridge, MA.

Russell, S. J., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach*. Pearson.

Saborowski, M., & Kollak, I. (2015). How do you care for technology? – Care professionals' experiences with assistive technology in care of the elderly. *Technological Forecasting and Social Change*, 93(1), 133-140.

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health,* 18(2), 179-183.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B. et al. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & Quantity*, 52, 1893-1907.

Schak, M., Blum, R., & Bomsdorf, B. (2022). Smart Home for the Elderly - A Survey of Desires, Needs, and Problems. P*roceedings of HCII 2022, Lecture Notes in Computer Science*, 13331. Springer, Cham. doi: 10.1007/978-3-031-05654-3_7.

Scheck, T., Seidel, R., & Hirtz, G. (2020). Learning from theodore: A synthetic omnidirectional top-view indoor dataset for deep transfer learning. *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision 2020*, 943-952.

Schermann, M., Böhmann, T., & Krcmar, H. (2009). Explicating design theories with conceptual models: Towards a theoretical role of reference models. *Wissenschaftstheorie und gestaltungsorientierte Wirtschaftsinformatik*, 175-194.

Schlagwein, D. et al. (2019). Ethical Norms and Issues in Crowdsourcing Practices: A Habermasian Analysis. *Information Systems Journal,* 29(4), 811-837.

Schmidt, J., Marques, M. R., Botti, S., & Marques, M. A. (2019). Recent advances and applications of machine learning in solid-state materials science. *npj Computational Materials*, 5(1), 83.

Schoormann, T., Behrens, D., Fellmann, M., & Knackstedt, R. (2018). Sorry, Too Much Information Design Principles for Supporting Rigorous Search Strategies in Literature Reviews. *Proceedings of CBI 2018*, 99-108.

Schoormann, T., Möller, F., & Chandra Kruse, L. (2022). Uncovering strategies of design principle development. *Proceedings of DESRIST 2022.*

Schoormann, T., Möller, F., Chandra Kruse, L., & Otto, B. (2024). BAUSTEIN—A design tool for configuring and representing design research. *Information Systems Journal*, 34(6), 1871-1901.

Schultz, M., & Hatch, M. J. (1996). Living with multiple paradigms the case of paradigm interplay in organizational culture studies. *Academy of Management Review*, 21(2), 529-557.

Seib, V., Lange, B., & Wirtz, S. (2020). Mixing Real and Synthetic Data to Enhance Neural Network Training - A Review of Current Approaches. arXiv:2007.08781.

Seifert, A., & Schlomann, A. (2021). The use of virtual and augmented reality by older adults: Potentials and challenges. *Frontiers in Virtual Reality*, 2, 51.

Shepherd, D. A., & Sutcliffe, K. M. (2011). Inductive top-down theorizing: A source of new theories of organization. *Academy of Management Review,* 36(2), 361-380.

Siepmann, C., & Kowalczuk, P. (2021). Understanding continued smartwatch usage: the role of emotional as well as health and fitness factors. *Electronic Markets,* 31(4), 795-809.

Singh, R., Mathiassen, L., Stachura, M. E., & Astapova, E. V. (2011). Dynamic capabilities in home health: IT-enabled transformation of post-acute care. *Journal of the Association for Information Systems*, 12(2), 2.

Singh, N., & Varshney, U. (2020). IT-based reminders for medication adherence: systematic review, taxonomy, framework and research directions. *European Journal of Information Systems*, 29(1), 84-108.

Siregar, J. A., & Tan, M. T. (2004). Leveraging Theoretical Pluralism in qualitative IS research: The example of IS professionals' identity as a complex phenomenon. *Proceedings of ECIS 2004*, 171.

Smith, G. F. (1992). Towards a theory of managerial problem solving. *Decision Support Systems*, 8(1), 29-40.

Spiekermann, S. et al. (2022). Values and Ethics in Information Systems. *Business & Information Systems Engineering*, 64(2), 247-264.

Steffen, J. H., Gaskin, J. E., Meservy, T. O., Jenkins, J. L., & Wolman, I. (2019). Framework of affordances for virtual reality and augmented reality. *Journal of Management Information Systems*, 36(3), 683-729.

Steinert, S., & Dennis, M. J. (2022). Emotions and digital well-being: On social media's emotional affordances. *Philosophy & Technology*, 35(2), 36.

Stilgoe, J., Owen, R., & Macnaghten, P. (2020). Developing a framework for responsible innovation. In *The Ethics of Nanotechnology, Geoengineering, and Clean Energy*, 347-359.

Strang, T. & Linnhoff-Popien, C. (2004). A context modeling survey. *Proceedings of the First International Workshop on Advanced Contextual Modelling, Reasoning and Management*, Nottingham, UK.

Sutton, R. I. & Staw, B. M. (1995). What theory is not. *Administrative Science Quarterly*, 371-384.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257-285.

Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10, 251-296.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive Load Theory*. Springer Science & Business Media.

Sweller, J. (2023). The Development of Cognitive Load Theory: Replication Crises and Incorporation of Other Theories Can Lead to Theory Expansion. *Educational Psychology Review,* 35(4), 95.

Takahashi, R., Matsubara, T., & Uehara, K. (2018). Ricap: Random image cropping and patching data augmentation for deep cnns. *Proceedings of the Asian Conference on Machine Learning 2018*, 786-798.

Tavares, P., Costa, C.M., Rocha, L., Malaca, P., Costa, P., Moreira, A.P., Sousa, A., & Veiga, G. (2019). Collaborative Welding System using BIM for Robotic Reprogramming and Spatial Augmented Reality. *Automation in Construction*, 106(1), 1-12.

Tazari, M. R., Furfari, F., Ramos, J. P. L., & Ferro, E. (2010). The PERSONA service platform for AAL spaces. *Handbook of Ambient Intelligence and Smart Environments,* Springer, 1171-1199.

Tezcan, O., Duan, Z., Cokbas, M., Ishwar, P., & Konrad, J. (2022). WEPDTOF: A Dataset and Benchmark Algorithms for In-the-Wild People Detection and Tracking from Overhead Fisheye Cameras. *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision 2022*, 503-512.

Tobin, J., Fong, R., Ray, A., Schneider, J., Zaremba, W., & Abbeel, P. (2017). Domain randomization for transferring deep neural networks from simulation to the real world. *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems 2017*, 23-30.

Treiblmaier, H., Putz, L. M. & Lowry, P. B. (2018). Setting a definition, context, and theory-based research agenda for the gamification of non-gaming applications. *AIS Transactions on Human-Computer Interaction*, 10(3), 129-163.

Tremblay, M., Vander Meer, D., & Beck, R. (2018). The effects of the quantification of faculty productivity: perspectives from the design science research community. *Communications of the Association for Information Systems,* 43, 625-661.

Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the longwall method of coal-getting: An examination of the psychological situation and defences of a work

group in relation to the social structure and technological content of the work system. *Human Relations*, 4(1), 3-38.

Truex, D., Holmström, J., & Keil, M. (2006). Theorizing in information systems research: A reflexive analysis of the adaptation of theory in information systems research. *Journal of the Association for Information Systems*, 7(1), 33.

Turja, T. et al. (2020). Robot Acceptance Model for Care (Ram-Care): A Principled Approach to the Intention to Use Care Robots. *Information & Management*, 57(5).

Tuunanen, T., Winter, R., & vom Brocke, J. (2024). Dealing with complexity in design science research: A methodology using design echelons. *MIS Quarterly*, 48(2).

Vaishnavi, V.K., & Kuechler, W. (2015). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*, 2nd Edition. CRC Press. https://doi.org/10.1201/b18448

Valtchev, S.Z., & Wu, J. (2021). Domain randomization for neural network classification. *Journal of Big Data,* 8(1), 94.

Van Den Haak, M., De Jong, M., & Jan Schellens, P. (2003). Retrospective vs. concurrent think-aloud protocols: testing the usability of an online library catalogue. *Behaviour & Information Technology*, 22(5), 339-351.

Vayena, E., Blasimme, A., & Cohen, I. G. (2018). Machine learning in medicine: Addressing ethical challenges. *PLoS Medicine*, 15(11), e1002689.

Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: a framework for evaluation in design science research. *European Journal of Information Systems*, 25(1), 77-89.

Venable, J. R., Pries-Heje, J., & Baskerville, R. L. (2017). Choosing a design science research methodology. *Proceedings of ACIS 2017.*

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 425-478.

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems. *MIS Quarterly,* 21-54.

Venkateswara, H. et al. (2017). Deep-learning systems for domain adaptation in computer vision: Learning transferable feature representations. *IEEE Signal Processing Magazine*, 34(6), 117-129.

Vertucci, R., D'Onofrio, S., Ricciardi, S., & De Nino, M. (2023). History of augmented reality. In *Springer Handbook of Augmented Reality*, 35-50. Cham: Springer International Publishing.

Vines, J., Pritchard, G., Wright, P., Olivier, P., & Brittain, K. (2015). An age-old problem: Examining the discourses of ageing in HCI and strategies for future research. *ACM Transactions on Computer-Human Interacion*, 22(1): 1-27. doi: 10.1145/2696867.

Von Arnim, C. A., Bartsch, T., Jacobs, A. H. et al. (2019). Diagnosis and treatment of cognitive impairment. *Zeitschrift für Gerontologie und Geriatrie,* 52(4).

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.

Walls, J. G., Widmeyer, G. R., & El Sawy, O. A. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research*, 3(1), 36-59.

Walls, J. G., Widermeyer, G. R., & El Sawy, O. A. (2004). Assessing information system design theory in perspective: how useful was our 1992 initial rendition?. *Journal of Information Technology Theory and Application*, 6(2), 6.

Wan, L., Zhou, J., & Zhang, B. (2020). Data Synthesis for Document Layout Analysis. *International Symposium on Emerging Technologies for Education*, 244-252.

Wegerich, A., Dzaack, J., & Roetting, M. (2010). Optimizing virtual superimpositions: User-centered design for a UAR supported smart home system. *Proceedings of IFAC*, 43(13), 71-76.

Weimann, T. G., Schlieter, H. & Brendel, A. B. (2022). Virtual coaches: Background, theories, and future research directions. *Business & Information Systems Engineering*, 64(4), 515-528.

Wertsch, J. V. (1984). The zone of proximal development: Some conceptual issues. *New directions for child development*, 23, 7-18.

WFMC (ed.) 1995. *The Workflow Reference Model*, TC00-1003.

Whetten, D. A. (1989). What constitutes a theoretical contribution?, *Acadamy of Management Review,* 14(4).

Wiesche, M., Jurisch, M. C., Yetton, P. W. & Krcmar, H. (2017). Grounded theory methodology in information systems research, *MIS Quarterly*, 41(3).

Williams, P.A., Jenkins, J.L. & Valacich, J.S. (2016). Real-Time Hand Tremor Detection via Mouse Cursor Movements for Improved Human-Computer Interactions: An Exploratory Study. *Workshop on the SIG HCI 2016.*

Wilson, G., & Cook, D.J. (2020). A survey of unsupervised deep domain adaptation. *ACM Transactions on Intelligent Systems and Technology*, 11(5), 1-46.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in software engineering*. Springer Science & Business Media.

Wolf, T., Trang, S., Weiger, W. H. & Trenz, M. (2023). The technology-behavioral compensation effect: Unintended consequences of health technology adoption. *Journal of Information Technology, 39(3)*.

Woo, C., Saghafi, A. & Rosales, A. (2014). What is a Contribution to IS Design Science Knowledge? *Proceedings of ICIS 2014,* Auckland.

Wutich, A., Beresford, M., and Bernard, H. R. (2024). Sample Sizes for 10 Types of Qualitative Data Analysis: An Integrative Review, Empirical Guidance, and Next Steps. *International Journal of Qualitative Methods*, 23.

Wynn Jr, D., & Williams, C. K. (2012). Principles for conducting critical realist case study research in information systems. *MIS Quarterly*, 787-810.

Xu, B., Yang, Z., Jiang, S., Zhou, Z., Jiang, B., & Yin, S. (2020). Design and validation of a spinal surgical navigation system based on spatial augmented reality. *Spine*, 45(23), E1627-E1633.

Yang, L., QI, L., & Zhang, B. (2022). Concepts and evaluation of saturation in qualitative research. *Advances in Psychological Science*, 30(3), 511.

Yang, Y., Park, Y.J., Ro, H., Chae, S., & Han, T.D. (2018). CARe-bot: Portable Projection-based AR Robot for Elderly. *Companion of HRI 2018*. ACM, 384.

Yang, L., Hu, G., Song, Y., Li, G., & Xie, L. (2020). Intelligent video analysis: A Pedestrian trajectory extraction method for the whole indoor space without blind areas. *Computer Vision and Image Understanding*, 196, 102968.

Yetim, F. (2011). Bringing discourse ethics to value sensitive design: pathways toward a deliberative future. *AIS Transactions on Human-Computer Interaction*, 3(2), 133-155.

Young, A. G., Majchrzak, A., & Kane, G. C. (2021). Reflection on writing a theory paper: How to theorize for the future. *Journal of the Association for Information Systems*, 22(5), 1212-1223.

Young, A. G., & Zhu, Y. (2021). Emancipatory Design Science: A Method of Designing IT for Social Good. *Proceedings of ICIS 2021*.

Yu, K. H., Beam, A. L., & Kohane, I. S. (2018). Artificial intelligence in healthcare. *Nature Biomedical Engineering*, 2(10), 719-731.

Yu, S., Chai, Y., Chen, H., Brown, R. A., Sherman, S. J., & Nunamaker Jr, J. F. (2021). Fall detection with wearable sensors: A hierarchical attention-based convolutional neural network approach. *Journal of Management Information Systems*, 38(4), 1095-1121.

Yu, J., Seidel, R., & Hirtz, G. (2019). Omnipd: One-step person detection in top-view omnidirectional indoor scenes. *Current Directions in Biomedical Engineering*, 5(1), 239-244.

Yu, J., Lam, C.L., & Lee, T.M. (2017). White matter microstructural abnormalities in amnestic mild cognitive impairment: A meta-analysis of whole-brain and ROI-based studies. *Neuroscience & Biobehavioral Reviews*, 83, 405-416.

Zhang, X. et al. (2018), Stacked multichannel autoencoder - An efficient way of learning from synthetic data. *Multimedia Tools and Applications*, 77, 26563–26580.

Zhu, H., Samtani, S., Chen, H., & Nunamaker Jr, J. F. (2020). Human identification for activities of daily living: A deep transfer learning approach. *Journal of Management Information Systems*, 37(2), 457-483.

Zoccarato, F., Manzoni, M., Minotti, D., Lettieri, E., & Boaretto, A. (2024). Unveiling the interplay between rational, psychological and functional factors in continuous glucose monitoring early adoption: Novel evidence from the Dexcom ONE case in Italy. *BMC Health Services Research*, 24(1), 747.

Zorin, D., & Barr, A.H. (1995). Correction of geometric perceptual distortions in pictures. *Proceedings of the 22nd Annual Conference on Computer Graphics and Interactive Techniques*, 257-264.

Appendix

Appendix A

Author's statement on the work shares in the Article: "Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health"

The article "*Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health*" was co-authored. The following table gives an overview of the authors' contributions to the article.

Authors

Martin Böhmer	MB
Stephan Kuehnel	SK
Johannes Damarowsky	JD

Aspect	**Authors**
Research concept	MB, SK
Research methodology	MB, SK
Problem definition and objective	MB, SK, JD
Literature review	MB
Conceptualization of the topic	MB, SK
Implementation and evaluation of the focus group	MB
Implementation and evaluation of the observational study	MB
Definition & conceptualization of design theory	MB, SK
Definition & conceptualization of the reference architecture	MB
Conducting and evaluating the evaluation episodes	MB
Adaptation of the concepts and relationships of design theory and reference architecture	MB, SK, JD
Qualitative and taxonomic classification of design theory and reference architecture	MB, SK, JD
Visualization of the research methodology	MB
Visualization of the theory	MB
Theoretical implications	MB, SK
Practical implications	MB
Discussion of limitations and further research	MB, SK
Conclusion	MB
Preparation of the manuscript	MB

Revision of the manuscript and the argumentation	MB, SK, JD
Review and revision before submission	MB, SK
Revision after review	-

Appendix B

Full text of the Article: “Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health”

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Decision Support Systems

Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health

--Manuscript Draft--

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Abstract:	As global demographic shifts intensify, amnestic mild cognitive impairment (aMCI) becomes an increasing challenge for digital healthcare, requiring assistive technologies that go beyond compensatory support to scaffold cognitive function actively. This paper develops a design theory for Enhanced Living Environments (ELiE), conceptualizing a Spatial Augmented Reality (SAR)-based decision support system as an adaptive cognitive scaffold that dynamically regulates assistance to promote autonomy preservation in individuals with aMCI. Using Vygotsky's zone of proximal development as a core theory, our study applies a heuristic design theorizing approach within the design science research paradigm, integrating context-aware SAR interfaces, multimodal sensor input, and workflow management systems to create an adaptive digital assistance system. The iterative development and evaluation of a prototypical instantiation demonstrate how ELiE enables intuitive, non-wearable, and dynamically adjusting support mechanisms that adjust as users internalize cognitive strategies, reducing technological dependence over time. Our contributions to the IS and DSR knowledge base include prescriptive design knowledge in the form of a design theory that provides actionable guidance for the design of cognitively adaptive healthcare IS. By bridging theoretical insights with practical implementation, this research advances digital health decision support in IS, SAR applications in healthcare, and the design of digital assistance systems for neurodegenerative diseases, paving the way for future innovations in human-centered, AI-driven adaptive health technologies.

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Heuristically Theorizing Prolonged Autonomy for Individuals With Amnestic Mild Cognitive Impairment: A Design Theory and Reference Architecture for Enhanced Living Environments in Digital Health

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Abstract: As global demographic shifts intensify, amnestic mild cognitive impairment (aMCI) becomes an increasing challenge for digital healthcare, requiring assistive technologies that go beyond compensatory support to scaffold cognitive function actively. This paper develops a design theory for Enhanced Living Environments (ELiE), conceptualizing a Spatial Augmented Reality (SAR)-based decision support system as an adaptive cognitive scaffold that dynamically regulates assistance to promote autonomy preservation in individuals with aMCI. Using Vygotsky's zone of proximal development as a core theory, our study applies a heuristic design theorizing approach within the design science research paradigm, integrating context-aware SAR interfaces, multimodal sensor input, and workflow management systems to create an adaptive digital assistance system. The iterative development and evaluation of a prototypical instantiation demonstrate how ELiE enables intuitive, non-wearable, and dynamically adjusting support mechanisms that adjust as users internalize cognitive strategies, reducing technological dependence over time. Our contributions to the IS and DSR knowledge base include prescriptive design knowledge in the form of a design theory that provides actionable guidance for the design of cognitively adaptive healthcare IS. By bridging theoretical insights with practical implementation, this research advances digital health decision support in IS, SAR applications in healthcare, and the design of digital assistance systems for neurodegenerative diseases, paving the way for future innovations in human-centered, AI-driven adaptive health technologies.

Keywords: enhanced living environments, amnestic mild cognitive impairment, spatial augmented reality, design theory, reference architecture, zone of proximal development theory

1. Introduction

Global demographic shifts, particularly an aging population, are contributing to a rise in neurodegenerative diseases, including Amnestic Mild Cognitive Impairment (aMCI) - a condition characterized by memory deficits, reduced executive function, and difficulties in performing complex daily activities [1,2,3]. While individuals with aMCI retain functional everyday autonomy, they often struggle with cognitive tasks such as planning, decision-making, and remembering, leading to a progressive decline in independent living abilities [3,4,5]. Digital assistance systems in the form of ambient assisted living (AAL) technologies or decision support systems have emerged to support individuals with cognitive impairments [6,7]. However, existing AAL approaches and decision support primarily focus on passive monitoring (e.g., fall detection or daily activity tracking) rather than actively engaging users in cognitive scaffolding processes that enable self-regulation, preservation of autonomy, and learning [8]. It has been shown that the adoption and use behavior (i.e., interaction with technology) of people with cognitive impairment, which may or may not include the elderly, differs from that of the general population, often requiring tailored approaches and interfaces that are more intuitive and less complex, as cognitive factors such as task difficulty, cognitive load, and their social environment affect the adoption process [9,10]. This reveals a critical research gap: while digital assistance systems can provide environmental awareness and safety measures, they lack a theoretically grounded framework to ensure that their interventions promote long-term autonomy and cognitive resilience rather than inducing dependency.

Augmented Reality (AR) has been examined as a potential solution for assisting individuals with aMCI in performing daily tasks. By integrating digital information into the physical environment, AR can provide contextual support to users struggling with memory and executive function impairments. However, head-mounted AR solutions

(HMDs), a common AR approach, pose significant challenges for individuals with cognitive impairments, including limited battery life, complex interfaces, reduced fields of view, and increased cognitive distractions [11,12,13]. An alternative to HMD-based AR is Spatial Augmented Reality (SAR), which utilizes projected, non-wearable visual overlays and interactive elements within a user's environment [14,15]. SAR reduces cognitive load while increasing accessibility and usability, making it a promising approach for non-intrusive, real-time cognitive assistance. Despite its potential, SAR remains underexplored in cognitive assistance research, with most studies focusing on industrial applications rather than personalized, adaptive healthcare interventions [16,17]. Furthermore, current research lacks a guiding theoretical foundation for how SAR-based digital assistance systems should be designed, structured, and implemented to facilitate progressive learning, adoption, and adaptation. Existing solutions focus on static reminders or task-specific automation [18,19], neglecting the dynamic cognitive needs of users with aMCI.

To address this challenge, we incorporate Vygotsky's [20] *Zone of Proximal Development* (ZPD) as kernel theory that provides a cognitive learning perspective for designing digital assistance systems that support progressive autonomy building or preservation. The ZPD conceptualizes the gap between tasks an individual can perform independently and those that require guided assistance, emphasizing adaptive scaffolding, intersubjectivity, and semiotic mediation as mechanisms that support cognitive development/adaptation [20,21]. Applied to digital health IS and decision support systems, ZPD suggests that assistive systems should not simply compensate for cognitive impairments but should guide users through structured learning experiences that enable them to internalize cognitive strategies and gradually reduce their reliance on external

interventions. By framing *Enhanced Living Environments*[1] (ELiE) within ZPD, this study advances digital assistance research by conceptualizing SAR-based systems as cognitive scaffolds rather than mere tools for task automation. In doing so, our research bridges a critical gap in AAL and digital health decision support by demonstrating how assistive systems can function as adaptive learning environments that dynamically adjust support based on a user's cognitive trajectory.

As such, the primary objective of this study is to develop a design theory (DT) for ELiEs - SAR-based digital assistance systems that dynamically adapt cognitive support to the evolving needs of cognitively impaired users. Unlike conventional assistive technologies that focus on static task support, ELiEs are designed to function as an interactive learning and support system that engages users in progressive autonomy building and preservation rather than reinforcing dependency. To achieve this, we are investigating the following research question (RQ):

RQ: *How can spatial augmented reality be effectively integrated into a decision support system to support the autonomy and cognitive functions of people with amnestic mild cognitive impairments?*

To answer this question, we adopt heuristic design theorizing [22] in a theory-driven design configuration [23] within the Design Science Research (DSR) paradigm [24]. Our study contributes to IS research in two ways. First, we iteratively develop and refine Design Requirements (DRs) and Design Principles (DPs) over two design cycles using ZPD as a guiding theoretical framework to ensure that ELiE is designed to scaffold cognitive learning, facilitate intersubjectivity, and promote gradual task internalization. Also incorporating practical foundations from focus group and observational study

[1] The term has been amended to ensure a double-blind peer review process.

findings in the context of aMCI, we present a DT that embodies a theoretical framework for how such ELiEs can be conceptualized. Second, as a by-product of the heuristic theorizing process, we develop a Reference Architecture (RA) for ELiEs that illustrates how SAR, context-aware sensors, and Workflow Management Systems (WFMS) can be integrated to create an adaptive digital assistance system that functions as an interactive cognitive learning environment. This RA is then used in the ideation and prototyping steps of the heuristic theorizing to operationalize the developed DT in a prototypical scenario and decision support system, which is evaluated by both our target group of individuals with aMCI and digital health experts. This ensures that our theorized design insights are not only conceptually rigorous but also practically actionable, establishing new design principles for cognitive scaffolding in digital assistance systems. Our study may demonstrate how assistive systems can transition from compensatory tools to adaptive cognitive scaffolds that promote progressive autonomy for individuals with aMCI. A key implication of our study is that ZPD can be extended beyond human facilitators to SAR- and AI-driven adaptive decision support systems, demonstrating that digital assistance technologies can serve as "more knowledgeable others" by modulating their level of intervention based on a user's cognitive state.

The remainder of the paper is organized as follows: Section 2 presents our research design and methodology, detailing the heuristic design theorizing and theory-driven process. Section 3 outlines the theoretical foundations and ZPD as kernel theory for an ELiE conceptualization. It also describes the practical foundations of our research, including a moderated focus group (MFG) and an observational study. Section 4 then presents the resulting DT with a subsequent instantiation through an RA in Section 5. Section 6 discusses the evaluation episodes, followed by Section 7, which outlines theoretical and practical implications, research limitations, and directions for future work.

2. Research Design

We drew on the DSR paradigm (Hevner et al., 2004), as our study seeks to provide prescriptive insights for research on cognitive support in enhanced living environments, rather than merely descriptive knowledge, as outlined by Gregor and Hevner [25]. Given that the DSR paradigm can be instantiated through a variety of methodological processes [26], and that design theories, in general, embody a form of theorizing in IS research [27,28,29,22,30,31,32,33] our study can be placed in the *theorizing* domain of the DSR focus matrix [27], which implies a higher focus on rigor and derivation of theoretical artifacts. This matrix domain generally involves using higher-level kernel theories (i.e., in our case, zone of proximal development theory) to form new design theories for a given problem space (i.e., in our case, cognitive support for individuals with aMCI in digital health IS). In this domain, the development of design principles and propositions, similar (but not equal) to hypothesis formulation, plays a central role, emphasizing the importance of grounding new theories in prior knowledge [27,23].

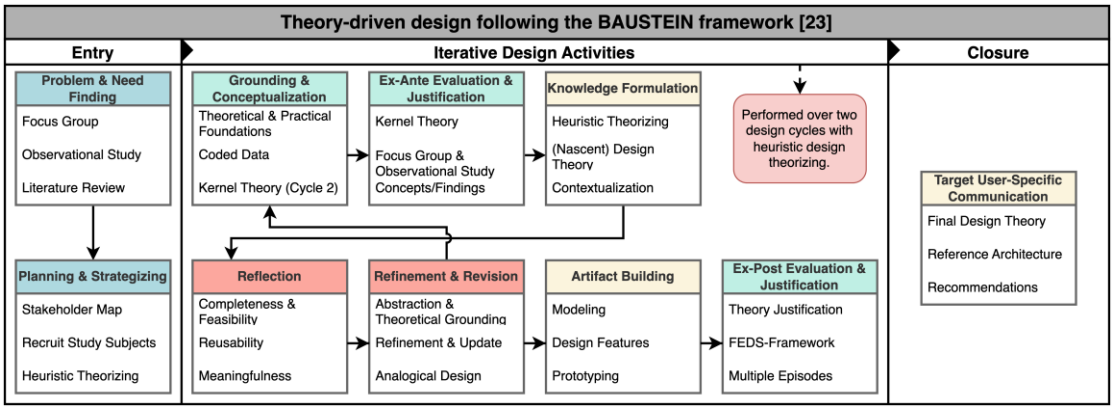


Figure 1. Theory-driven design configuration following Schoormann et al. [23].

To structure our theorizing process, we adopted configuration 4 *Theory-Based Design* from Schoormann et al. [23] as an overarching framework, which supports the systematic derivation of design theories by iterating between abstraction and application. As shown in Figure 1, this configuration enabled us to align DRs and DPs with an iterative intake of a kernel theory and evaluation findings, ensuring their theoretical grounding before operationalization. As such, we iteratively refined our design knowledge through abductive reasoning, balancing theoretical rigor with practical applicability as well as the

option to reflect and refine the (nascent) DT whenever we found a non-satisficing solution. The structured ex-post evaluation further ensured coherence and generalizability, reinforcing the validity of our emerging design theory.

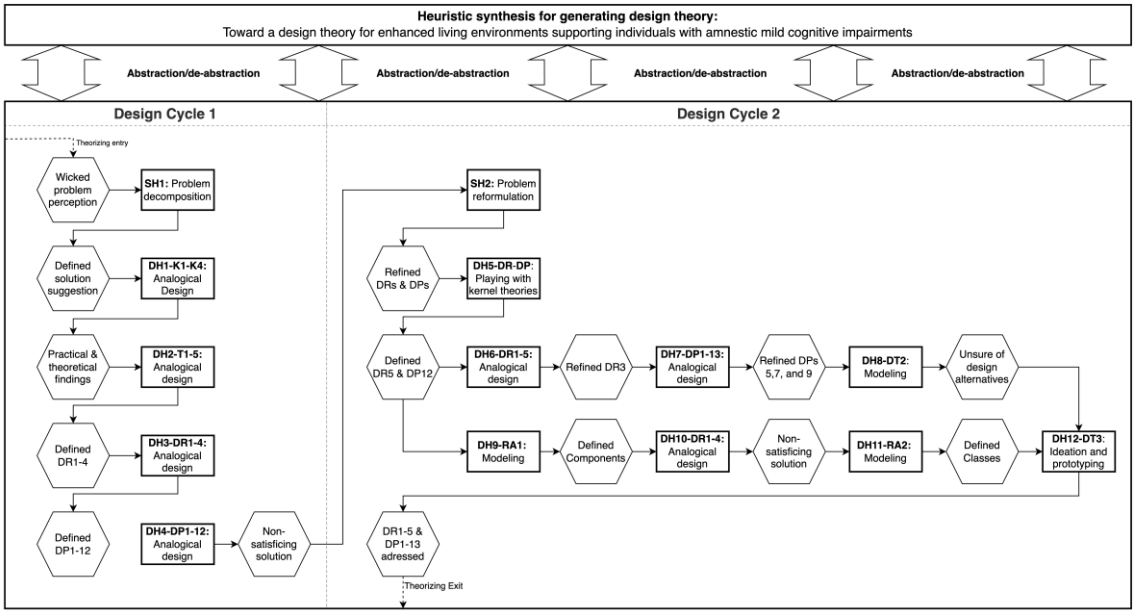


Figure 2. Heuristic design theorizing approach, adapted from Gregory and Muntermann [22].

Note: SH=structuring heuristics; DH=artifact design heuristics; DR=design requirement; DP=design principle; DT=design theory; RA=reference architecture.

Following the heuristic design theorizing framework proposed by Gregory and Muntermann [22], our approach emphasizes the iterative and intertwined processes of problem structuring, artifact design, and theorizing, which is consistent with proactively generating design theory. Heuristic theorizing, as applied in this research (Figure 2), integrates problem-solving activities with theorizing through heuristic search and synthesis. This framework guided the development of our design theory through two iterative design cycles. These cycles alternated between structuring wicked problems (e.g., addressing the needs of individuals with amnestic mild cognitive impairment), playing with kernel theories, and synthesizing new knowledge through iterative artifact design and modeling (i.e., both the design theory and reference architecture). Each

iteration included abstraction (i.e., deriving general design knowledge) and de-abstraction (i.e., applying general knowledge to specific problems), as described in Gregory and Muntermann [22]. Here, our design theorizing approach is located in the abstract theoretical domain, seeking an abstract solution that solves an abstract problem and using abductive reasoning because there is an objective to guide learning and problem-solving [31].

From a more metatheoretical perspective of our theorizing approach, and in line with the general design theory development directions mentioned above, we followed the *envision*-strategy proposed by Burton-Jones et al. [28] for next-generation theorizing. In doing so, our proposed design theory helps to study new phenomena (i.e., SAR coupled with context-aware components in healthcare) emerging in a *changing world* (i.e., demographic change and increased occurrence of neurodegenerative diseases), which effectively leads to a new IS theory. Therefore, a multi-method research approach [35] consisting of a focus group and observational study session for data collection coupled with six evaluation episodes (think-aloud sessions and questionnaires) for evaluating the theorized artifacts was chosen to address the shortcomings of single methods and ensure validity. While the heuristic design theorizing process does not require formal evaluation [22], we incorporated these evaluation episodes to align our design theory with the broader principles of DSR, ensuring both theoretical rigor and practical applicability. As such, our iterative, heuristic process of data collection and analysis ensured that the findings from these sessions were continually refined.

Therefore, this paper presents the approach and results of both design cycles, with the DT refined through the lens of our kernel theory compared to its first nascent iteration. Hence, our theorizing process employed problem-structuring and artifact-design heuristics throughout the two design cycles. In the first cycle, we decomposed the

problem space into subproblems related to user needs and system requirements (SH1: Problem Decomposition). Analogical design (DH1) was used to derive initial DRs and DPs based on literature, prior knowledge, and practical foundations (i.e., focus group and observational study) based on user-centered design [35]. These heuristics enabled us to iteratively refine the artifact design, leading to an initial nascent design theory [Anonymized].

Facing a non-satisficing solution with this nascent DT in terms of its actionability [36], the second cycle focused on addressing limitations identified in the first cycle, expanding the theoretical grounding of the artifact, and operationalizing the DT. Problem reformulation (SH2) was used to reevaluate and redefine system objectives, followed by iterative ideation and prototyping (DH6) to address newly identified requirements and operationalize the design theory artifact. Additionally, the kernel theory of ZPD [20,21] was integrated into the design by "playing with kernel theories" (DH5), ensuring that the resulting principles were theoretically grounded and revising the initial nascent DT. In addition, as part of the modeling steps in heuristic design theorizing [22], we developed an initial component-level RA [Anonymized], which in turn was revised into a more thorough class-level representation of the problem solution after encountering a non-satisficing solution. Hence, for this study, we used different types of representation of the problem solution to graphically, conceptually, or technically capture artifact solution components for both the DT and RA (e.g., Figures 5 and 9) as a kind of DSS [37,38,22]. This is also consistent with Gregor and Jones' [39] expanded definition of a *design theory*, which states that knowledge is developed about why an IS artifact behaves the way it does. To provide reference design knowledge on a possible instantiation of the DPs into a software artifact, we derive DFs to address the established DPs [40] and ensure they are actionable [41]. Even though not a required part of a DT (cf. [42]), DFs can be utilized to

document how DPs could be implemented in a specific instance (see e.g., [43]). The DFs then serve as a basis to systematically develop UML diagrams and textual descriptions that utilize a common visual development language to model and document the conceptual structure of our ELiE system.

3. Theoretical and Practical Foundations

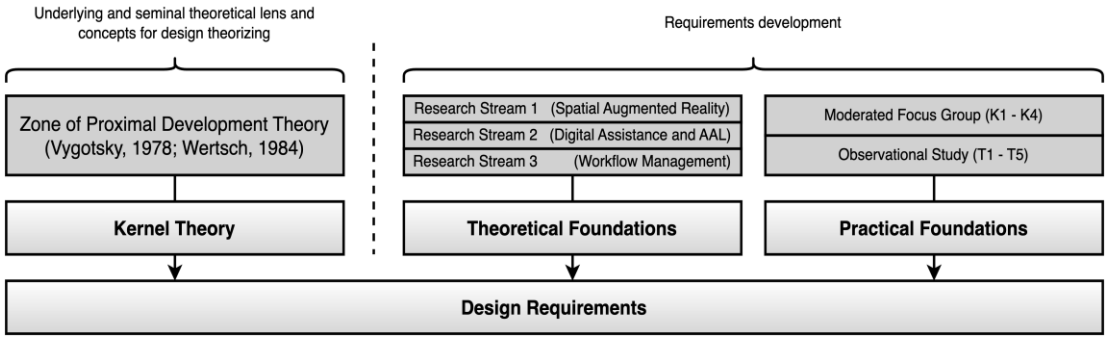


Figure 3. Synthesis of the kernel theory, theoretical, and practical foundations

Our research motivation draws from a real-world issue, namely, the adequate cognitive support of aMCI people to maintain and foster their autonomy in everyday life while accounting for their impairments. The highlighted problem originates from several observation studies prior to our research as well as the ongoing global demographic change (see, e.g., [1]). We analyzed the scientific literature to identify kernel theories and appropriate research streams that define and frame our problem-centered approach. These theoretical foundations are fortified by methodologically underpinned focus group and observation study findings. Figure 3 depicts the synthesis of the kernel theory, theoretical literature streams, and practical foundations from which we developed our DRs. To avoid a possible order bias (e.g., focus group prior to observation), the focus groups and observational studies were each conducted with different subjects. We also ensured that observations, focus group facilitation, and analyses were conducted independently by different researchers with a common understanding of the topic.

3.1 Theoretical Lens and Kernel Theory

To maintain scientific rigor and strict methodology, DSR efforts may employ kernel theories to derive foundational DPs. The genesis of novel systems is grounded not merely in prototyping and user participation, but fundamentally hinges on a kernel theory [44]. Essentially, these serve as a form of foundational knowledge in the field of design knowledge development, as pointed out by Gregor and Hevner [25], including the formulation of DPs, as highlighted in the research of Gregor et al. [45]. Therefore, leveraging a kernel theory as a foundational framework facilitates the delineation of normative prescriptions within DTs, guiding both the strategies and methodologies to be employed in achieving specific solutions through design. Consequently, our study adopts the *analyze with lens*-mechanism proposed by Möller et al. [46], which includes the use of kernel theories for in-depth analysis. Incorporating such a theoretical framework allowed us to extract theory concepts indirectly, thereby guiding the analysis and structuring of data within the defined boundaries of a particular theory. Also, theoretical lenses offer support for the formulation of meta-requirements and DPs [47].

The development of digital assistance systems for individuals with aMCI requires a theoretical foundation that captures both the cognitive processes involved in learning and the adaptive nature of assistance mechanisms. Traditional models in digital health and assistive technologies often prioritize usability, efficiency, and automation, but they lack a clear framework for understanding how individuals internalize assistance and progress toward greater autonomy. Vygotsky's [20] *Zone of Proximal Development Theory* (ZPD) provides a robust sociocultural lens for addressing this gap, emphasizing the dynamic interplay between guidance, learning, and independent functioning. In general, it conceptualizes the distance between what an individual can accomplish independently and what they can accomplish with guidance from a more knowledgeable

other, traditionally a human facilitator such as a teacher or peer – or a tool. For this study, we extend this to the context of digital health technologies, where ELiE serve as the more knowledgeable other. Through the use of real-time adaptations and cognitive scaffolding, ELiE facilitates transitions from dependence on external assistance to greater independence in managing cognitive challenges. Building on Wertsch's [21] elaboration of ZPD, we incorporate three central theoretical constructs that deepen the applicability of this theory to digital interventions.

First, Wertsch [21] emphasizes the importance of how individuals and systems define and represent a given situation or task context. In ZPD, the process of collaboration often involves misaligned representations of the task by the facilitator and the learner. For example, a person with aMCI may interpret a task such as setting reminders differently than the system intended, potentially leading to confusion or failure to engage effectively. We address this by negotiating shared representations of tasks through context-sensitive interactions, ensuring that interventions are tailored to the user's understanding and abilities. This dynamic reinterpretation of context underscores the need for adaptive digital environments that actively reconstruct situation definitions to facilitate effective collaboration.

Second, a critical aspect of ZPD is the negotiation of shared understanding between facilitator and learner, referred to as intersubjectivity [20,21]. In the context of digital health, intersubjectivity is established when ELiE and its users co-construct a shared understanding of goals, tasks, and actions. Wertsch [21] emphasizes that achieving intersubjectivity requires iterative exchanges that bridge the diverse perspectives of participants and foster alignment over time. We intend to operationalize this by using interactive interfaces and semiotic feedback mechanisms to align user goals with system functionality, enabling mutual understanding and smoother transitions to autonomy.

Third, both Vygotsky [20] and Wertsch [21] emphasize the role of tools, symbols, and language as mediators in the learning process. In digital systems, semiotic mediation is realized through visual, auditory, and interactive cues that guide users in interpreting tasks and actions. For individuals with aMCI, semiotic mediation enables ELiE to transform abstract cognitive challenges into manageable, concrete steps. By progressively internalizing these steps, users move from relying on external cues to independently managing their tasks, such as daily reminders or cognitive exercises. Wertsch's [21] insights into the role of linguistic and symbolic mediation underscore the importance of designing assistive systems that not only support task completion but also facilitate cognitive transformation.

Wertsch [21] argues that growth within the ZPD often involves a qualitative redefinition of the learner's understanding rather than a mere quantitative improvement. In the context of this study, this means designing for cognitive transitions that allow users to redefine their relationship with technology - from external reliance to integrated cognitive support. By embedding the concepts of situation definition, intersubjectivity, and semiotic mediation, we aim to use this lens to transcend the limitations of static assistive systems and evolve a digital tool into a dynamic, learning-oriented environment. As such, this study positions ELiE as an adaptive learning environment rather than a passive assistive tool. Unlike traditional assistive systems that assume a one-way model of support (where users receive static interventions or reminders), a ZPD-based framework envisions a progressive reduction of support as users internalize cognitive strategies. This theoretical foundation thus aligns with the broader goal of promoting independence rather than dependency, a key concern in designing ethical and sustainable digital health interventions for individuals with aMCI. Furthermore, using ZPD as a theoretical lens allows for a more nuanced understanding of the human-technology

relationship in assistive environments. Rather than focusing solely on system efficiency or user acceptability, this perspective highlights the process-oriented nature of learning and adaptation in digital interventions, making it particularly relevant for users with progressive cognitive impairments who require continuous yet flexible support.

3.2 Research Streams and Gap

In accordance with our DSR approach and to define the objectives of a solution to the aforementioned problem, we analyzed the scientific literature on the research streams of digital assistance systems, AAL, SAR, and workflow management. While considerable research has been conducted in each of these research streams, a holistic and unifying approach is lacking (see Figure 4). Nevertheless, each of these research streams has provided valuable insights, such as guidelines for the use of SAR, specific requirements for AAL for the elderly and aMCI, and RAs for WFMSs, which will be discussed in the following paragraphs.

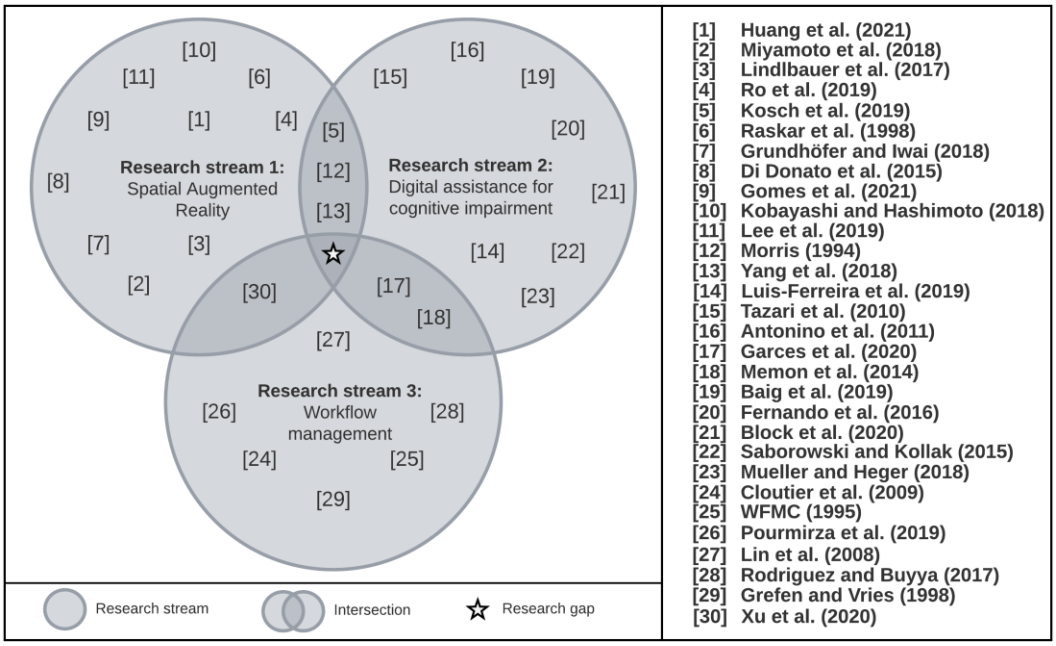


Figure 4: Venn diagram for classifying research streams

Note: Number references in brackets are not consistent with the general referencing in the paper.

To ensure state-of-the-art results, the analysis of the first research stream was performed on current ontologies and techniques of SAR, where key findings cover, inter alia, error-free compensation methods for projection [48], projection manipulation [49,50], ideal projection surfaces [51], and successful practical applications of SAR in different areas such as cooking assistance for cognitively impaired people [51]. Furthermore, the conceptualization of ELiEs is based on the work of Raskar et al. [14] on SAR, which introduced the idea of surface shape extraction, rendering methods, and acquisition artifacts. These concepts have been further developed by subsequent research in the field, as identified by our literature stream analysis. Grundhöfer and Iwai [53] provide a comprehensive overview of the current state-of-the-art algorithms, hardware, and applications of projection mapping in SAR. Di Donato et al. [54] conducted significant work on exploring different surface projections to determine the most suitable surfaces for SAR. The use of artificial intelligence to enable projection onto moving objects has also been explored in recent studies [55,56,57].

The analysis of the second research stream targeted digital assistance systems as well as AAL in health care, identifying possible technical and conceptual IS architectures that capture the essence of existing applications and could serve as a guide for developing user-centric requirements. Key findings include guidelines for projection design [58], SAR as a method for digital assistance in health care [18], and sensor technology for digital assistance systems [59]. Moreover, we identified conceptual [60] and technical [61] RAs for digital assistance and AALs for the elderly. Beyond that, Garces et al. [62] and Memon et al. [63] showed that current systems lack a holistic approach, quality, and modularity while being elusive and difficult to understand. A more connective and contextual perspective was revealed in the work of Baig et al. [64], who conducted a systematic analysis of wearable sensors in the context of the Internet of Things (IoT) for

individuals in need of care. Furthermore, the work of Fernando et al. [65] provides foundational requirements for smart assisted living, and Block et al. [66] conducted interviews with caregivers of cognitively impaired individuals to explore the use and acceptance of digital assistance systems. These systems are perceived by caregivers as a valuable addition to health care [67]. Additionally, the study by Kosch et al. [52] examines the extent to which decision rules and decision points can be formulated for a smart kitchen environment for cognitively impaired individuals and the potential design implications that can be derived. The ethical considerations of digital assistance systems for elderly individuals are also of significant importance, as addressed by Mueller and Heger [68], who translated fundamental values into concrete norms and formulated specific DRs for a digital assistance system in physical therapy to prevent potential conflicts.

A holistic, SAR-based assistance system for elderly and aMCI people critically utilizes complex reasoning and highly individual needs processes. Therefore, we analyzed the third research stream on incorporating RAs for WFMSs that could potentially serve as blueprints or guidelines for developing concrete workflow concepts behind ELiE and thus, being consistent with the definition of RAs according to Cloutier et al. [69]. We found the WFMC [70] as the most popular RA, with the architecture of Pourmirza et al. [71] building upon that as well as Grefen and Vries' RA [72] to provide an RA for business process management systems. We further conducted a review of existing RAs for WFMSs focusing on service-oriented design that addresses complex and dynamic processes as found in the context of ELiEs. Our findings indicated that Lin et al. [73] proposed a "visual scientific" WFMS with a service-oriented design. Additionally, Rodriguez and Buyya [74] discussed a cloud-based WFMS for scientific processes. As of yet, consideration of workflow management approaches concerning SAR has been

under-explored and only superficially addressed in the healthcare domain for spine surgery [75].

As can be seen in Figure 3, to the best of our knowledge, a holistic, highly modular, flexible, and demand-driven approach to assisting the elderly and aMCI has yet to emerge (highlighted with ☆ in the middle of the diagram). Looking at research stream 2, most of the AAL and digital assistance systems only cover specific disease patterns (i.e., employing easy-to-use solutions rather than cognitively tailored ones), while there is still a research gap in SAR-based approaches. Regarding the intersection between research streams 1 and 2, it can be seen that SAR-based assistance systems covering both domains are scarce, remain basic [58], lack holistic orientation [52,18], and neglect workflow management. Furthermore, workflow management research in the area of digital assistance for the elderly and cognitively impaired (intersection between research streams 2 and 3) is only superficially covered, with Garces et al. [62] and Memon et al. [63] calling for holistic, modular, and innovative healthcare approaches. The intersection between research streams 1 and 3 also revealed that workflow-related research in SAR is underexplored, as it relates to very specific areas of medical surgery [75]. In addition to our kernel theories and from a theoretical perspective, we used the literature findings to derive requirements for AAL, the use of SAR, and WFMSs (see Figure 4).

3.3 Moderated Focus Group

After the analysis of the described research streams and kernel theories, we further conducted an MFG with healthcare specialists and an observation study with our target group that was aimed at rigorously deriving DRs, matching them to the literature analysis findings, and establishing them in the DT. MFGs as a qualitative method are useful to gain deep insights into a subject and the development of prototypes [76]. Furthermore,

and through our theoretical user-centered design lens, MFGs enable a strong discussion of issues and requirements concerning the intended artifact [35].

Our MFG consisted of n=10 participants, including five caregivers in the field of cognitive impairment, two AR healthcare experts, and three IS researchers with healthcare and decision support system development backgrounds. The goal was to develop user-specific requirements for varying degrees of aMCI. In this context, we decided not to directly involve the target group, i.e., people with aMCI, because they tend to have reduced and biased assessments of their daily lives with cognitive impairment [77]. On the other hand, the accompanying caregivers tend to have a more unbiased view regarding the needs, actions, and challenges of aMCI people and thus can provide a better data foundation. To contextually evaluate the transcribed protocols, the method of *qualitative content analysis* according to Mayring and Fenzl [78] was utilized, which is an iterative process that involves developing categories and subcategories inductively from the collected data, followed by deductive categorization using a coding frame. The underlying content-analytical communication model [78] implies the direction of the analysis to generate statements about the emotional, cognitive, and action-oriented background of the subjects. In this context, inductive categories were formed as the central instrument of the analysis, which further contain sub-categories. The corresponding developed categories (***K#***) can be formulated as follows:

- **K1:** everyday life of mild cognitively impaired and care-dependent people;
- **K2:** challenges regarding cognitively impaired people;
- **K3:** development of cognitively impaired persons over time;
- **K4:** cognitive and physical condition.

An important aspect of the MFG was to gain an in-depth insight into the everyday life of aMCI persons (**K1**). Here, the focus group participants particularly emphasized the structure of everyday life and considered it to be of decisive relevance. This includes everyday processes, with the focus mainly on meals. The everyday structure of aMCI persons is largely determined by the individual itself, whereby key points (e.g. meals, occupation, hygiene, etc.) are largely universal. Furthermore, affected persons need concrete anchor points in the form of objects, tasks, or processes through which they manage their everyday lives. Another major topic was the challenge of dealing with aMCI persons (**K2**). For this category, the sub-categories of *interaction & communication*; *living situations*; *digital & haptic signals*; and *application scenarios* were formed through analysis of the focus group results. The participants unanimously recommended calm, clear, and concise speech and communication for aMCI persons, since the individual reaction to auditory or visual stimuli usually differs. The direct and indirect gathering of application scenarios enabled a classification into *guided activities* (e.g. medicine, occupation, household, or therapy) and *reminding/activating activities* (e.g. cognitive activation, everyday structure, or memories). Furthermore, the practical implications regarding the cognitive development of impaired individuals (**K3**) also seemed decisive. The MFG participants reported that the cognitive development of aMCI people is often regressive as they try to avoid challenges with increasing age. However, cognitive regression can be slowed by targeted training, with the possibility of cognitive revitalization through neural plasticity in old age, consistent with the study findings of Von Arnim and Bartsch [79], which highlight the critical interplay between neural plasticity and cognitive functionality, especially in aging populations. These neuroscience findings suggest that routine and familiar tasks can stimulate cognitive engagement and potentially slow cognitive decline through the mechanisms of neural plasticity. The fourth

category to emerge from the MFG discussion was the cognitive and physical condition (**K4**) of aMCI individuals and a lack of ability to *anticipate the unpredictable* as challenges for their daily life. In practice, a categorical classification of more pronounced cognitive and physical conditions is highly dependent on the individual, whereas aMCI leaves ample room for support in daily living and adaptive interventions. This individual variability underscores the need for personalized care plans tailored to the specific needs and abilities of each person with aMCI. Such plans should prioritize the maintenance of independence and quality of life while taking into account the evolving nature of the condition.

3.4 Observational Study

In addition to the structured literature review and MFG as well as drawing on the theoretical lens of ZPD, an observational study (n=15) in a care facility for aMCI people has been conducted. Residents in that specific care facility inhabit their apartment units and go about their daily lives largely independently (depending on the degree of their cognitive impairments), as caregivers act as a monitoring and supporting authority. For the observational study, we meticulously followed the *CSOR* framework proposed by Morgan et al. [80] since it explicitly focuses on observational data for complex topics in healthcare. Morgan et al. [80] argue that observation is an optimal method for investigating healthcare phenomena that are most commonly of qualitative nature in a naturalistic setting. Therefore, we adapted the focus group analysis categories and created cross-case themes with their corresponding observational case reports. These themes (***T#***) were directly developed through the observational study methodology and are categorized into **T1:** daily routine; **T2:** everyday life challenges; **T3:** daily life activities; **T4:** physical and mental condition; and **T5:** communication and interaction. Table 1 summarizes our findings.

Table 1. Cross-case themes from the observation study

Cross-case theme	Descriptive reports from observation
T1 *Daily routine*	• Most daily routines are carried out independently by the subjects (e.g. hygiene measures, cooking, or minor household activities). When a need arises, caregivers support the residents. • Subjects retrieve information from caregivers on everyday life topics such as meal times, news, grocery shopping opportunities, or daily activities. • The structure of each day is centered around key commitments, appointments, and meals. It therefore rather depends on external than intrinsic variables. • Subjects use some form of tool to support memorization, e.g., paper-based calendars, or simple notes, or these tools are verbally expressed through caregivers. • Subjects have anchoring objects that accompany their daily routines (e.g. radio, TV, pictures, or general memorabilia). These can be considered as fixed points in everyday life and make them feel comfortable.
T2 *Everyday life challenges*	• Subjects tend to forget minor things such as object locations (e.g. cups, remote, or keys), appointments, and turning off appliances (e.g. stove or microwave). However, the latter is uncommon but bears a high risk. • Objects standing in the way are usually not noticed and therefore represent a potential source of danger. • Caregivers act calm and indulgent in situations of forgetfulness, which makes subjects feel comfortable.
T3 *Daily life activities*	• Subjects engage in many different activities throughout the day. Most common are watching TV, playing board games, eating, and talking to other residents or caregivers. • Subjects barely use any handhelds (e.g. smartphones, tablets, etc.). • Subjects generally pursue the same activities daily, which often is only interrupted by doctoral appointments or social activities. However, new activities are generally well received as long as they do not break the routine. • Subjects need certain daily activities (see above) to not break down mentally and cognitively. There is a need for activation and cognitive stimuli.
T4 *Physical and mental condition*	• The cognitive, as well as the physical condition, differs substantially between the subjects. However, all of them manage the majority of their daily lives alone. • Subjects seem to be aware of their surroundings, living environment, and the purpose of the care facility. No one seems out of place or in discomfort. • Some subjects show signs of obliviousness and feel a little bit caught when they are helped. • Their cognitive perception and physical condition often lead to them not perceiving objects and fall hazards. • Motor skills are quite limited and instructions must be repeated.
T5 *Communication and interaction*	• Subjects react better to a calm, persistent, yet gentle and definite tone when getting instructions or help from caregivers. • Subjects show great joy in interacting among themselves. However, they do not like intrusive behavior and need their personal space. • Subjects receive and process both, written and spoken, messages equally as good.

4. Design Theory for Enhanced Living Environments

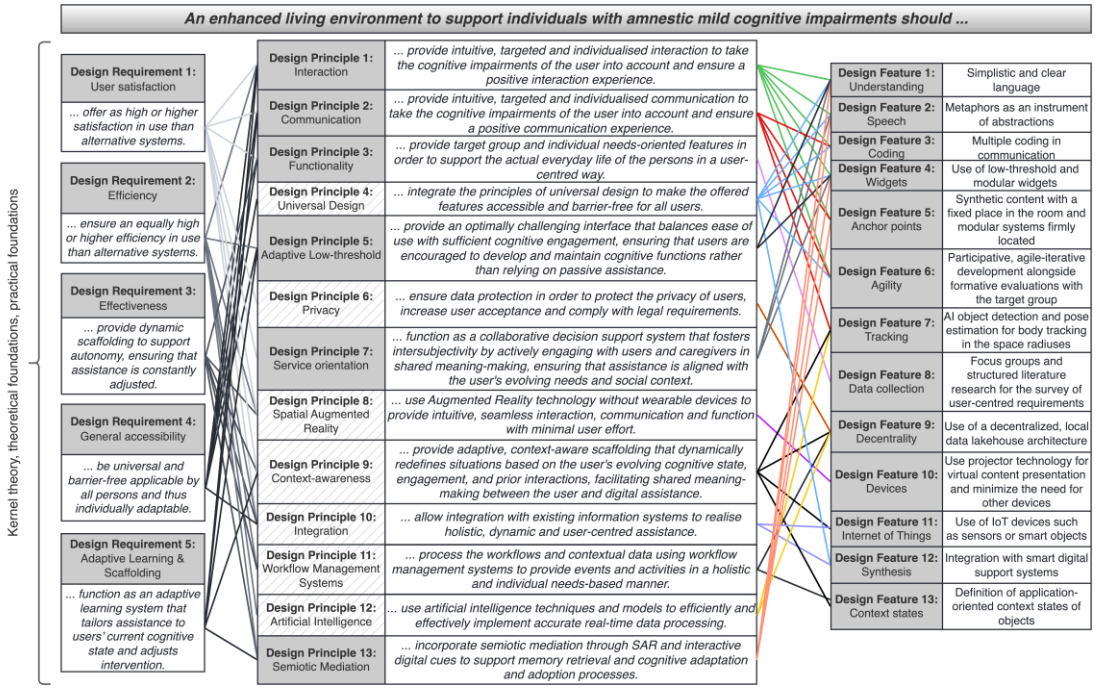
The analysis of current research streams reveals that existing digital assistance systems using SAR and projection techniques in the healthcare sector primarily address specific disease patterns and often provide only superficial support for users' daily activities. Consequently, a research gap exists for a modular, adaptive, and cognitively assistive system that enables people with aMCI to maintain autonomy in their daily lives. Findings from the MFG and the observational study reinforce the need for digital assistance solutions that do not merely compensate for impairments but actively scaffold cognitive processes to prolong independent living at home.

However, the lack of strategic and theoretical guidance in the current literature hinders the systematic design and development of such systems. This calls for the development of a DT that integrates a cognitive learning perspective by thoroughly investigating the meta-requirements of ELiEs in healthcare and establishing generalizable design requirements and principles. As a by-product of the heuristic design theorizing process in the modeling step, we also develop an RA that serves as a concrete instantiation of the DT. The RA illustrates how a decision support system based on the DT can be technically implemented and developed, and provides a structured conceptualization of how ELiEs can operationalize the principles of cognitive scaffolding, progressive autonomy, and semiotic mediation. Finally, the broader implications of ELiEs for both theory and practice remain underexplored, highlighting the need for a structured methodological and conceptual foundation to ensure their effective integration into digital health environments.

Table 2. Refined design theory components by kernel theory incorporation

Design Requirement / Principle	Revision upon Reflection	Justification by Kernel Theory
DR3 *Effectiveness*	Modify	Focus on **scaffolding** and **progressive/maintaining autonomy** rather than static effectiveness.
DP5 *Low Threshold*	Modify	Change focus from simply **reducing cognitive load** to **providing an optimal level of challenge** to foster cognitive engagement.
DP7 *Service Orientation*	Modify	Ensure ELiE fosters **intersubjectivity**, adapting assistance collaboratively with users and caregivers.
DP9 *Context-Awareness*	Modify	Integrate **situation definition**, ensuring ELiE dynamically adapts how it frames assistance.
DR5 *Adaptive Learning and Scaffolding*	New	Establish ELiE as a **learning system**, not just an assistive system, ensuring scaffolding and gradual reduction of help.
DP13 *Semiotic Mediation in Digital Assistance*	New	ELiE should leverage **SAR as a cognitive tool**, providing **symbolic and interactive scaffolds** rather than just static reminders.

As mentioned in the explanation of our research methodology and shown in Table 2, during the second design cycle we used heuristic design theorizing to iteratively refine the DRs and DPs to ensure their alignment with our kernel theory of ZPD. This refinement process was guided by Problem Reformulation (SH2), where we reevaluated how cognitive support in ELiE should be structured as a learning-oriented system rather than a static tool. Through iterative ideation by playing with kernel theory [22] and theoretical grounding [23], we revised existing principles to emphasize adaptive scaffolding, intersubjectivity, and semiotic mediation to ensure that ELiE dynamically adapts its interventions as users internalize cognitive strategies, as cognitive adoption processes in individuals with aMCI differ from those of unaffected individuals [9]. This allowed us to introduce new DRs and DPs that explicitly capture progressive autonomy-building and preservation mechanisms, thereby strengthening the theoretical coherence of our emerging design theory. As a result, the second cycle led to a deeper operationalization of ZPD within ELiE, transforming it from a system of contextual reminders into an interactive cognitive learning environment, thereby strengthening both theoretical rigor and practical applicability.



Note: Light-grey and hatched DPs = universal ELiE design principles.

Figure 5: Core constructs and simplified representation of the ELiE design theory with additionally derived design features.

As our theorizing output, this study proposes a DT that addresses the lack of formalized guiding design knowledge for ISs using SAR for comprehensive support of the elderly and aMCI in their daily lives. The analysis of the literature findings, the moderated focus group, and the observational study results, coupled with the iterative refinements and revisions based on the evaluation findings and the incorporation of the kernel theory, resulted in 5 essential DRs, which are further addressed by 13 DPs and 13 specific use case-derived DFs for our implementation of an ELiE design (Figure 5). Thus, the DRs and DPs describe components upon which any ELiE for the elderly and cognitively impaired should be built. In contrast, the DFs refer to our prototype development features and represent only one possible operationalization of the DPs. The connections between the theoretical and practical foundations are explained in the following sections.

4.1 Design Requirements

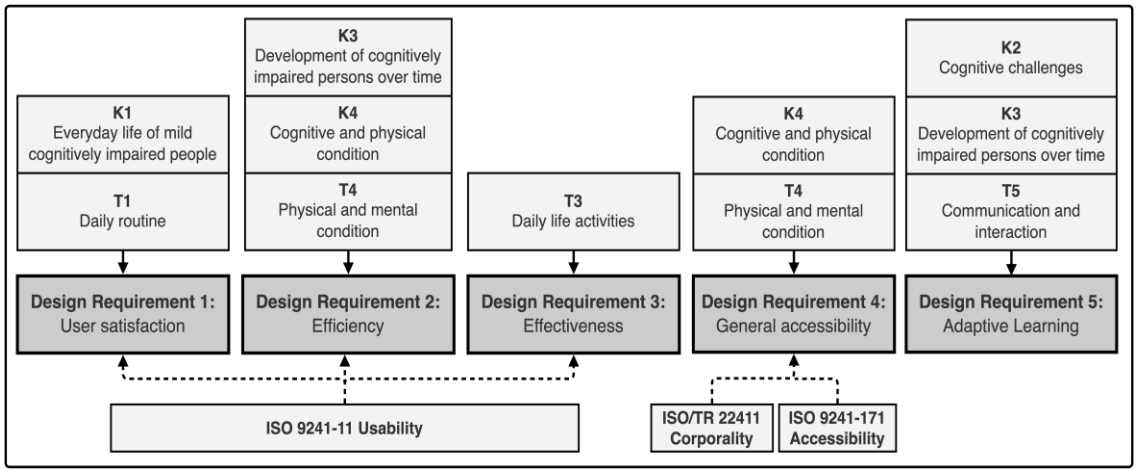


Figure 6: Assignment of the practical foundations to the DRs

The DRs outlined here serve as the main objectives for the theoretical and conceptual artifact. Theoretically grounded on the ISO 9241-11:2018 standard for "usability", the paradigm of user-centered design [35], value-sensitive design [81], and our kernel theory of ZPD [20,21] as well as practically grounded on the MFG and observational study findings, we derived the DRs *user satisfaction* (**DR1**), *efficiency* (**DR2**), *effectiveness* (**DR3**), *general accessibility* (**DR4**), and *adaptive learning & scaffolding* (**DR5**). They are further theoretically underpinned by the ISO 9241-171 standard for ergonomics of human-system interaction and the ISO/TR 22411 report for corporality that helps us to apply a universal design according to Connell [82] and the Center for Universal Design [83]. Further specifying the initially depicted connection between the kernel theories, theoretical as well as practical foundations (see Figure 3), Figure 6 visualizes the concrete mapping of the practical foundation categories and ISO standards to their respective DRs.

DR1 requires that users prefer using an ELiE over alternative systems (e.g. wearable-based AALs) and thus, addresses the results of research stream 2 which further affects their everyday life (***K1***) and daily routine (***T1***). Using a non-wearable intuitive digital assistance system will be less frustrating and lowers the burden of technology

acceptance which makes users feel comfortable. Beyond that, a clear and understandable distinction between efficiency and effectiveness of the ELiE system is needed. These terms should not be considered from an economic perspective but rather in terms of their relevance to the task at hand. Here, interaction must scaffold cognitive engagement, ensuring that users feel supported rather than overwhelmed. Satisfaction should come from increased or maintained autonomy, not just ease of use [20,21]. This satisfaction should be driven by the system's ability to facilitate cognitive empowerment - providing guidance when necessary while gradually fostering independent competence in daily tasks.

DR2 states that an ELiE should be easy for users to operate, while also being easily configurable by administrators which devotes itself to the cognitive and physical condition of the users (***K4***; ***T4***). To embark on the users' cognitive decline over time (***K3***), the undertaken effort of using the system should be considerably low. At the same time, an ELiE should provide at least the same level of efficiency as alternative systems. In other words, efficiency should not be defined as "completing tasks faster" but as optimizing the learning curve within the ZPD, ensuring users internalize assistance over time [20,21].

DR3 specifies that an ELiE should provide dynamic scaffolding to support autonomy, which effectively addresses ***T3*** and the users' daily activities. Day-defining activities, such as cooking, medication intake, therapy, or entertainment epitomize these functionalities. In other words, this implies that ineffective functions that are non-beneficial for a target group become obsolete. In this context, ZPD emphasizes that support should be dynamic and adaptive, not just functionally effective. Assistance should gradually fade out as users internalize cognitive strategies, allowing them to progressively take over tasks instead of relying on ELiE permanently [9,20,21].

With **DR4** we aim to make ELiE generally accessible to everyone which requires principles like “equitable use”, “flexibility in use”, “simple and intuitive use” or “low physical” effort [83] and requires the inclusion of the users’ cognitive and physical condition (***K4***; ***T4***). Accessibility should be dynamic, meaning interfaces should scale from guided to self-directed interactions, reinforcing user independence through progressive scaffolding, and thus, fostering cognitive adoption processes [9,20,21].

Finally, mainly based on concepts from ZPD theory, **DR5** addresses the need for an ELiE to function as an adaptive learning system that tailors assistance to users’ current cognitive state (**K2**; **K3**) and progressively reduces intervention as competence increases, ensuring long-term autonomy [20,21]. For communication and interaction design (**T5**), the ZPD approach emphasizes scaffolding and the gradual reduction of assistance as the learner gains competence. This means, that ELiE should move beyond just functional support (traditional decision support) and instead provide an adaptive learning process that reduces support over time – given the cognitive state and development of the user.

4.2 Design Principles

The DPs of ELiE are prescriptive and universal in the context of prototype design, meaning that they specify how a prototype should be designed to meet the above-mentioned DRs of our target group [40,45,84]. The DPs were derived within the *selective application category* [85] using a supportive approach, as suggested by Möller et al. [86], which involves specifying the DPs in advance and in a prescriptive manner [84]. This approach allows for the creation of clear and specific guidelines for prototype design as well as value-sensitive design [82], ensuring that the result meets the needs of the target group.

DP1 addresses a user-centered, personalized, and intuitive interaction with the ELiE serving the need for individuality within digital assistance systems [35,58,87,88].

This DP hereby accounts for individual, yet low-threshold interaction (***T5***) in pursuance of the most adequate way to address the cognitive state (***K4***; ***T4***) of the user. As such, interaction should accommodate cognitive impairments and actively scaffold users so they learn to navigate tasks while decreasing reliance on the system [20,21].

With **DP2** we further ensure that the communication with the ELiE is individual (***T5***), adapted to the specific impairments (***K4***; ***T4***), and provides a satisfactory experience as emerged from the value-sensitive design [82], user-centered design [35], and literature [52,58]. Communication should not just simplify information but function as a tool for structured learning, ensuring semiotic mediation [20] supports cognitive adaptation and adoption [9]. For example, multi-modal communication could ensure that external prompts evolve into internalized cognitive schemas, reducing external dependence over time.

DP3 and the principle of functionality implement modularity which enables the system to allocate individual needs-oriented features and be vastly flexible at the same time [52,60,61,62,88] as well as accounting for the technical suitability of the system according to the value-sensitive design [81] and user-centered effectiveness [35]. Moreover, the principle of functionality ensures adequate support regarding daily activities (***T3***) and fosters autonomy to overcome everyday challenges (***K2***; ***T2***). As such, ELiE should provide features that are not only need-oriented but also designed to evolve (or rather adapt) with users' cognitive progress [20,21]. Functional support should transition from directive assistance to supporting self-regulation, ensuring that users progressively internalize system-supported cognitive strategies [9].

DP4 was introduced to establish the principles of universal design and general accessibility (ISO 9241-11; ISO/TR 22411) [82] as well as participatory design [35]. This DP is closely connected to the cognitive and physical state of the users (***K4***; ***T4***) and aims

at accommodating cognitive development over time (***K3***). Universal design should accommodate different ZPD stages, ensuring that support can be intensified or reduced dynamically. The system should provide gradual support reduction (or increase) where appropriate, reinforcing users' ability to complete tasks autonomously over time [20,21].

DP5 and the principle of low threshold propose the need for accessible user interfaces to reduce the cognitive load which is a key technology acceptance and comprehension factor [60,62] and necessary to come by cognitive prerequisites and impairments (***K4***; ***T4***). However, instead of simply making ELiE "as easy as possible," it should be designed to provide optimal difficulty - not overwhelming, but engaging enough to promote learning and cognitive development [9,20,21]. Hence, an ELiE should provide an optimally challenging interface that balances ease of use with sufficient cognitive engagement, ensuring that users are encouraged to develop and maintain cognitive functions rather than relying on passive assistance.

Privacy-related, **DP6** ensures personal data protection which further fosters user acceptance [60,62] and is strongly connected to the moral aspect of value-sensitive design [81]. This principle is further important since despite having potentially high usability scores, the system may not be perceived as socially acceptable by some individuals due to their moral value of privacy [89]. An ELiE should ensure privacy by balancing data protection with caregiver-mediated support, enabling a collaborative model where users gradually gain more control over privacy settings as their cognitive independence improves.

Moreover, an ELiE shall not be seen as a mandatory burden but rather as supporting and service-oriented which is addressed through **DP7**. According to the results of our focus group and observation study, we have determined that aMCI individuals do not respond well to patronizing or urging behavior (***T5***) when interacting with them. This

insight offers potential solutions to the challenges of effectively communicating and interacting with this target group as well as overcoming defiances in engaging with them (***K2***; ***T2***). However, ZPD highlights intersubjectivity, meaning ELiE should not only be non-intrusive or patronizing but should actively collaborate with users and their caregivers to co-regulate autonomy [20,21]. It should provide just-in-time assistance and adapt based on user engagement.

Subsequently, we specify the use of SAR with **DP8** which reduces cognitive load via non-wearable devices and ensures minimal user effort [14]. Thus, this principle accounts for the restricted interaction and constrained use of wearables or handhelds (***K4***; ***T4***; ***T5***) which further extends usability and access to the system according to value-sensitive design [81]. Here, SAR should not just provide passive information, but actively guide users through their zone of proximal development, ensuring semiotic mediation [20,21].

DP9 addresses the context-awareness and reasoning of ELiE as a technical component that is based on the RAs for context-aware systems according to Alegre et al. [90] and Costa et al. [91]. It further epitomizes the context modeling techniques of Strang and Linnhoff-Popien [92] as well as the concept of *Pervasive AR* by Grubert et al. [93]. Through context-awareness, the ELiE system adequately supports users in their daily life activities (***T3***) and fosters autonomy within their routines (***K1; T1***). However, ZPD stresses situation definition, where learning occurs through negotiated meaning between the system and the user [20,21]. ELiE should not just detect static user states but should engage in an interactive process of adjusting how situations are presented and scaffolded to trigger appropriate responses.

With **DP10** as the integration principle, seamless integration with existing ISs is proposed to provide a dynamic, flexible, and holistic user experience with features

considering value-sensitive [81] and user-centered [35] design as well as support daily routines (**T1**). Hence, a potential synthesis with other applications via external APIs (e.g. calendar applications, virtual medical office, or therapy) is enabled. This means that system integration should allow seamless transitions between different levels of support, ensuring adaptive support without abrupt shifts [20].

Moreover, **DP11** focuses on the WFMS component of the DT and is closely connected to the WFMC [70] RA which enables ELiE to adequately process sensory data and contextual states and triggers the projection or auditory information. This principle ensures reasoned information processing to adequately provide useful functionalities for daily routines (***T1***).

DP12 adds artificial intelligence (AI) as a component to enable real-time object detection, pose estimation, and body tracking due to precise context reasoning. This principle enables an intuitive, comprehensible, and accessible way to interact and communicate (***T5***) with users based on their gaze direction and position within the ELiE. As such, AI should not only predict behavior but dynamically adjust the level of cognitive assistance, ensuring that users remain in their zone of proximal development [20,21].

Lastly, **DP13** addresses the need for an ELiE to incorporate semiotic mediation through SAR and interactive digital cues, using symbols, metaphors, and progressive visual/auditory aids to support memory retrieval and cognitive adaptation/adoption [9,20,21]. In semiotic mediation, external symbols, signs, and representations help structure cognition (**K2**) and enable individuals to transition from externally supported to internally regulated actions (**K3**). As such, an ELiE's SAR projections should not just provide reminders but serve as interactive cognitive tools that support meaning-making and self-regulation (**T5**).



Figure 7: Visual instantiation of our early prototype with idle (1), focus (2), and active (3) widget state.

To instantiate the DPs, we derived 13 specific DFs to develop our ELiE prototype, whose visual design for an example scenario is depicted in Figure 7. As the DFs provide the conceptual foundation of the ELiE reference architecture, they are explained in Section 5.

4.3 Design Theory Artifact

Following general design theory communication, justification, and cumulation, we adopted the outlined process for design theory "anatomy" proposed by Gregor and Jones [39]. Table 3 provides a summary of this process and shows how we have theorized along it. While Figure 5 shows the core constructs and a simplified representation of our design theory artifact, Table 3 shall be treated as the theorized artifact, accompanied by the aforementioned models, textual descriptions, and prototypical scenarios. As such, the DT enables us to classify ELiE as *passive pervasive assistant* (type 4) according to Knote et al. [94], since it acts unobtrusive and suggestive and converges into a digitally enhanced experience.

Table 3. Components of a design theory [39]

Component	Description
Purpose and scope	The current trajectory of AAL and digital health is burdensome and may hinder technology adoption among aMCI individuals. The purpose of the DT is to enable the development of ELiEs that will not only alter this trajectory but also maintain the autonomy of this population through SAR. The goals of an ELiE are: providing a satisfactory user experience for interaction (**DR1**); improving digital health efficiency and therefore low effort use (**DR2**); providing holistic health care and everyday life functionalities (**DR3**); and ensuring a universal design that is generally accessible for everyone (**DR4**).
Constructs	We conceptualize an ELiE consisting of SAR, context-aware deep learning, diverse sensors, and workflow management. These constructs range from everyday and living environment augmentation to individually tailored health care for aMCI individuals.
Principles of form and function	Features of current AAL and digital health solutions are fundamentally epitomized by high entry barriers, burdensome wearables, and overall low usability for people with neurodegenerative diseases. The dynamic nature of digital health hence requires novel innovative approaches to enhance usability, autonomy, and adoption. Through theorizing, the following DPs were developed to address this goal: **DP1**: interaction, **DP2**: communication, **DP3**: functionality, **DP4**: universal design, **DP5**: low-threshold, **DP6**: privacy, **DP7**: service orientation, **DP8**: augmented reality, **DP9**: context-awareness, **DP10**: integration, **DP11**: workflow management systems, **DP12**: artificial intelligence, **DP13**: semiotic mediation (Figure 5).
Artifact mutability	We theorize an ELiE as an alternative type of AAL system that works in a complementary and symbiotic relationship to current digital health solutions for elderly and aMCI individuals, emphasizing innovative, intuitive, and efficient interaction with health IS. ELiEs can be used in different environments, are accessible to everyone, and do not relate to specific hardware/software. The projection design, auditory communication, and scenario functionality are modular and can be adapted for different user use cases. It can be tweaked based on specific practical, personal, or theoretical requirements.
Testable propositions	ELiEs for supporting people with aMCIs offer higher user satisfaction, efficiency, effectiveness, and accessibility than alternative AAL approaches. Developers and researchers can design AAL systems in such a way as to support human autonomy, not hindering it, by altering the design theory and its implementational features. We view the testable propositions as varying in their degree of generality and as truth statements about our design theory, meaning that these general statements describe expected outcomes (i.e., addressing the DRs) based on the application of the DPs. Thus, we hypothesize that in the context of digital support for people with aMCI, if System A uses our design theory, it will work or be more effective/efficient than a System B that does not. On a more granular level, the testable propositions here refer to the relationships between DRs and DPs, as shown in Figure 5, emphasizing that if someone has similar DRs in a different context, the corresponding DPs from our design theory can be applied and their effective relationship can be tested. To give a specific example, if DP5 (Adaptive Low-threshold) is applied during system development, the resulting outcome will (partially - since multiple DPs address DR5) satisfy DR5 (Adaptive Learning & Scaffolding), leading to improved cognitive adoption and health interventions, which can be tested by conducting cognition and perception tests with users.
Justificatory knowledge	A three-step literature analysis, MFG, and observation study alongside established kernel theories of user-centered and value-sensitive design that remain consistent across various applications in various settings justify the derivation of DRs and DPs. A multi-episode evaluation strategy containing artificial and naturalistic settings justified the theorized artifact which was overall perceived as useful for developing ELiEs from a theoretical and practical perspective. An evaluation of user satisfaction, effectiveness, efficiency, and accessibility was conducted to further assess and validate the derived system architecture. Close evaluation with the target group is vital since

	ELiE offers novel functionalities for non-wearable devices and digital, smart, and context-aware health assistance.
Principles of implementation	The universal design knowledge suggests various implementation criteria that yield the desired user-centered outcomes. These are defined as DFs and guide the implementation alongside the RA (Figure 7).
Expository instantiation	We develop a series of DRs and DPs that, alongside an RA, show how researchers and developers can apply the proposed characteristics to create ELiEs. We developed a technical IS architecture and thereupon a prototype implementation, encompassing the derivable components of the DT within two reference scenarios.

Note. AAL= ambient assisted living, AI = artificial intelligence, ELiE = enhanced living space, DT = design theory, DP = design principle, DR = design requirement, DF = design feature, aMCI = amnestic mild cognitive impairment, MFG=moderated focus group, IS = information system, SAR = spatial augmented reality, RA = reference architecture, WFMS = workflow management system.

5. Reference Architecture

Being a „by-product“ of our heuristic design theorizing approach, we developed an RA by creating and experimenting with different graphical types of representation of the problem solution [22]. RAs generally represent theoretical guidance and a kind of template solution for ISs regarding a particular application domain [95,96]. Oussalah [97] states that the design of an RA should incorporate pre-defined requirements as well as establish them, whereas domain concepts and ontologies should also be identified. Thus, this approach can use DRs and DPs of a general DT as they respectively depict application-specific meta-requirements [42,44] and the prescriptive implementation of these [84] to represent a theoretically sound foundation for the RA. The RA for ELiE depicted in this paper is constituted by a component system architecture, a universally applicable UML class diagram, and a reference user interface (UI) design, supplemented with textual descriptions in addition to the respective figures. Therefore, the RA is the second main artifact besides the DT and is intended to support the practical implementation of ELiEs, generally depicting an instantiation of the DT. To show how the DT is used to deduce RA objects, the DRs, and DPs are connected and given for the respective component of the RA in the next section, where Fig. 10 shows a prototypical implementation of the ELiE RA.

5.1 System Architecture for ELiE

A conceptual model for cognitively supporting aMCI people without wearables requires four main components at a higher level of granularity: (1) a sensor interface consisting of smart sensors and an AI-powered tracking module; (2) a database interface to store the sensory and contextual data; (3) a workflow interface to process the contextual data; and (4) a projection interface to adequately present the relevant information. These four interface components are highly modular, meaning that every sub-component can be addressed by an individual solution which reduces the overall complexity of the IS. Figure 8 visualizes the developed technological artifact instantiated as a component system architecture and derived from our theoretical DT. Considering that the component representation aims to portray the IS architecture at an elevated level of abstraction, certain underlying characteristics (e.g., pre-processing unit, messenger workflow) are merely referenced and shall be expounded upon subsequently through the class diagram (Figure 9).

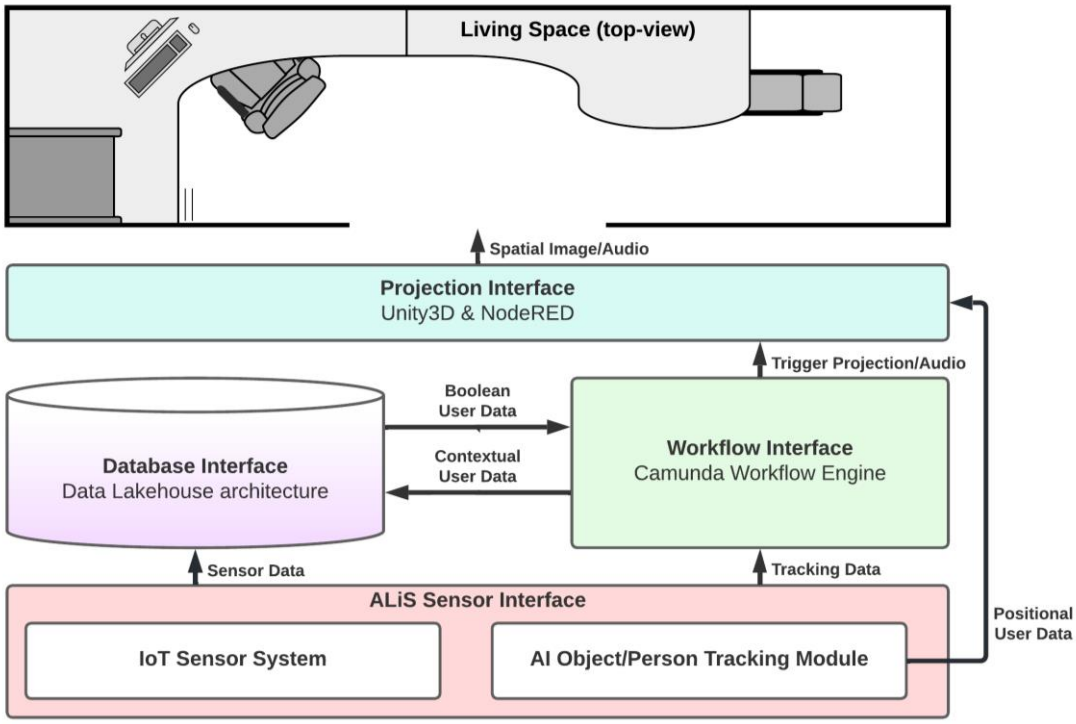


Figure 8. IS component architecture of the ELiE prototype reference scenario.

The *sensor interface* bundles all sensory hardware as well as machine learning-powered tracking. The semi- or unstructured data of sensors (e.g., heat sensors, water level sensors, or fall detection sensors) are forwarded to the pre-processing unit, where the data is parsed and every sensor is given a specific ID for further processing. The data pre-processing unit then specifies the destination, data content, and format of the sent data, enabling higher efficiency (**DR2**). On the other side, synthetically trained deep-learning models track people and create context-aware zones for gaze projection. (**DP12**). This data will be pre-processed and sent to the *workflow interface* as well as directly to the *projection interface*, allowing fast process time for real-time information delivery, which is essential for the conceptualization of RAs for AAL and the realization of **DR1, DR2**, and **DR5**.

The *database interface* is structured as a data lakehouse [98], enabling near real-time data storage, processing, and retrieval. Hence, the data structure is irrelevant upon storage. Furthermore, the *database interface* creates context variables through the incoming and pre-processed data, e.g., storing the stove temperature at a specific time with a defined ID. This specific context data is sent as a variable to the workflow interface, which then reasons the data. Nonetheless, the *database interface* also contains contextual states that come from the *workflow interface*, storing context states (e.g., stove is hot, door is open) based on the context variables in circulation (**DP9**).

Moreover, the workflow interface acts as a reasoning engine for ELiE, establishing contextual connections between raw sensory data and its implications for the user, and thus, following the RA for context-aware ISs by Alegre et al. [90] and Costa et al. [91] as well as addressing **DP11**. Our WFMS defines, interprets, instantiates, and manages the execution of workflows, integrates external applications, and interacts with human workflow participants according to the definition of the WFMC. Moreover, it

manages and controls the sequences. Hence, it is responsible for creating, reasoning, and combining context (**DP9**). For example, a raw temperature context variable from the *database interface* has generally no meaning to it. However, if the stove has to be off at a certain time (e.g. after 10 pm) but the WFMS detects a hot temperature, it creates a reasoned context for the raw variables and adds value to it. Furthermore, the WFMS also integrates external services such as the user's phone, personal health applications, smart home systems, or health insurance services via secured API sockets (**DP7**, **DP10**). Lastly, the *workflow interface* triggers projection or auditive communication, which is implemented through the application (e.g., triggering and augmenting the information of a hot stove plate).

Lastly, the *projection interface* includes the SAR application which parses the sent information to project or communicate with a certain widget or widget bubble (**DP8**). Widgets can be seen as a form or expression of information representation, embodying a kind of visual container that consists of various visually represented information or data. With pre-defined, yet highly modular and flexible widget appearances, it is possible to assemble certain widgets as well as orchestrate them. This allows the application to change color schemes or data composition according to the individual needs of the user [52,60,61,62,88], accounting for individual impairments (**DR4**, **DP3**, **DP4**). Since the application is equipped with positional user data, suitable projection mapping is enabled and the right projector or speaker is selected automatically.

5.2 Conceptual Class Diagram

The UML class diagram (Figure 9) for ELiE maps out the structure of the particular system by modeling its classes, attributes, methods, and relationships between them on a lower level of abstraction. Thus, it extends and instantiates the simplified component architecture. Below, we link the elements of the UML class diagram with the DFs (see

Figure 5) to bridge the abstraction gap between DT and implementation.

Referencing the component architecture, the reasoning workflow interface is represented through the classes *Workflow Management System, Workflow, Java Class, Area Decision, External Services API*, and the interface class *Context Reasoning*. The *Workflow* class is unidirectionally connected to the *Workflow Management System* class and can be seen as a sub-class. These two classes are responsible for orchestrating and processing workflows, thus creating reasoned context and thus, addressing **DF13** (context states). The class methods enable receiving, processing, and sending data in the form of contextual states, signal triggers, or application states. Workflows themselves can also be in a certain enumeration state, meaning that they are either active, idle or on hold in most cases. The *Java Class* acts as a script class consisting of many Java scripts that connect the workflow interface with the database and projection interface. Thus, it can be seen as a connection layer that sends the relevant information to the correct recipient. This also includes sending reasoned data (contextual data) to the application. The *Area Decision* class parses the tracking data to the action areas around objects within the ELiE to effectively send the positional data, which is chosen to realize gaze projection via spatial augmentation (**DF7** – Tracking; **DF10** – Devices). Lastly, all external services (e.g. Amazon Alexa, Google Calendar, etc.) are bound to the WFMS which grants access, initializes the service, and sends its data to the application for further processing and adequate widget selection (**DF12** – Synthesis).

The database interface only consists of the *Data Lakehouse* class to store relevant data from the workflow and sensor interfaces. Implemented through **DF9** (Decentrality), the functions of access permission, receiving, storing, and sending data are carried out. Since we are working with sensitive and unstructured data, using a local network with a data lakehouse seems appropriate. It combines the merits of a data warehouse with rapid

processing of unstructured deep learning data, while at the same time being isolated from external services (as these are part of the workflow interface). Notably, the *Data Lakehouse* class is not responsible for context reasoning or triggering any processes, but solely for storing purposes.

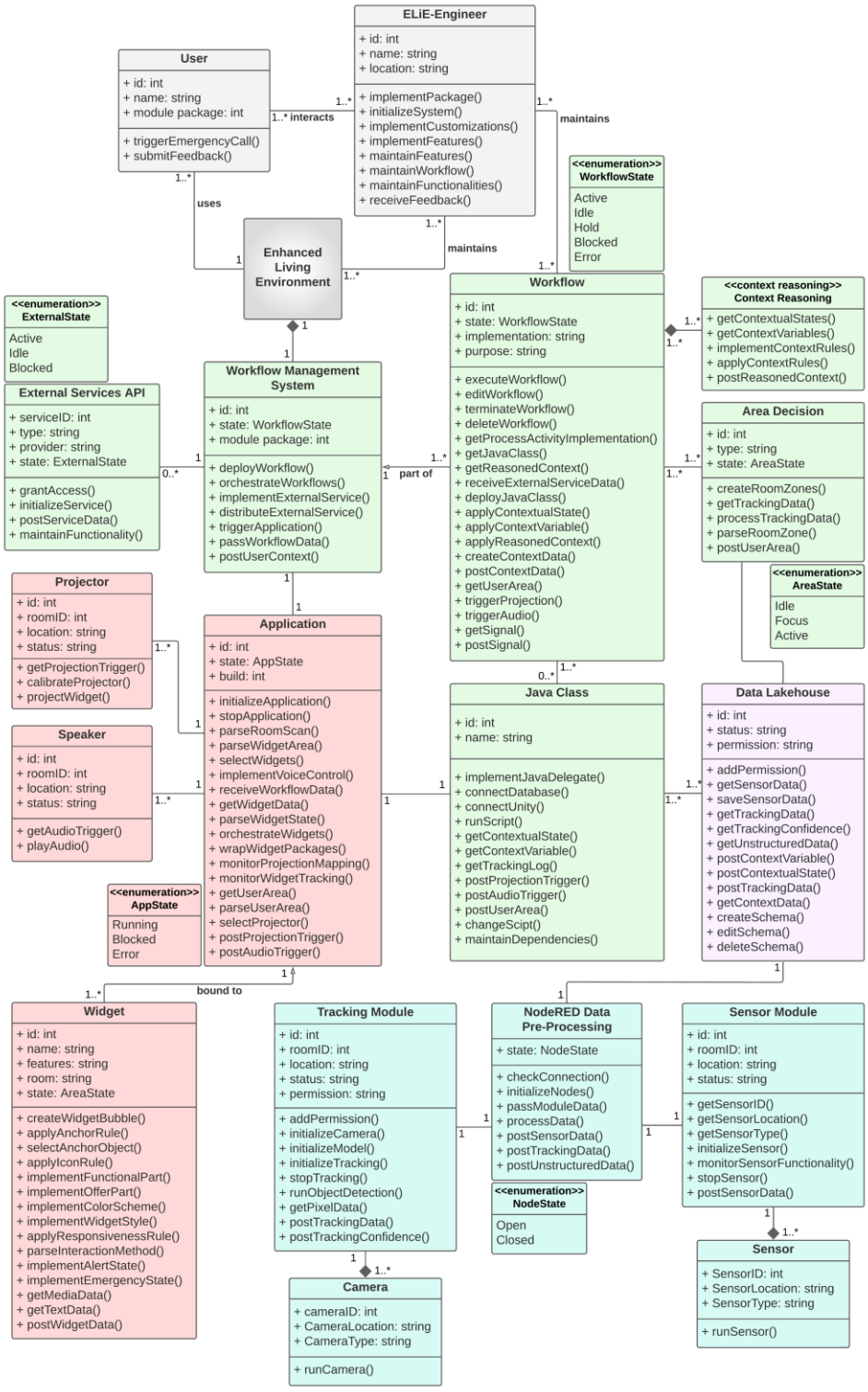


Figure 9. Conceptual class diagram for enhanced living environments.

Furthermore, the sensor interface includes the classes *Sensor, Sensor Module, Camera, Tracking Module,* and *Data Pre-Processing*, epitomizing the initial layer for data reception. To adequately project meaningful information, necessary data need to be gathered through sensors (**DF11** – Internet of Things). These can be object-integrated sensors (e.g., inside a stove), manually placed sensors (humidity), or optional wearables for health purposes. The *Sensor Module* class hereby orchestrates the sensors and is responsible for passing the gathered data. Additionally, the *Tracking Module* class is responsible run the deep learning-powered tracking model which can detect users and objects through a 360-degree camera and hereby adequately compensates for the lens distortion. After gathering, this data is sent to the *Data Pre-Processing* class, which implements a unified flow of information realized via the software tool *NodeRED*. It should be noted that the data itself will still be in a semi- or unstructured format most of the time, but will be transported in a unified way for performance reasons. The interface as a whole is also in control of the connection between the sensors and the *Data Lakehouse* class. Thus, we have established an enumeration class depicting the node state (open or closed).

Again drawing on the component diagram, the projection interface contains the classes *Application, Projector, Speaker,* and the bound-to class *Widget*. It is mainly aimed at composing and augmenting the relevant widgets at the right time, thus providing user-centered cognitive support in almost any area of everyday life (**DF4** – Widgets). Therefore, the *Application* class is responsible for matching the widgets (and their states respectively) with the widget data from the workflow interface as well as the positional user data from the tracking. The widget data itself is wrapped into a widget package and final appearance, which takes the perception of the communicated information (**DF1** –

Understanding) as well as adequate visualization and sound (**DF3** – Coding) into account. Since most of the people from our target group struggle with hearing and vision impairments, we make use of simple and clear language regarding the communicated information and tone (**DF2** – Speech). Especially in dangerous situations (i.e. a hot stove or flooded sink) that require fast action, our target group needs to process information quickly and comprehensibly. Therefore, our implementation follows the slogan "metaphors as an instrument of abstractions" which does not target to digitize the real world but rather integrates virtual information into it – mainly to make an ELiE the "more knowledgeable other" as per ZPD [20,21]. As an illustration, suppose a user inadvertently neglects to turn off the stove or faucet. In such cases, a pervasive overlay present across all widgets serves as a conspicuous indication of a potentially hazardous circumstance, demanding quick action. Lastly, the *Application* class triggers the projection via the *Projector class* and/or the audio via the *Speaker* class, which will then be the information presented to the user.



Figure 10. Prototypical implementation of ELiE along with visionary visualization

Besides all the mentioned classes, we have the two human classes *User* and *ELiE-Engineer*. The user can submit feedback on the system's performance and trigger emergency calls through a dedicated function. The user uses the ELiE, whereas the *ELiE-Engineer* maintains it. The latter class is responsible for the implementation and initialization of the system, which also includes customization and/or parametrization that is specifically tailored to the individual needs and preferences of the user. Moreover, the engineer should maintain the features and functionalities as well as implement the received feedback inquiries. This can either be done remotely or at the user`s location.

6. Evaluation

To anticipate a thought that might come up, the evaluation approach for this study is intended to be complementary rather than mandatory. While evaluation episodes for the theorized artifact (i.e., design theory) are neither integral nor necessary in heuristic design theorizing [22], we decided to evaluate the DT, subsequent RA, and prototypical scenarios to validate their actionability, practicality, and relevance to ensure that they "work" in real-world applications and resonate with stakeholder needs. Thus, the overall focus of this study was to ensure that heuristic search generated sufficient depth and breadth of design insights, rather than a formalized, conclusive evaluation of design theory [22]. Nonetheless, general DSR emphasizes the importance of actionable and validated artifacts, consistent with its practical orientation, so we complemented our heuristic design theorizing with an evaluation to operationalize and instantiate the design theory artifact. We aimed to translate the DT into actionable models and prototypical scenarios, ensure their applicability and relevance, and iteratively refine the artifact to meet both theoretical and practical goals. While providing a form of "pre-validation" that enhances its clarity and actionability for readers, we contemplate further evaluation through the theoretical discourse that this DT could initiate.

As proposed by the value-sensitive design theory [81], we have two classes of stakeholders: 1) aMCI individuals, and 2) researchers, developers, and practitioners. Following the user-centered design paradigm, a close evaluation and testing with the target group is of great necessity [35]. Thus, a two-part evaluation seems appropriate that 1) assesses the usability and usefulness of the implementation with aMCI people in a natural setting, and 2) validates the theoretical DT and RA in an artificial setting with experts. The evaluation strategy of our DSR approach follows the well-known FEDS evaluation framework by Venable et al. [99], containing naturalistic and artificial evaluation episodes that are either normative or summative (Figure 11). Designing and implementing ELiEs for aMCI people is significantly influenced by cognition and usability variables: First, the social behavior and human factor of people using the system, their needs-oriented requirements as well as characteristics, and second, engineers that are intended to set up, compose, and maintain the system. Hence, the main risks in designing and implementing such an ELiE are user-oriented [35], for which Venable et al. [99] recommend the evaluation strategy "Human Risk & Effectiveness" (Figure 11).

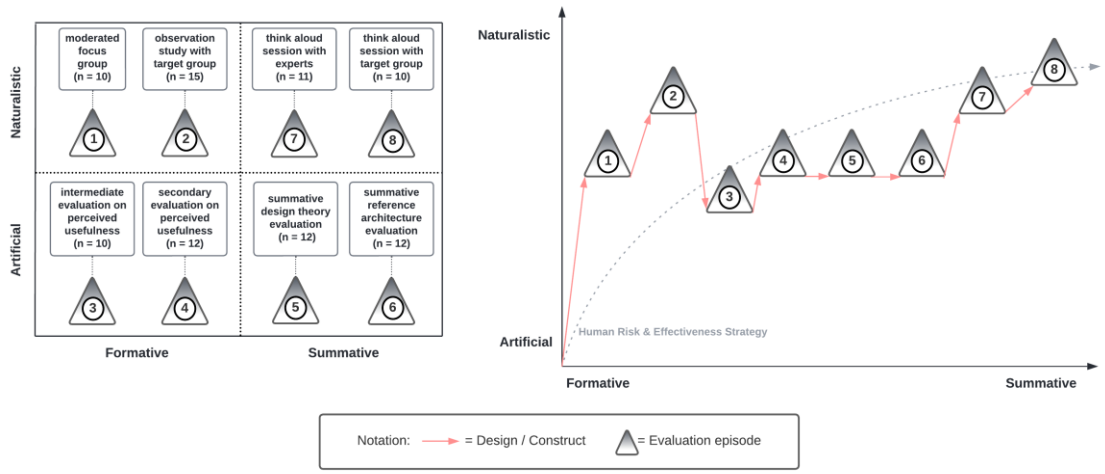


Figure 11. ELiE evaluation strategy

Thus, we conducted two naturalistic, formative evaluation (or rather data collection) episodes (n=10 and n=15) (Figure 11, 1 & 2) early in our research to inform

our DT development (see Section 3.3-3.4). We then conducted two formative evaluations via questionnaires on the perceived usefulness (n=22) during and after DT development, which are extensively described in [Anonymized] (Figure 11, 3 & 4) and included an *artificial* scenario where subjects were asked to emphasize with and utilize the DT. Using the six items of Davis [100] to ask researchers, practitioners, and experts in the field of IS and healthcare for their perceived usefulness of the DT in the hypothetical scenario of conceptualizing, designing, or developing ELiEs, we obtained generally positive results. The subjects stated that they could accomplish tasks more quickly and that their overall job performance and effectiveness would be improved. They found the DT useful, expressing that the specific DPs helped them visualize a possible solution. Overall, the subjects agreed with the statement that the number of DRs and DPs makes the DT meaningful without being unwieldy or overwhelming.

After the development of the DT and RA, we conducted two summative, artificial evaluations to ascertain the *performance expectancy* (PE) and *effort expectancy* (EE) of the DT and RA via a survey of potential users, i.e., IS researchers, developers, or practitioners (n=11 respectively for DT and RA) (Figure 11, episodes 5 and 6). As the PE and EE as constructs are not directly measurable, we drew on the well-known scale items by Venkatesh et al. [101]. For PE: usefulness (PE1), quickness (PE2), productivity (PE3), and increased chance of getting a raise (PE4). For EE: clarity (EE1), easiness to master (EE2), easiness to use (EE3), and easiness to learn (EE4). We specified the PE and EE for our application context, i.e., for the development of ELiEs for aMCI individuals. Additionally, we asked the experts about the conciseness (CON), extendibility (EXT), and explanatory power (EXP) of the artifacts, following Nickerson et al.'s [102] approach to subjective ending conditions from their well-known taxonomy development method. The questionnaire included: 1) an introductory text about the research project, 2) the DT

as presented in this paper, 3) a prompt to imagine an application scenario for the DT, 4) the statements on the EE, CON, EXT, and EXP, 5) the RA as presented in this paper, 6) a prompt to imagine an application scenario for the RA, 7) the statements on the PE, EE, CON, EXT, and EXP, and 8) some socio-economic questions. For data collection, we used interval-scaled verbal numeric 7-point Likert style scales. In choosing the sample size, we considered the so-called "10±2 rule" [103], which states that 8 to 12 respondents are sufficient for usefulness evaluations. Based on an expected response rate of 50%, we sent the DT questionnaire to a total of 21 DSR experts and received 11 completed questionnaires (actual response rate: 52.4%), while the RA questionnaire was sent to 19 conceptual modeling and RA experts and we also received 11 responses (57.9%). The respondents included CEOs, project managers, senior researchers, research assistants, senior consultants, and AR developers, all active in the healthcare and IS domain, possessing 3-25 years of experience in their roles. Among the experts, 18 work in large, and four in micro-sized companies/organizations. Figure 12 depicts the boxplots of the responses.

For both the DT and RA we received high levels of agreement on all items, with medians of m=7 (DT) and m=6 (RA). The sum scores of the PE and EE for the DT and RA with medians of m=25 (PE-DT), m=27 (EE-DT), m=25 (PE-RA), and m=26 (EE-RA) on a 7-28 scale summarize the overall positive evaluation well. The subjects stated that using the DT and RA would enable them to accomplish tasks (e.g. developing and implementing an ELiE) more quickly while also increasing the productivity and understanding of the artifacts. Overall, subjects found the DT and RA useful and easy to use/comprehend.

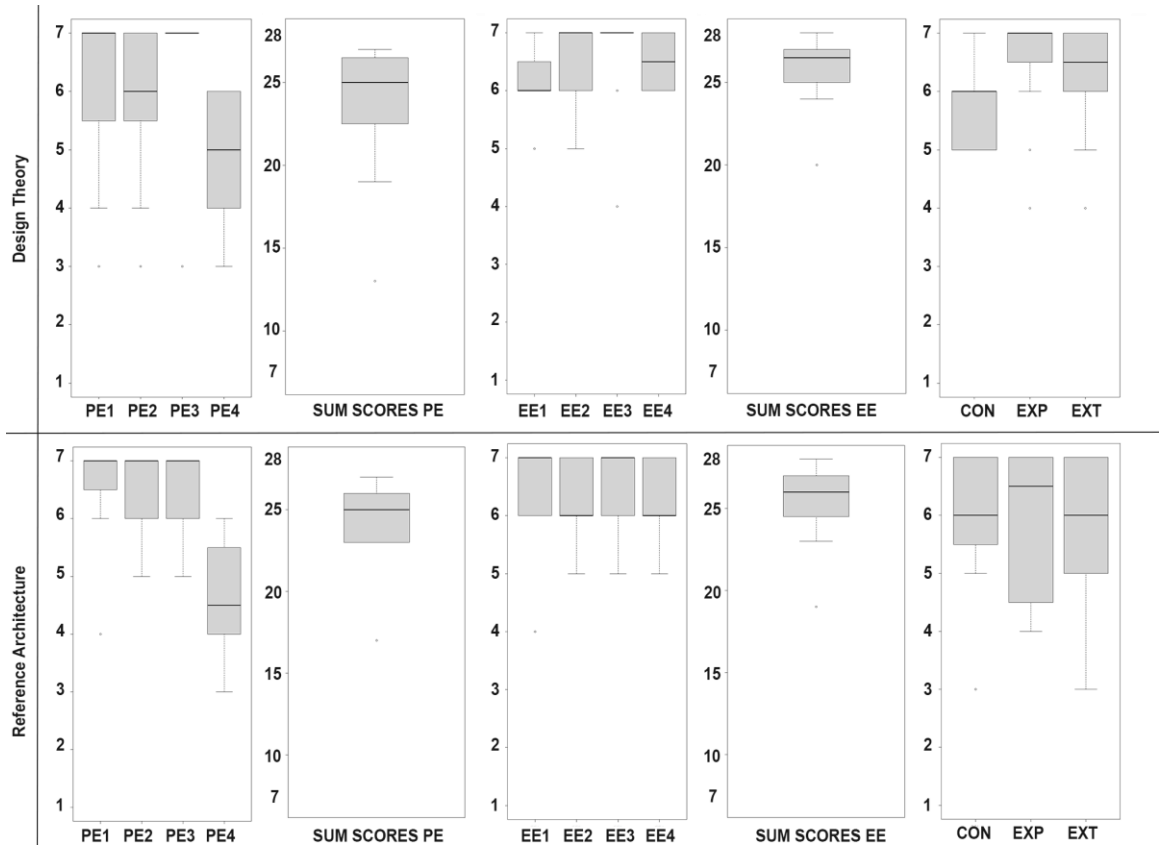


Figure 12. Boxplots for design theory (top row) and reference architecture (bottom row) evaluations.

Moreover, both artifacts are perceived to be easily extendable while simultaneously being sufficiently concise and explained. To validate the quality of the constructs PE and EE, we examine individual item reliability (loadings), composite construct reliability (CCR), and average variance extracted (AVE) [104]. Item reliability is examined by evaluating the loadings of the measured items on their respective construct. We performed a confirmatory factor analysis in R for this purpose (Table 4). It is generally known that items with low loadings (rule of thumb: < 0.4) should be carefully scrutinized as they offer little additional explanatory power but attenuate (and thus bias) parameter estimates [104,105]. In our models, all item loadings exceed the 0.4 limit. The average variance extracted (AVE) is also above the limit of 0.5 for all items and artifacts, indicating that the variance captured by the construct is greater than the measurement

error [106]. Composite construct reliability (CCR) measures the overall reliability of items loading on a construct and should exceed the threshold of 0.7 [104,105], which is given for all items and artifacts. Discriminant validity was evaluated through the comparison of the AVE and the squared correlation among the constructs, as outlined by Fornell and Larcker [106]. To compute the correlation, the Kendall tau coefficient, specifically suited for Likert-style scales as suggested by Jamieson [107], was employed. The comparison shows that the AVE of PE and EE (see Table 4) are each higher than the squared correlations (cor) between PE and EE for both the DT ($cor^2 = 0.007$) and the RA ($cor^2 = 0.204$). Based on these validity criteria, our measurement models with four items each for the constructs PE and EE are suitable for evaluation. Our evaluation focused on conclusion validity (the relationship between treatment and outcome) and construct validity (accurate measurement), using established measures from prior research [101,108]. While internal validity (risk of other factors influencing results) was a concern, the detailed scenario and participant expertise mitigated it [108]. External validity (generalizability) was addressed by the design's broad applicability, expert participants, and consistent results, suggesting similar positive outcomes in future evaluations [108,109].

Table 4. Construct validation

Performance Expectancy		Design Theory	Reference Architecture	**Effort Expectancy**		Design Theory	Reference Architecture
Loadings	Usefulness	.888	.699	Loadings	Clarity	.789	.739
	Quickness	.777	.754		Easy to Master	.718	.720
	Productivity	.723	.866		Easy to Use	.665	.877
	Chance of Raise	.580	.792		Easy to Learn	.740	.712
	AVE	.563	.609		**AVE**	.532	.585
	CCR	.834	.861		**CCR**	.819	.848

Pursuing a summative and natural evaluation as well as ensuring scientific rigor and a functioning system, the RA was implemented in a prototype scenario and evaluated

in two independent naturalistic sessions (n=21) (Figure 11, 7 & 8). The first session was directed to get feedback from IS researchers and cognitive caregiving experts (n=11), whereas the second session was aimed at evaluating the system use by our target group (n=10). We followed the theoretical lens of user-centered design for evaluation [35] and used the qualitative research method of *Concurrent Think-Aloud* [110], where users are asked to use the system or complete a set of tasks and verbalize their thoughts to evaluate the software design and implementation. To conduct the think-aloud sessions, we followed three steps: (1) provision of information about the system prototype and the task to be performed, (2) systematic protocolling of verbalized user thoughts, and (3) analysis of protocols. Seeking qualitative rigor in these sessions, we followed the well-known method of Gioia et al. [111] and developed *first-order concepts*, *second-order themes* as well as *aggregate dimensions* based on the thoughts expressed by the subjects. Subsequently, we assigned the clustered comments to the respective DPs to assess how the DT was implemented through the IS architecture. Table 5 contains the clustered results as we could derive both positive aspects (marked by "+") and potential for improvement (marked by "o").

Table 5. Results of the think-aloud-sessions

DP	Clustered verbalized thoughts
DP1 *Interaction*	+ Intuitive user interface and technology access without the need for extra devices + Overall positive user experience due to low entry barriers and fast understanding
DP2 *Communication*	+ Colour schemes and animations are helpful regarding information assimilation o Certain objects within the living space could be emphasized through projection techniques
DP3 *Functionality*	+ Different use cases and scenarios are well-implemented + Necessary functionality and information are provided in a needs-oriented manner + Transition between action areas and the respective widget state is perceived as useful
DP4 *Universal Design*	+ Communicated information is easily accessible and comprehensible o Auditory information could be improved by adding different voices and alert types
DP5 *Low-threshold*	+ Cognitive relief due to minimized complexity + Cognitive relief due to easily understandable and object-oriented information
DP6	+ A data privacy concept fosters user acceptance

Privacy	o Privacy and data protection should be made more transparent
DP7 *Service Orientation*	+ Individual and functionality-oriented widgets are perceived as useful + Content of communicated information is sufficient o Widgets should always represent the real object (i.e. number of stovetops)
DP8 *SAR*	+ Cognitive relief due to pleasant and naturally fitting projections o Some widgets within the active state area could be displayed in smaller
DP9 *Context-awareness*	+ Context-specific information is useful and communicated + Cognitive relief due to individual needs-oriented assistance
DP10 *Integration*	+ Cognitive relief due to the reduced amount of specialized smart systems o ELiE should cooperate with and integrate local community initiatives
DP11 *WFMS*	+ Intuitive workflow management interface for developers + Use of process-oriented data streams fosters user experience regarding delays
DP12 *AI*	+ Gaze-based projection facilitates the perception of communicated information + Monitoring was perceived as useful regarding anomaly detection or emergencies
DP13 *Mediation*	+ Differences in required cognitive effort are appreciated rather than static reminders + (Subjective) perception that such decision support helps structure cognition
Note. ELiE = enhanced living environment; DP = design principle; + = positive aspect; o = potential for improvement	

In summary, our findings indicate an ELiE with user-tracking event-based projections is intuitive to use and doesn't require additional devices, e.g., wearables. The widget view provides useful information intuitively, while aMCI users perceived the cognitive support as cooperative rather than intrusive, consistent with the idea of addressing their zone of proximal development [20,21]. Using color schemes and SAR reduces cognitive load, especially suitable for aMCI individuals. The subjects felt comfortable with the ELiEs communication style and could imagine themselves using it every day, as it provides them with useful functionalities. The proposed improvements are all minor adjustments but do not necessitate a major architectural revision.

7. Discussion

Since the development and introduction of innovative healthcare solutions is an ever-emerging challenge, healthcare and management authorities should be equipped with the relevant knowledge to provide user-centered and needs-oriented services/products. As discussed in the previous chapter, the results of our complementary evaluation episodes

indicate the high usefulness of guiding design and practical implementation knowledge, thus validating the DT and RA. The positive evaluation substantiates the practical relevance of the DT and RA as practitioners can adapt our DT to develop new, related, and context-aware ELiE systems using the generally applicable and target group independent DPs. Our core argument is straightforward: if decision support systems in digital health, especially in the context of cognitive impairments, fail to address the right interaction design and cognitive mechanisms necessary, the resulting solutions won't benefit affected individuals and undermine the very goals they are intended to serve. We argue that the DRs and DPs we developed not only add to the body of IS knowledge but also have the potential to change the way we approach the design and implementation of decision-support systems for individuals with cognitive impairments. As such, our defined DRs and DPs merged in an inter-field DT [112]. The derivation of DFs enabled an IS architecture implementation, thus, contributing to the prescriptive knowledge base of the IS community according to Gregor and Hevner [25] along with the IS design science knowledge base according to Woo et al. [113]. Since our study is located within the theorizing area of the DSR focus matrix [27], and according to the classification of DSR artifacts by Gregor and Hevner [25], the DT can be seen as *Design Theory*, whereas its instantiation as conceptual model is a *Model*. We developed several DRs and DPs that are useful for further theorizing and the development of artifacts that address similar problems or AALs in the healthcare sector. Furthermore, the evaluation through our target group showed a positive user experience without any need for wearables, thus improving current healthcare solutions for aMCI people. People feel comfortable using the system, perceive it as useful, find projections easy to comprehend, and appreciate the kind of cognitive support.

7.1 Theoretical Implications

Our study extends the theoretical discourse on DTs by highlighting the usefulness of DTs as a forward-thinking approach to theorizing for the future, steering practical and replicable advancements in technology toward fostering a more prosperous future in various domains [33]. In general, DT provides a foundational framework for rethinking system design methodologies and their intended functionalities, emphasizing a deliberate consideration of technological advancements and their consequential societal implications [28,30,32,114]. In our specific research, the DRs and DPs form an emancipatory DT [114], stimulating emancipatory outcomes that improve the aMCI user's cognitive state of being. We also address the delicate balance between crafting universal design principles and ensuring they are detailed enough to offer valuable guidance to designers. Our DT stands out as it is derived from various qualitative methods, aiming to tackle a wide array of strategic management issues, necessitating a certain level of abstraction yet retaining actionable insights. In terms of next-generation theorizing [28] and applying the *envision*-strategy, we invented a new IS theory that is positioned to study a new phenomenon emerging in a changing world, which is to adequately support the autonomy of the ever-increasing number of elderly and aMCI people through ELiEs. By delving deeply into the needs of a specific population (in our case people with neurodegenerative diseases), our research underscores the importance of integrating socio-technical perspectives when innovating for future landscapes. Furthermore, our study leverages the findings of Ienca et al. [10] on the unique technology adoption behaviors of individuals with cognitive impairments, highlighting the need for intuitive and less complex interfaces. This is directly addressed by our application of SAR technology, which, as shown in the work of Baumeister et al. [15] and Raskar et al. [14], can significantly reduce cognitive load compared to traditional head-mounted display-

based AR systems, thereby enhancing the zone of proximal development for aMCI individuals [20,21]. Our research thus contributes to the literature by demonstrating how SAR can be effectively integrated into digital assistance systems, thereby enriching the theoretical discourse on the use of ambient and decision-support technologies in healthcare settings, a gap previously identified in the research streams analyzed.

Our incorporation of Vygotsky's [20] ZPD as a kernel theory advances the theoretical discourse on digital assistance systems in healthcare by reframing them as adaptive cognitive scaffolds rather than mere compensatory tools. Traditional assistive technologies in digital health are often designed with a functionalist paradigm, focusing on automation and usability rather than cognitive engagement. In contrast, by embedding the principles of scaffolding, intersubjectivity, and semiotic mediation, we argue that an ELiE actively facilitates cognitive maintenance and autonomy building rather than promoting passive reliance on technology. This shift underscores the importance of designing systems that dynamically adapt to users' evolving cognitive abilities rather than providing static, one-size-fits-all support. A key implication of our study is that ZPD can be extended beyond human facilitators to AI-driven adaptive systems, demonstrating that digital assistance technologies can serve as "more knowledgeable others" by modulating their level of intervention based on users' cognitive development. This challenges prevailing conceptualizations of assistive IS as static decision-support tools, instead positioning them as active participants in users' learning, adoption, and adaptation processes [9]. Furthermore, our findings highlight the need to reconceptualize context-aware systems in digital health - not simply as information retrieval mechanisms, reminding tools, or alerting systems, but as interactive environments that construct and refine shared representations of cognitive tasks with the user. This is consistent with Wertsch's [21] elaboration of ZPD, which emphasizes that successful scaffolding is not

only about task simplification but also about negotiating meaning and aligning system guidance with the user's mental model. Moreover, by applying ZPD's notion of semiotic mediation to SAR interfaces, this study provides novel insights into how digital interventions can transition from external guidance to internalized cognitive strategies. This implies that assistive systems must be designed to dynamically fade out their support, allowing users to progressively take ownership of cognitive processes rather than perpetuating technological dependence, which we would argue, challenges the traditional notion of assistive health systems only being "easy-to-use." This rethinking of assistive IS as cognitive learning environments extends the IS and DSR literature, particularly in the context of digital health, adaptive interfaces, and AI-driven human-technology collaboration. By mapping ZPD's theoretical constructs to digital health interventions, our research may broaden the applicability of sociocultural learning theories in IS while simultaneously identifying gaps where existing theories must evolve to accommodate AI-driven cognitive assistance. In doing so, we lay the groundwork for future research at the intersection of human cognition, intelligent digital assistance, and adaptive system design, ultimately advancing how IS research conceptualizes and develops assistive technologies for cognitively impaired users.

Our approach amalgamates the strengths of a multi-method research approach [34] and existing frameworks, facilitating an iterative analysis to formulate a comprehensive DT. From a theorizing and research approach perspective, this method can be replicated even in single-project studies, offering a pathway to create more abstract DTs and thus, showcasing a possible way of theorizing in the field of IS and digital health. Moreover, our study showcases a possible hybrid approach to heuristic design theorizing [22], incorporating multiple qualitative methods (observation, think-aloud, focus groups) and methodological frameworks to identify different levels of design knowledge. Hence,

subsequent studies in digital health can utilize, adapt, or modify such an approach to not only theorize but also develop applicable artifacts. Our study shows and informs these potential subsequent studies on how the DSR paradigm can be utilized to iteratively develop, analyze, and evaluate design knowledge in the form of DRs and DPs as well as their instantiated technical artifacts. Furthermore, the integration of a kernel theory through the "analyze with lens-mechanism" approach [46] hereby equips the study with a robust methodological framework to dissect and interpret underlying design concepts. This not only advances the broader discourse on design science, both theoretically and practically, but it further emphasizes a nuanced comprehension of the subject matter, going beyond surface-level observations to deepen the analysis of digital health and SAR research in general. The alignment between the chosen kernel theory and the research objectives is particularly pertinent in the context of supporting people with neurodegenerative diseases through SAR and context-aware ISs. This alignment is evident in scenarios where designing for usability and ethical considerations becomes paramount, ensuring technology is intuitive, user-centered, and accessible.

An often-noticed concern with DPs is the difficulty in balancing their abstraction and universality with their actionability for designing less abstract artifacts. Through our theory-driven [23] and prescriptive [84] approach, we addressed the issue of DT indeterminacy [36] by providing DPs and design knowledge that bridges the gap between theory and practice. Hence, we aimed at developing DRs and DPs that are applicable in practice and not only mere theoretical constructs, which we showed through the RA and its instantiation. This further means that our design knowledge is projectable, in terms of the framework by Goodman [115], and provides some form of generalizability in terms of its application, for which we ensured that the DPs are projectable across multiple instantiations while maintaining clarity for our specific research case. Respectively, our

study provides illustrative support concerning the DT characteristics, highlighting the necessity for detailed descriptions and examples to facilitate understanding and offer concrete projections of the DPs. This further aligns with Chandra et al. [116] in framing DPs that are both material and action-oriented.

Since design science is epitomized by problem-centered research phenomena, a solution-driven synthesis is the logical consequence. Our study therefore drives knowledge accumulation through solution domain synthesis, focusing on midrange designs as per Offermann et al. [117], whereas from a theorizing perspective, our DT can be defined as midrange theory [33,118] since the theory and its assumptions are testable across various populations and environments but not necessarily applicable to all. The underpinnings of our work affirm the essence of connecting theory with practice, where both benefit from each other's insight and adaptation. As we move further into this age of rapid technological evolution, researchers and designers alike must have a keen understanding of the profound ripple effects their creations may have, ensuring that they remain purposeful, user-centered, and progressive - as can be ensured through rigorous theorizing. As more researchers embrace next-generation theorizing, it will undoubtedly lead to the emergence of solutions that not only align with current trends but also equip us for the various healthcare challenges and opportunities in the future.

7.2 Practical Implications

Digital healthcare solutions for aging people with aMCI are becoming increasingly important as a result of the ongoing demographic change. Our research provides practical guidance on the implementation of ELiEs for health authorities, management, researchers, and developers. At the organizational level, health authorities face several significant challenges when trying to introduce or implement innovative changes or systems [119]. Our DT and RA support health authorities by providing the vocabulary,

concepts, and design knowledge necessary to efficiently communicate with other stakeholders, e.g., policymakers or developers, about changes to existing systems, e.g., when introducing ELiEs or similar solutions in nursing facilities, thus bridging the gap between theory and practice as demanded by Larsen et al. [41]. Our findings emphasize that digital healthcare solutions for aMCI individuals must go beyond static assistive functions and instead serve as adaptive scaffolding mechanisms that align with users and their zone of proximal development. This requires progressive adaptation, where systems like ELiE do not simply compensate for impairments but dynamically adjust their level of intervention based on the user's progress or cognitive state, ensuring a transition from dependency to autonomy. This insight is particularly relevant for health authorities, developers, and decision-makers, as it highlights the need to design assistive decision support systems in IS that promote gradual cognitive adaptation and adoption rather than imposing rigid system logic [9]. By integrating ZPD-based semiotic mediation and intersubjectivity, ELiE may enhance user-system co-construction of meaning, making digital interventions more intuitive and increasing long-term adoption and usability. Thus, from a practical perspective, these findings provide a strategic framework for the design and implementation of next-generation digital health solutions, ensuring sustainable autonomy and reduced caregiver burden in aging populations.

From a user perspective, such innovative digital health solutions might appear complex and intrusive to some extent, which was made a subject of discussion in our development and evaluation episodes, by both users and healthcare professionals. Hence, transparency, communication, and inclusion of the target group are of unconditional relevance when theorizing and developing such digital health systems, which correspondents with our applied kernel theory of ZPD [20,21] as well as user-centered [35] and value-sensitive design [81]. In general, elderly and aMCI people approach

healthcare ISs differently than younger people. During the theoretical development and the practical implementation of our ELiE system, we often found ourselves presuming functionalities for our target group that later turned out not to help them in their everyday life. Through the early integration of healthcare experts and our target group, a user-centered, value-sensitive, and functionality-oriented DT accounting for the special needs of MCI people addressed specifically these issues. The subsequent derivation of the RA made it possible to transfer that theorized knowledge directly into practical implementation. Furthermore, the direct on-site evaluation by our target group enabled us to specifically tailor the system to the specific needs and preferences, e.g. changing widget information quantity, color schemes, sizing, or functionality. Given that our system enhances the experiences of the elderly and those with aMCIs, healthcare providers, and organizations can either adopt or adapt our theoretical as well as practical solutions for improved care. Hence, for developers and innovation teams in the healthcare sector, our research serves as a roadmap. By following our defined DRs and DPs, they can efficiently address similar problems and develop AALs that are not necessarily based on SAR. Moreover, our emphasis on the balance between universal and detailed DPs ensures these guidelines remain both comprehensive and actionable. The positive feedback from our target group hereby suggests a favorable acceptance rate among similar user groups, eliminating the need for wearables and further simplifying the adoption process.

Regarding implications for strategic healthcare management in the field of digital health, healthcare managers and decision-makers can leverage our findings to address strategic management challenges in care for the elderly and those with neurodegenerative diseases. Our research provides a bird's-eye view of the potential of SAR and context-aware ISs, ensuring that technological solutions align with the pressing needs of this ever-

increasing population. The phenomenon of aMCI and elderly individuals experiencing barriers in utilizing new technologies is prevalent, even though such technologies are largely advantageous for their use [120]. Our research found initial user distrust towards a lack of understanding of the system's purpose and features. However, this quickly turned into a positive experience after using it. To address this, we propose model environments where users can familiarize themselves with the system, test its functionalities, and discuss any concerns. Healthcare providers could offer these sessions to introduce innovative technologies and build user comfort, ultimately lowering barriers to adopting these beneficial solutions.

The global demographic shift towards an aging population is undeniable. According to the World Health Organization, the number of people aged 60 years or older is expected to double by 2050. This burgeoning demographic comes with unique healthcare needs and challenges and given the rapid pace of technological advancements, solutions that are static and rigid become obsolete quickly. Building on recent ethical discourse on the deployment of assistive technologies in healthcare [10,121,122], our design prioritizes user-centered and value-sensitive design. This ensures usability and aligns technology with user needs, like eliminating wearables for elderly or aMCI users. Our approach goes beyond usability, incorporating ethical considerations like non-invasiveness, privacy, and well-being, setting a benchmark for ethical technology design in healthcare. Our DT and RA, with their adaptability, ensure that as the needs of society change, the technology can evolve accordingly. This resonates with the views of Carayannis and Campbell [123], who advocate for "Mode 3" systems that are knowledge-driven, and dynamic, ensuring relevance in a rapidly evolving landscape. As discussed earlier, next-generation theorizing, like ours, leads to solutions that not only align with current societal needs but also anticipate future challenges and opportunities. Our

approach, thus, isn't just about addressing today's problems, but about building a resilient and flexible foundation for healthcare solutions of the future. In conclusion, by bridging the often-divergent worlds of theory and practice, our research offers healthcare practitioners, managers, and developers a holistic toolkit to address the pressing challenges of our times. As we continue our journey into this digital age, grounded, actionable, and empathetic research like ours will be instrumental in shaping a more inclusive, user-centric, and progressive healthcare landscape.

7.3 Limitations & Future Research

Meanwhile, in the context of the utility of our DT, RA, and prototype, the following limitations should be considered: On the one hand, DRs, DPs, and DFs are based on the subjective creativity of the researcher even after rigorous literature analysis, MFGs, or observational studies. However, not all design decisions can or should stem from behavioral or mathematical theories since a degree of creativity is vital to developing a cutting-edge design artifact [124,125]. While this design theory is presented as a comprehensive theorized artifact, it can also be interpreted as a nascent design theory [25], depending on the lens or context through which it is viewed. We argue that positioning the design theory as a comprehensive artifact is more consistent with its multi-cyclical approach to addressing the everyday cognitive challenges of individuals with aMCI, which transcends the characteristics of a nascent design theory. Herein, our DT is further supported by the methodological approaches of heuristic design theorizing [22] and Schoormann et al. [23] regarding the outcomes of a theory-driven research approach in DSR. In this regard, our study further acknowledges the potential for refinement in the abstraction and granularity of its design principles, since general approaches in DSR vary in their abstraction and explanatory levels (i.e., either smaller sets of specific DPs or broader sets for a more holistic theoretical perspective). We would like to take up this

idea and see future research exploring strategies for optimizing the conciseness and specificity of the DPs, depending on their use and actionability in theory and practice. We believe that initiating this ongoing dialogue is essential to advancing the theoretical and practical discourse on supporting individuals with aMCI in digital health IS and beyond.

On the other hand, as with any other evaluation, our results describe only a few samples, and our qualitative think-aloud sessions were subject-specific, which means that different results could be expected by choosing other participants or a different focus. One could argue that, e.g., the questionnaire-based evaluation episode on the UTAUT constructs did not contain a sufficient number of sample subjects and responses, where a higher number often improves statistical validity. However, our claim was not to test an empirical research model (e.g., through structural equation modeling) but to generate a general expert opinion poll with qualitative, yet quantifiable variables. Since that would logically not be sufficient for a summative evaluation of the presented artifacts, we decided to follow the *FEDS* framework [99] and therefore applied a multi-episode evaluation strategy focusing on the impact on our explicit target group of aging individuals with aMCI rather than a mere theoretical artifact assessment. In that regard, big-size evaluation episodes with our target group would not have been efficient, insightful, or informative, because therein lies the strength of small-grouped qualitative methods such as think-aloud sessions or MFGs. Thus, our total aggregated sample size over all evaluation episodes equals n=92 which should be sufficient for an iterative and qualitative DSR study. Whereas bigger sample sizes do not always yield better results [103], we are sure that evaluation results from differing sample compositions and sizes would only allow for richer insights and better interpretation. Hence, this challenge could be addressed in future research or by fellow researchers.

With the presented DT and RA of this paper, future research could be conducted regarding quantitative target group evaluation concerning the three components of usability (ISO 9241-11:2018) [126]. In regards to our prototype reference scenario, the scalability of the current setup is still limited and was aimed at validating the theoretically derived IS architecture. Based on these findings, future research can be conducted concerning the form factor, scalability, and projection mapping. It is thereby expected to work with even smaller, yet more powerful laser projectors in the future to compensate for lighting challenges.

Moreover, future research could also be conducted with a more theoretical scope, for example developing a theoretical framework for the introduction of ELiEs in the healthcare sector, based on the DPs proposed through the DT. This could include examining the potential organizational implications of such systems and providing guidance for management and policy authorities.

8. Conclusion

The paper has shown a heuristically theorized DT and RA for ELiEs which were implemented in a prototype scenario. The complementary evaluation results show that ELiE can be considered a promising solution to support the autonomy of aMCI people and thus, improve their everyday lives. Consequently, to answer the initially formulated research questions of this paper, we presented the results of our DSR approach throughout two completed design theorizing cycles, focusing on a traceable and comprehensive approach. Through the proposed novel and intuitive application of SAR into healthcare, we took an important step toward the digitalization and improvement of healthcare for the elderly and aMCI people. We contribute a DT that combines a kernel theory and requirements from literature with observations and MFG findings. Moreover, we present a second main artifact, an RA for ELiEs based on the proposed DT, and aimed at bridging

the gap between theoretical development and practical implementation. Furthermore, we present theoretical and practical implications for the introduction of such decision support systems that aim at equipping researchers, developers, and mainly healthcare management authorities with guiding knowledge. Therefore, our research provides prescriptive knowledge that assists in developing, implementing, and introducing ELiEs and extends existing AAL approaches in these areas.

References

[1] D.E. Bloom, & D. Canning, Global demographic change: Dimensions and economic significance, Population and Development Review, 34 (2008).

[2] C. Flicker, S.H. Ferris, & B. Reisberg, Mild cognitive impairment in the elderly: predictors of dementia, Neurology, 41 (1991).

[3] R.C. Petersen, Mild cognitive impairment, CONTINUUM: Lifelong Learning in Neurology, 22 (2016) 404-418.

[4] R.C. Petersen, O. Lopez, M.J. Armstrong et al., Practice guideline update summary: Mild cognitive impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology, Neurology, 90 (2018) 126-135.

[5] J. Yu, C.L. Lam, & T.M. Lee, White matter microstructural abnormalities in amnestic mild cognitive impairment: A meta-analysis of whole-brain and ROI-based studies, Neuroscience & Biobehavioral Reviews, 83 (2017) 405-416.

[6] R. Singh, L. Mathiassen, M.E. Stachura & E.V. Astapova, Dynamic capabilities in home health: IT-enabled transformation of post-acute care, Journal of the Association for Information Systems, 12 (2011).

[7] S. Yu, Y. Chai, H. Chen, R.A. Brown, S.J. Sherman & J.F. Nunamaker Jr., Fall detection with wearable sensors: A hierarchical attention-based convolutional neural network approach, Journal of Management Information Systems, 38 (2021) 1095-1121.

[8] H. Zhu, S. Samtani, H. Chen & J.F. Nunamaker Jr., Human identification for activities of daily living: A deep transfer learning approach. Journal of Management Information Systems, 37 (2020) 457-483.

[9] M. Böhmer, J. Kendziorra & S. Kuehnel, A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Cognitive Impairments, Proceedings of ECIS (2024).

[10] M. Ienca, A. Ferretti, S. Hurst, M. Puhan, C. Lovis & E. Vayena, Considerations for ethics review of big data health research: A scoping review, PloS one, 13 (2018) e0204937.

[11] F. Biocca, C. Owen, A. Tang & C. Bohil, Attention issues in spatial information systems: Directing mobile users' visual attention using augmented reality, Journal of Management Information Systems, 23 (2007) 163-184.

[12] J.H. Steffen, J.E. Gaskin, T.O. Meservy, J.L. Jenkins & I. Wolman, Framework of affordances for virtual reality and augmented reality. Journal of Management Information Systems, 36 (2019), 683-729.

[13] R. Vertucci, S. D'Onofrio, S. Ricciardi, M. De Nino, History of Augmented Reality, A.Y.C. Nee, S.K. Ong (Eds) Springer Handbook of Augmented Reality. Springer Handbooks, 2017 Springer, Cham. https://doi.org/10.1007/978-3-030-67822-7_2.

[14] R. Raskar, G. Welch & H. Fuchs, Spatially Augmented Reality, First International Workshop on Augmented Reality, (1998).

[15] J. Baumeister, S.Y. Ssin, N. El Sayed et al., Cognitive Cost of Using Augmented Reality Displays, IEEE Transactions on Visualization and Computer Graphics, 23 (2017) 2378-2388.

[16] L.F. Cardoso, F.C. Mariano & E.R. Zorzal, A survey of industrial augmented reality, Computers & Industrial Engineering, 139 (2020).

[17] P. Tavares, C.M. Costa, L. Rocha et al., Collaborative Welding System using BIM for Robotic Reprogramming and Spatial Augmented Reality, Automation in Construction, 106 (2019).

[18] Y. Yang, Y.J. Park, H. Ro, S. Chae & T.D. Han, CARe-bot: Portable Projection-based AR Robot for Elderly, Companion of HRI (2018).

[19] A. Wegerich, J. Dzaack & M. Roetting, Optimizing virtual superimpositions: User-centered design for a UAR supported smart home system, IFAC Proceedings Volumes, 43 (2010) 71-76.

[20] L.S. Vygotsky, Mind in society: The development of higher psychological processes (86), 1978, Harvard University Press.

[21] J.V. Wertsch, The zone of proximal development: Some conceptual issues. Children's learning in the zone of proximal development, 1984, Jossey-Bass Inc., Publishers.

[22] R.W. Gregory & J. Muntermann, Research note - Heuristic theorizing: Proactively generating design theories, Information Systems Research, 25 (2014) 639-653.

[23] T. Schoormann, F. Möller, L. Chandra Kruse & B. Otto, BAUSTEIN - a design tool for configuring and representing design research, Information Systems Journal (2024).

[24] A.R. Hevner et al., Design Science in Information Systems, MIS Quarterly, 28 (2004) 75–105.

[25] S. Gregor & A.R. Hevner, Positioning and Presenting Design Science Research for Maximum Impact, MIS Quarterly, 37 (2013) 337-355.

[26] J.R. Venable, J. Pries-Heje & R.L. Baskerville, Choosing a design science research methodology, Proceedings of ACIS (2017).

[27] A.B. Brendel, T.B. Lembcke & L.M. Kolbe, Towards an integrative view on design science research genres, strategies, and pivotal concepts in information systems research, ACM SIGMIS Database: the DATABASE for Advances in Information Systems, 53 (2022) 9-23.

[28] A. Burton-Jones, B.S. Butler, S. Scott & S.X. Xu, Next-generation information systems theorizing: A call to action, MIS Quarterly, 45 (2021) 301-314.

[29] T. Dehling & A. Sunyaev, A design theory for transparency of information privacy practices, Information Systems Research (2023).

[30] G.C. Kane, A.G. Young, A. Majchrzak & S. Ransbotham, Avoiding an oppressive future of machine learning: A design theory for emancipatory assistants, MIS Quarterly, 45 (2021) 371-396.

[31] J.S. Lee, J. Pries-Heje & R. Baskerville, Theorizing in design science research, Proceedings of Service-Oriented Perspectives in Design Science Research: 6th International Conference DESRIST (2011).

[32] M. Mandviwalla, Generating and justifying design theory, Journal of the Association for Information Systems, 16 (2015).

[33] A.G. Young, A. Majchrzak & G.C. Kane, Reflection on writing a theory paper: How to theorize for the future, Journal of the Association for Information Systems, 22 (2021) 1212-1223.

[34] J. Mingers & J. Brocklesby, Multimethodology: Towards a framework for mixing methodologies, Omega, 25 (1997) 489-509.

[35] C. Abras, D. Maloney-Krichmar & J. Preece, User-centered design. Bainbridge, W. Encyclopedia of Human-Computer Interaction, 37 (2004) 445-456.

[36] R. Lukyanenko & J. Parsons, Research perspectives: design theory indeterminacy: what is it, how can it be reduced, and why did the polar bear drown?, Journal of the Association for Information Systems, 21 (2020).

[37] P.G. Rowe, Design Thinking, MIT Press, Cambridge, MA, 1987.

[38] G.F Smith, Towards a theory of managerial problem solving. Decision Support Systems, 8 (1992) 29–40.

[39] S. Gregor & D. Jones, The Anatomy of a Design Theory, Journal of the Association for Information Systems, 8 (2007) 312-335.

[40] T. Schoormann, F. Möller & L. Chandra Kruse, Uncovering strategies of design principle development, Proceedings of the 17th International Conference on Design Science Research in Information Systems and Technology DESRIST, 2022.

[41] K.R. Larsen, R. Lukyanenko, R.M. Mueller et al., Validity in design science research. 15th International Conference on Design Science Research in Information Systems and Technology, DESRIST (2020) 272-282.

[42] R. Baskerville, & J. Pries-Heje, Explanatory Design Theory, Business Information Systems and Engineering, 2 (2010) 271-282.

[43] H. Meth, B. Mueller, & A. Maedche, Designing a Requirement Mining System, Journal of the Association for Information Systems, 16 (2015) 799-837.

[44] J.G. Walls, G.R. Widmeyer, & O.A. El Sawy, Building an Information System Design Theory for Vigilant EIS, Information Systems Research, 3 (1992) 36-59.

[45] S. Gregor, L. Chandra Kruse & S. Seidel, Research perspectives: the anatomy of a design principle, Journal of the Association for Information Systems (2007).

[46] F. Möller, T. Schoormann, G. Strobel & M.R.P. Hansen, Unveiling the Cloak: Kernel Theory Use in Design Science Research, Proceedings of ICIS (2022).

[47] F. Niederman & S. March, The theoretical lens concept: We all know what it means, but do we all know the same thing?, Communications of the Association for Information Systems, 44 (2019).

[48] B. Huang, T. Sun & H. Ling, End-to-end Full Projector Compensation, IEEE Transactions on Pattern Analysis and Machine Intelligence (2021).

[49] J. Miyamoto, H. Koike, H. & T. Amano, Gaze navigation in the real world by changing visual appearance of objects using projector-camera system, Proceedings of VRST (2018), 1–5.

[50] D. Lindlbauer, J. Mueller & M. Alexa, Changing the Appearance of Real-World Objects By Modifying Their Surroundings, Proceedings of CHI (2017) 3954–3965.

[51] H. Ro, Y.J Park, J.H. Byun & T.D. Han, Display methods of projection augmented reality based on deep learning pose estimation, Proceedings of ACM SIGGRAPH (2019).

[52] T. Kosch, K. Wennrich, D. Topp, M. Muntzinger & A. Schmidt, The digital cooking coach: using visual and auditory in-situ instructions to assist cognitively impaired during cooking, Proceedings of PETRA (2019) 156–163.

[53] A. Grundhöfer & D. Iwai, Recent Advances in Projection Mapping Algorithms, Hardware and Applications, Computer Graphics Forum, 37 (2018) 653-675.

[54] M. Di Donato, M. Fiorentino, A.E. Uva, M. Gattullo, & G. Monno, Text legibility for projected Augmented Reality on industrial workbenches, Computers in Industry, 70 (2015) 70–78.

[55] A. Gomes, K. Fernandes & D. Wang, Surface Prediction for Spatial Augmented Reality Applications, Virtual Reality, 25 (2021).

[56] D. Kobayashi, N. Hashimoto et al., Spatial augmented reality by using depth-based object tracking, Proceedings of ACM SIGGRAPH (2014).

[57] Y.Y. Lee, J.H. Lee, B. Ahmed, M.G. Son, & K.H. Lee, A New Projection-based Exhibition System for a Museum, Journal on Computing and Cultural Heritage, 12 (2019).

[58] J.M. Morris, User interface design for older adults, Interacting with Computers, 6 (1994) 373-393.

[59] F. Luís-Ferreira, M. Zamiri, J. Sarraipa, G. McManus, P. O'Brien. P. & R. Gonçalves, Survey on assistive technologies for people with Dementia, IEEE Inst. & Meas, 22 (2019) 45-52.

[60] M.R. Tazari, F. Furfari, J.P.L. Ramos & E. Ferro, The PERSONA service platform for AAL spaces, Handbook of Ambient Intelligence and Smart Environments (2010) 1171-1199.

[61] P.O. Antonino, D. Schneider, C. Hofmann & E.Y. Nakagawa, Evaluation of AAL platforms according to architecture-based quality attributes, AmI (2011) 264-274.

[62] L. Garcés, F. Oquendo & E.Y. Nakagawa, Assessment of reference architectures and reference models for ambient assisted living systems: Results of a systematic literature review, International Journal of E-Health and Medical Communications 11 (2020) 17-36.

[63] M. Memon, S.R. Wagner, C.F. Pedersen, F.H.A Beevi & F.O. Hansen, Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes, Sensors 14 (2014) 4312-4341.

[64] M.M. Baig, S. Afifi, H. Gholam, H. & F. Mirza, A Systematic Review of Wearable Sensors and IoT-Based Monitoring Applications for Older Adults - a Focus on Ageing Population and Independent Living, Journal of Medical Systems 43 (2019).

[65] N. Fernando, F.T.C Tan, R. Vasa, K. Mouzaki & I. Aitken, Examining digital assisted living: towards a case study of smart homes for the elderly, Proceedings of ECIS (2016).

[66] L. Block, A. Gilmore-Bykovskyi, A. Jolliff, S. Mullen & N.E. Werner, Exploring dementia family caregivers' everyday use and appraisal of technological supports, Geriatric Nursing 41 (2020), 909-915.

[67] M. Saborowski & I. Kollak, How do you care for technology? – Care professionals' experiences with assistive technology in care of the elderly, Technol. Forecast. Soc. Change 93 (2015) 133-140.

[68] M. Mueller & O. Heger, Health at Any Cost? Investigating Ethical Dimensions and Potential Conflicts of an Ambulatory Therapeutic Assistance System through Value Sensitive Design, Proceedings of ICIS (2018).

[69] R. Cloutier, G. Muller, D. Verma, R. Nilchiani, E. Hole & M. Bone, The Concept of Reference Architectures, Systems Engineering 2 (2009) 14-27.

[70] WFMC (ed.), The Workflow Reference Model, TC00-1003, 1995.

[71] S. Pourmirza, S. Peters, R. Dijkman & P. Grefen, BPMS-RA: a novel Reference Architecture for Business Process Management Systems, ACM Transactions on Internet Technology 19 (2019) 1-23.

[72] P. Grefen & R.R. de Vries, A reference architecture for workflow management systems, Data & Knowledge Engineering 27 (1998) 31-57.

[73] C. Lin, S. Lu, Z. Lai, A. Chebotko, X. Fei, J. Hua & F. Fotouhi, Service-Oriented Architecture for VIEW: a visual scientific workflow management, Proceedings of SCC (2008) 335-342.

[74] M.A. Rodriguez & R. Buyya, Scientific Workflow Management System for Clouds, Software architecture for big data and the cloud, I. Mistrik, R. Bahsoon, N. Ali, M. Heisel & B. R. Maxim (Eds.), Cambridge, MA, Elsevier, 2017, 367-387.

[75] B. Xu, Z. Yang, S. Jiang, Z. Zhou, B. Jiang & S. Yin, Design and validation of a spinal surgical navigation system based on spatial augmented reality, Spine, 45 (2020).

[76] D.L. Morgan, Qualitative Research Methods: Focus groups as qualitative research, 1997, Thousand Oaks SAGE Publications, Inc.

[77] J.C. Chung & D.W. Man, Self-appraised, informant-reported, and objective memory and cognitive function in mild cognitive impairment, Dementia and Geriatric Cognitive Disorders, 27 (2009) 187-193.

[78] P. Mayring & T. Fenzl, Qualitative Inhaltsanalyse, in Handbuch Methoden der empirischen Sozialforschung, in N. Baur and J. Blasius (eds.) Springer VS, 2019, 633-648.

[79] C.A.F von Arnim, T. Bartsch, A.H. Jacobs et al., Diagnosis and treatment of cognitive impairment, Z Gerontol Geriat, 52 (2019) 309–315.

[80] S.J. Morgan, S.R. Pullon, L.M. Macdonald, E.M. McKinlay & B.V. Gray, Case study observational research: A framework for conducting case study research where observation data are the focus, Qualitative Health Research 27 (2017) 1060-1068.

[81] B. Friedman, P.H. Kahn, A. Borning & A. Huldtgren, Value sensitive design and information systems, Early engagement and new technologies: Opening up the laboratory (2013) 55-95.

[82] B.R. Connell, The principles of universal design, 1997, Version 2.0. http://www.design.ncsu.edu/cud/univ_design/princ_overview.htm.

[83] Center for Universal Design (eds.) College of Design, 2009, North Carolina State University, https://projects.ncsu.edu/ncsu/design/cud/about_ud/udprinciples.htm.

[84] K.K. Fu, M.C. Yang & K.L. Wood, Design Principles: Literature Review, Analysis, and Future Directions, Journal of Mechanical Design 138 (2016).

[85] L. Chandra Kruse, S. Purao & S. Seidel, How designers use design principles: design behaviors and application modes, Journal of the Association for Information Systems 23 (2022) 1235-1270.

[86] F. Möller, T.M. Guggenberger & B. Otto, Towards a method for design principle development in information systems, Proceedings of the 15th International

Conference on Design Science Research in Information Systems and Technology DESRIST (2020).

[87] A. Blackler, L.H. Chen, S. Desai & A. Astell, Intuitive Interaction Framework in User-Product Interaction for People Living with Dementia, HCI and Design in the Context of Dementia, Human–Computer Interaction Series, R. Brankaert and G. Kenning (Eds.), 2020, Springer, Cham.

[88] R. Graf, P. Benawri, A.E. Whitesall, D. Carichner, Z. Li, M. Nebeling & H.S. Kim, IGYM: An Interactive Floor Projection System for Inclusive Exergame Environments, Proceedings of CHI PLAY (2019) 31–43.

[89] J. Nielsen, Usability engineering 1994, Morgan Kaufmann.

[90] U. Alegre, J.C. Augusto & T. Clark, Engineering context-aware systems and applications: A survey, Journal of Systems and Software 117 (2016) 55-83.

[91] P.D. Costa, L.F. Pires, & M. Van Sinderen, Architectural Patterns for Context-Aware Services Platforms, IWUC (2015) 3-18.

[92] T. Strang & C. Linnhoff-Popien, A context modeling survey, Proceedings of the First International Workshop on Advanced Contextual Modelling, Reasoning and Management (2004).

[93] J. Grubert, T. Langlotz, S. Zollmann & H. Regenbrecht, Towards pervasive augmented reality: Context-awareness in augmented reality, IEEE Trans. Vis. Comput. Graph. 23 (2016) 1706-1724.

[94] R. Knote, A. Janson, M. Söllner & J.M. Leimeister, Classifying smart personal assistants: an empirical cluster analysis, Proceedings of HICSS (2019) 2024-2033.

[95] S. Angelov, P. Grefen & D. Greefhorst, A classification of software reference architectures: Analyzing their success and effectiveness, Joint Working IEEE/IFIP Conference on Software Architecture & European Conference on Software Architecture (2009).

[96] E.Y. Nakagawa, F. Oquendo & M. Becker, Ramodel: A reference model for reference architectures, Proceedings of Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture (2012).

[97] M.C. Oussalah, Software architecture, 1. ISTE, 2014, 56-82.

[98] M. Armbrust, A. Ghodsi, R. Xin & M. Zaharia, Lakehouse: A New Generation of Open Platforms that Unify Data Warehousing and Advanced Analytics, Proceedings of CIDR (2021).

[99] J.R. Venable, J. Pries-Heje & R. Baskerville, FEDS: a framework for evaluation in design science research, European Journal of Information Systems 25 (2016) 77-89.

[100] F.D. Davis, Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, MIS Quarterly 13 (1989) 319-340.

[101] V. Venkatesh, M.G. Morris, G.B. Davis & F.D. Davis, User acceptance of information technology: Toward a unified view, MIS Quarterly (2003) 425-478.

[102] R.C. Nickerson, U. Varshney & J. Muntermann, A method for taxonomy development and its application in information systems, European Journal of Information Systems 22 (2013) 336-359.

[103] W. Hwang & G. Salvendy, Number of people required for usability evaluation: the 10+-2 rule, Communications of the ACM 53 (2010).

[104] J. Hulland, Use of partial least squares (PLS) in strategic management research: A review of four recent studies, Strategic Management Journal 20 (1999) 195-204.

[105] J.C. Nunnally, Psychometric Theory, 2, 1978, McGraw-Hill, New York.

[106] C. Fornell & D.F. Larcker, Evaluating Structural Equation Models with Unobservable Variables and Measurement Error, Journal of Marketing Research 18 (1981) 39-50.

[107] S. Jamieson, Likert scales: How to (ab) use them?, Medical Education 38 (2004) 1217-1218.

[108] C. Wohlin, P. Runeson, M. Höst, M.C. Ohlsson, B. Regnell & A. Wesslén, Experimentation in software engineering, 2012, Springer Science & Business Media.

[109] S.N. Haynes, D. Richard & E.S. Kubany, Content validity in psychological assessment: A functional approach to concepts and methods, Psychological Assessment 7 (1995).

[110] M. Van Den Haak, M. De Jong & P. Jan Schellens, Retrospective vs. concurrent think-aloud protocols: testing the usability of an online library catalogue, Behaviour & Information Technology 22 (2003) 339-351.

[111] D. Gioia, K. Corley & A. Hamilton, Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology, Organizational Research Methods 16 (2013) 15-31.

[112] L. Darden & N. Maull, Interfield theories, Philosophy of Science 44 (1977).

[113] C. Woo, A. Saghafi & A. Rosales, What is a Contribution to IS Design Science Knowledge?, Proceedings of ICIS (2014), Auckland.

[114] A.G. Young & Y. Zhu, Emancipatory Design Science: A Method of Designing IT for Social Good, Proceedings of ICIS (2021).

[115] N. Goodman, Fact, Fiction, & Forecast, 1955, Harvard University Press, Cambridge.

[116] L. Chandra, S. Seidel & S. Gregor, Prescriptive knowledge in IS research: Conceptualizing design principles in terms of materiality, action, and boundary conditions, Proceedings 48th Hawaii International Conference on System Sciences (2015) 4039-4048.

[117] P. Offermann, S. Blom, M. Schönherr & U. Bub, Design range and research strategies in design science publications, Proceedings of DESRIST (2011) 77-91.

[118] D.E. Leidner & O. Tona, A thought-gear model of theorizing from literature, Journal of the Association for Information Systems 22 (2021).

[119] R. Thakur, S.H. Hsu & G. Fontenot, Innovation in healthcare: Issues and future trends, Journal of Business Research, 65 (2012) 562-569.

[120] M. Tacken, F. Marcellini, H. Mollenkopf, I. Ruoppila & Z. Szeman, Use and acceptance of new technology by older people. Findings of the international MOBILATE survey: 'Enhancing mobility in later life', Gerontechnology 3 (2005) 126-137.

[121] U. Diaz-Orueta, L. Hopper & E. Konstantinidis, Shaping technologies for older adults with and without dementia: Reflections on ethics and preferences, Health Informatics Journal 26 (2020) 3215-3230.

[122] T. Wangmo, M. Lipps, R.W. Kressig & M. Ienca, Ethical concerns with the use of intelligent assistive technology: findings from a qualitative study with professional stakeholders, BMC Medical Ethics, 20 (2019).

[123] E.G. Carayannis & Campbell, Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other?: a proposed framework for a trans-disciplinary analysis of sustainable development and social ecology, International Journal of Social Ecology and Sustainable Development (2010) 41-69.

[124] A. Hevner & S. Chatterjee, Design science research in information systems, Design research in information systems, 2010, Springer, Boston.

[125] R. Baskerville, M. Kaul, J. Pries-Heje, V.C. Storey & E. Kristiansen, Bounded creativity in design science research, Proceedings of ICIS (2016).

[126] J.R. Venable, J. Pries-Heje & Baskerville, Choosing a design science research methodology, Proceedings of ACIS (2017).

Appendix C

The qualitative content analysis, as referenced in Chapters 2.3 and 3.2.2.

QUALITATIVE INHALTSANALYSE NACH MAYRING (2015)

1. Festlegung des Materials

Bei den ausgewählten Protokollstellen aus der Fokusgruppe „Volkssolidarität“ handelt es sich um ein moderiertes Fokusgruppengespräch aus dem ersten Untersuchungsblock und Erhebungszeitpunkt. Dabei wurde das Fokusgruppengespräch vollständig erfasst, wobei nur der letzte Teil aufgrund von organisatorischen Gesprächsthemen aus dem Transkript entfernt wurde. Die Auswahl aus dem Transkript zur Fokusgruppe kann wegen ihrer hohen Praxisnähe und die Spezialisierung der Fachkräfte nur als eingeschränkt repräsentativ gelten, da jene Fokusgruppe nur mit Fachkräften eines Pflegeträgers durchgeführt wurde. Dabei handelt es sich um folgende Personen:

Pflegekraft 1: Pflegedienstleiterin Demenz-Wohngemeinschaften (1)
Pflegekraft 2: Pflegekraft Demenz-Wohngemeinschaft (2)
Pflegekraft 3: Pflegekraft Demenz-Wohngemeinschaft (3)
Pflegekraft 4: Pflegekraft Demenz-Wohngemeinschaft (4)
Pflegeleiterin: Geschäftsführung Pflegeeinrichtungen (5)

Alle Proband*innen haben dabei langjährige Erfahrung in der Pflege, speziell in Hinblick auf demenziell erkrankte und kognitiv eingeschränkte Menschen. Die Fokusgruppen-Teilnehmer*innen wurden dabei durch einen Projektpartner direkt angesprochen.

2. Analyse der Entstehungssituation

Die Teilnahme an der moderierten Fokusgruppe war freiwillig. Den Proband*innen wurden a priori keine Informationen zum Projekt und der Fokusgruppe mitgeteilt, da es keiner Vorbereitung auf Seite der Fachkräfte bedurfte. Bei der hiesigen moderierten Fokusgruppe handelt es sich um halbstrukturierte (die Fragenden haben einen Leitfaden mit Fragen, deren konkrete Formulierung und Reihenfolge jedoch variiert werden kann) und offene (die Befragten können frei auf die Fragen antworten) Diskussionen. Die moderierte Fokusgruppe wurde im Rahmen des ALiS-Projekts vom Autor sowie dem Konsortiums-Führer DENKUNDMACH durchgeführt. Die Fokusgruppe fand in den Räumlichkeiten der Hallenser Volkssolidarität statt.

3. Formale Charakteristika des Materials

Die Fokusgruppe wurde mit einem Smartphone-Rekorder aufgenommen und daraufhin in maschinengeschriebene (per Computer) Form transkribiert.

4. Richtung der Analyse

Das Projekt, aus dem das Material stammt, ist agil und entwicklungsorientiert ausgerichtet. Durch die moderierte Fokusgruppe sollen die Proband*innen angeregt werden, über ihre alltägliche Erfahrung mit kognitiv eingeschränkten Personen, die in dem Kontext auftretenden Herausforderungen, ihre eigenen, eventuellen Erfahrungen hinsichtlich digitaler Assistenzsysteme und potentielle Anforderungen an ein System zur Unterstützung kognitiv eingeschränkter Personen zu reden und diskutieren. Nach dem inhaltsanalytischen Kommunikationsmodell (Abb. 1) ist die Richtung der

Analyse also, durch den Text Aussagen über den emotionalen, kognitiven und Handlungshintergrund der Kommunikatoren zu machen.

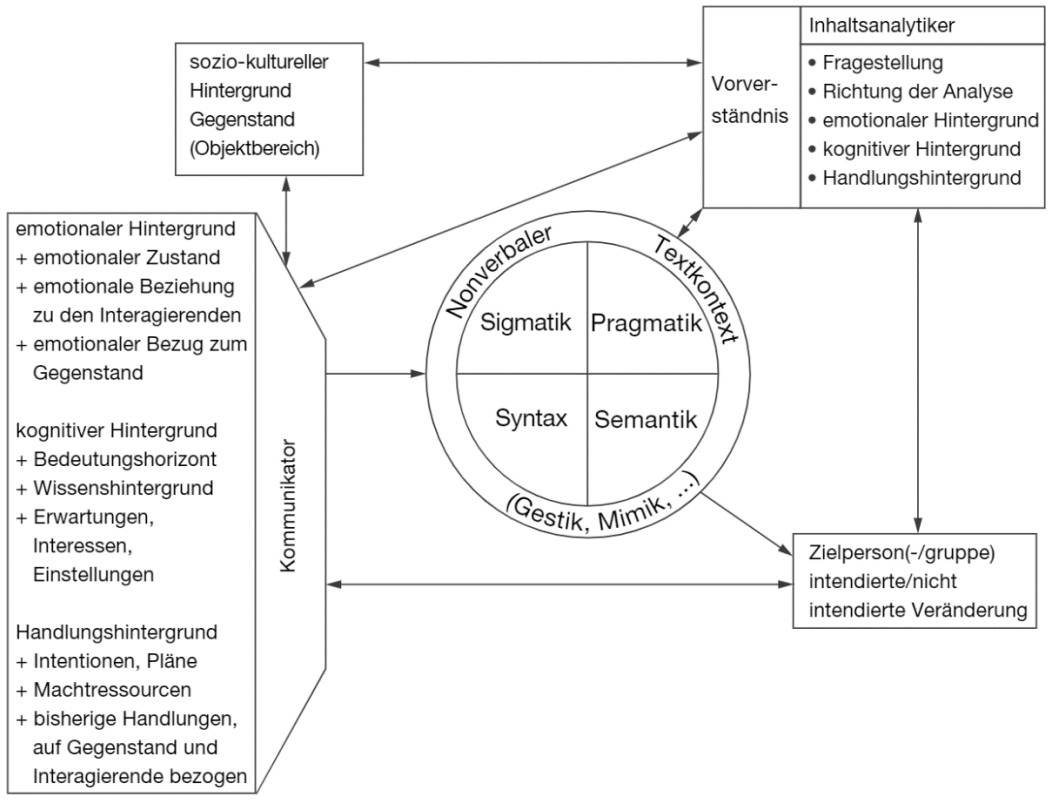


Abbildung 1: Inhaltsanalytisches Kommunikationsmodell nach Mayring (2015)

5. Theoriegeleitete Differenzierung der Fragestellung

Das Material aus der Fokusgruppe enthält Aussagen von fünf aktuell in der Pflege von kognitiv eingeschränkten Personen arbeitenden Pflegekräften über ihre Erfahrungen im Pflegealltag und Umgang mit jenen Personen. Im Allgemeinen versteht man unter kognitiven Einschränkungen Einbußen der geistigen Leistungsfähigkeit, also Störungen in der Wahrnehmung, im Erkennen, im Erinnern, im Denken und im Urteilen (Bartsch und von Arnim 2018). Dabei sollte jedoch der Unterschied zur Demenzerkrankung, welcher die Proband*innen in ihrem Alltag begegnen, noch einmal deutlich abgegrenzt werden. Kognitive Einschränkungen sind nicht gleichbedeutend mit Demenz und deren schweren/dysfunktionalen Folgen, jedoch stellen sie häufig ein hohes Risiko hin zu einer demenziellen Entwicklung dar (Gauthier et al. 2006). Bartsch und von Arnim (2018) sowie Gauthier et al. (2006) sagen zudem, dass Menschen mit milden kognitiven Einschränkungen, bei denen noch keine Demenz-Diagnose gestellt wurde, auch weiter autonom ihren Alltag beschreiten können, dabei jedoch an kognitiver Performanz Einbuße hinnehmen müssen, die Arbeiten im Alltag (Kochen, Anziehen, etc.) beeinflussen können. Das Projekt ALiS setzt genau an diesem Punkt an und soll versuchen, kognitiv eingeschränkte Personen im Alltag digital zu unterstützen und somit deren Autonomie zu stärken. Des Weiteren scheint diese Art der Unterstützung, auch hinsichtlich kognitiver Revitalisierung jener Personen, durch die Fähigkeit und das Potential für kognitive und neuronale Plastizität speziell im hohen Alter, sehr geeignet zu sein. Dabei gibt es in der Praxis digitale Assistenzsysteme, welche die Lebensqualität kognitiv eingeschränkter Personen steigern können (Lockerbie und Maiden 2020) und Anforderungen an die Darstellung solcher Systeme stellen (Morris

1994). Zudem zeigen die Arbeiten von Chang et al. (2014) und Yang et al. (2018), dass eine Anwendung von Augmented Reality oder Spatial Augmented Reality in diesem Kontext durchaus erfolgsversprechend sein kann.

In diesem Zusammenhang ist es nun von Interesse, ob die Erfahrungen von Pflegekräften in der Praxis ähnlich sind. Vor allem jedoch sind die unterschiedlichen Stufen der kognitiven Einschränkungen / Demenz von großem Interessen, um zu eruieren, ob jene Leute empfänglich für ein solches digitales Unterstützungssystem wären. Zudem interessiert die Einschätzung der Pflegekräfte hinsichtlich der kognitiven Erreichbarkeit von potentiellen Endanwender*innen und der letztlichen Gestaltung eines solchen Systems.

Daraus ergeben sich nun zwei Fragestellungen für das Material aus der Fokusgruppe:

- **Fragestellung 1:** Welchen generellen Herausforderungen stehen Menschen mit kognitiven Einschränkungen im Alltag entgegen und welche Formen der Einschränkungen existieren?
- **Fragestellung 2:** Lassen sich aus diesen Herausforderungen und Erfahrungen modulare Kategorien bilden, die von einem digitalen Assistenzsystem aufgegriffen werden können?

6. Analysetechniken

Die „Welche-Fragestellung“ deutet dabei auf eine induktive Kategorienbildung hin. Hierbei werden nun die beiden relevanten Regeln für die induktive Kategorienbildung definiert:

- **Kategoriendefinition:** Subjektiv wahrgenommene Herausforderungen von kognitiv eingeschränkten Personen in ihrem Alltag sowie deren kognitive Aufnahmefähigkeit. In diesem Zusammenhang sollen die kontextuellen Anforderungen, um jene Menschen digital anzusprechen, ebenfalls direkt/indirekt herausgefiltert werden. Auch die verschiedenen Arten der Einschränkungen sollen dabei aufgenommen werden. Dabei sollen auch subjektive oder objektive Grenzen zwischen autonomen und nicht-autonomen Alltagsleben relevant erscheinen.
- **Abstraktionsniveau:** Subjektive und objektive Faktoren, Empfehlungen, Anforderungen, Erfahrungswerte, allgemeine Situationsbeschreibungen, keine Wertungen

Zudem werden folgende Analyseeinheiten definiert:

- **Kodiereinheit:** Klare bedeutungstragende Elemente im Text
- **Kontexteinheit:** Die ganze moderierte Fokusgruppendiskussion sowie Protokollnotizen der Autoren
- **Auswertungseinheit:** s. Kontexteinheit, da nur eine Fokusgruppe durchgeführt wurde

Als Analyseform wurde aufgrund der Leitfragen folgende gewählt:

- Zusammenfassung & Induktive Kategorienbildung

Nach Prüfung und Interpretation der Zusammenfassung des Inhalts der Fokusgruppe wird evaluiert, inwiefern eine Sortierung der induktiv gebildeten Kategorien und die damit verbundene Relevanzsortierung Sinn ergibt.

Kategoriensystem

K1: Alltag von Pflegebedürftigen

- S1: Allgemein
- S2: Prozesse
- S3: Soziale Aspekte

K2: Herausforderungen mit kognitiv eingeschränkten Personen

- S1: Ansprache & Kommunikation
- S2: Anwendungsszenarien
- S3: Digitale & Haptische Signale
- S4: Wohnsituation
- S5: Anwendungsbeispiele Praxis

K3: Entwicklung kognitiv eingeschränkter Personen

K4: Kognitive und körperliche Verfassung

- S1: Individualität
- S2: Kognitive & Physische Fähigkeiten
- S3: Selbst- & Fremdeinschätzung
- S4: Herausforderungen

Proband*in	Seite Transkript	Teil	Zitat	Paraphrase	Generalisierung	Kategorie	Subkategorie
1	2	A	I: Wie das so abläuft, wie die Leute da zusammenleben und wie der Alltag so aussieht? P: Strukturiert.	Alltag der Pflegebedürftigen ist strukturiert	Alltagsstrukturierung notwendig	K1: Alltag von Pflegebedürftigen	S1: Allgemein
5	2	A	Erklären, dass das eine ambulant versorgte WG ist und die Leute oder die Bewohner die da drin sind, werden bis zum Ableben ambulant versorgt durch Pflegekräfte und Pflegefachkräfte.	Pflegebedürftige werden ambulant versorgt, leben selbständig	Ambulante Versorgung und Selbständigkeit	K1: Alltag von Pflegebedürftigen	S1: Allgemein
5	2	A	Ich erzähle also von wirklich einer beginnenden Demenz bis zu einem schweren Fall mit im Bett liegen und nicht mehr alleine essen können, dürfen die in der WG wohnen. Das ist eine selbstorganisierte WG. Da ist das oberste Ziel der strukturelle Tagesablauf.	Alle Grade der Demenz werden abgedeckt, oberste Priorität ist Struktur im Tagesablauf	Alltagsstrukturierung hat Priorität	K1: Alltag von Pflegebedürftigen	S1: Allgemein
1	3	A	Ja, das sind maximal elf bis zwölf.	Max. elf bis zwölf Bewohner*innen	Bewohneranzahl in WG	K1: Alltag von Pflegebedürftigen	S1: Allgemein
1	3	A	Ja, weil Demenzerkrankte sehr oft keine Zurückführung in ihrem Alltag haben und dadurch ganz schnell an ihre Grenzen stoßen. Oder Angehörige an ihre Grenzen stoßen, wenn sie die ganze Nacht Anrufe kriegen nach dem Motto: Wann kriege ich mein Frühstück? Wann kommt der Pflegedienst?	Demenzkranke stoßen an ihre Grenzen und verwechseln Tageszeiten	Alltagstruktur im Wandel	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

1	3,4	A	Weil hier ist die Struktur das A und O und die Mahlzeiteneinnahme ist das A und O. Weil wir festgestellt haben, wenn die Mahlzeiten ordentlich eingenommen werden, also wenn regelmäßig getrunken und gegessen wird, kann man diese Demenz nicht aufhalten. Aber so ein bisschen auf dem Stand halten, wo sie ist. Und das ist schon mal was, was wir als erstes mit anstreben.	Struktur (bspw. Mahlzeiten) ist das Wesentliche. Damit kann Krankheitsverlauf subjektiv gebremst werden	Alltagstruktur und Herauszögern der Demenz	K3: Entwicklung kognitiv beeinträchtigter Menschen	
1	4	A	Genau, die können sich zurückziehen in ihre eigene Wohnung. Es ist eine eigene Wohnung. Deswegen ist es ja eine Wohngruppe. Und wenn der Bedarf ist bzw. sind wir bemüht und möchten es gerne, dass die Mahlzeiten immer zusammen eingenommen werden, weil das wirklich festgestellt wurde, zuhause alleine, da packen wir es weg, weil es nicht mehr geht. Dort in der Gemeinschaft, wo man sieht, "ach die isst das auch, das will ich auch", da wird einfach mitgegessen.	Selbständigkeit vorhanden, aber bei Bedarf Gemeinschaftsgefühl stärken. Gemeinschaft macht Dinge einfacher.	Selbständigkeit und Gemeinschaftsgefühl	K1: Alltag von Pflegebedürftigen	S1: Allgemein
3	4	A	Dass man sie den ganzen Tag begleitet, ist schon mal eine Herausforderung […].	Ständige Begleitung ist Herausforderung	Begleitung im Alltag	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
3	4	A	[…] dass man sie auch dort abholt, wo sie sich gerade befinden, weil die befinden sich nicht heute am 02.06,	Pflegebedürftige befinden sich in anderen Zeiten/Orten (mental und physisch)	Geistige Abholung von Demenzerkrankten	K2: Herausforderungen im Alltag kognitiv	S1: Ansprache & Kommunikation

			sondern ganz woanders. Und selbst wenn irgendjemand auf dem Feld steht, holt man ihn einfach vom Feld ab, begleitet ihn […]			eingeschränkter Personen	
3	4	A	[…] und das ist auch für uns eine Herausforderung, dass man das alles so ruhig und bedacht, alles so macht.	Ruhige und bedachte Interaktion	Interaktion mit Demenzerkrankten	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
2	4	A	Das ist ganz unterschiedlich. Also wenn jetzt jemand zu uns kommt, der am Anfang der Phase von der Demenz steht, hat vielleicht noch ein paar klare Momente oder kann sich unter Anleitung danach waschen.	Tätigkeiten (bspw. Waschen) mit Anleitung bei milder Demenz möglich	Angeleitete Tätigkeiten	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	4	A	Versuchen wir diese Ressourcen, die Sie haben, so lange zu erhalten, wie es geht. Das heißt, wir sagen dann nicht: "Ach ich wasch Sie jetzt, weil das jetzt einfach schneller geht", sondern achten da schon individuell drauf, was derjenige noch kann und fördern das auch.	Ressourcen der Pflegebedürftigen sollen erhalten bleiben.	Selbständigkeit der Pflegebedürftigen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	4	A	Wir arbeiten da z.B. auch mit der Physiotherapie zusammen. Wir sprechen da dann auch wo wir Hilfe gebrauchen könnten bei der Mobilisation oder einfach mal an den Bettrand setzen, wenn jemand lange liegt. Das ist halt auch ganz wichtig.	Hilfe und Physiotherapie bei der Mobilisation von Pflegebedürftigen.	Mobilisation von Pflegebedürftigen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	4,5	A	Genau und das ist wichtig, weil jeder Mensch an sich individuell und so	Individualität der Personen sowie verschiedene Stufen der Demenz stehen	Individualität und Stufen der Demenz	K4: Kognitive und körperlich	S1: Individualität

			sollte auch die Pflege sein. Nicht jeder Mensch ist ja gleich oder hat den gleichen Grad an Demenz. Es gibt so viele Gesichter von Demenzerkrankten und deswegen gestalten wir das alles individuell.	im Vordergrund und beeinflussen Gestaltung		e Verfassung	
2	5	A	Also es gibt Beschäftigungsangebote, verschiedene.	Pflegebedürftige haben Beschäftigungsangebote	Beschäftigung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	5	A	Aber ansonsten haben wir zum Beispiel auch Sport gemacht. Da haben wir eine PP, also Pflegepersonal was das macht einmal wöchentlich.	Pflegebürftige betätigen sich sportlich	Sportliche Betätigung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	5	A	Ansonsten haben wir normale Beschäftigungsangebote, halt spielen […]	Pflegebeürftige spielen oft	Spielerische Betätigung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	5	A	[…] oder singen […]	Pflegebedürftige singen oft	Musikalische Betätigung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	5	A	[…] oder auch mal so ein bisschen rätseln, um da die Erinnerungen zu festigen.	Rätseln um Erinnerungen aufzufrischen	Kognitive Aktivierung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	5	A	Und bei schönem Wetter so wie jetzt, gehen die Bewohner natürlich auch gerne raus.	Bei schönem Wetter Spaziergänge machen	Frische Luft	K1: Alltag von Pflegebedürftigen	

5	5	A	Tiertherapie […] Sie kommt regelmäßig zu uns, hat dann Hunde dabei, Meerschweinchen oder Hasen. Es wird sich halt in den Kreis gesetzt. Dann wird halt darüber geredet, was das für ein Tier ist, was es gerne isst.	Pflegebedürftige nehmen an Tiertherapie teil	Tiertherapie	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	5	A	Die dürfen sie dann auch auf den Schoß mal nehmen, dürfen streicheln, dürfen tasten. Das ist ja auch ganz wichtig. Wie fühlt sich das noch an? Kenne ich das vielleicht von früher? Und dann freuen Sie sich da eigentlich auch immer ganz sehr.	Pflegebeürftige streicheln Tiere und freuen sich über das haptische Gefühl	Tiertherapie	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
3	5	A	Es gibt ja festgelegte Pflegegrade, so meinen Sie das. Da stehen wir ja Verbindung mit dem MDK und die legen ja dann die Pflegegrade fest. Und so haben wir dann den Pflegeprozess. Was er noch selbständig kann, wo die Hilfe besteht, ja das wird genau festgelegt.	Pflegegrade der Pflegebeürftigen werden durch Assessment bewertet	Pflegegrade	K4: Kognitive und körperliche Verfassung	K4: Kognitive und körperliche Verfassung
1	6	A	Die Demenz selber wird nicht in irgendwelchen Graden unterschieden. Die Demenz ist ja ein riesengroßer Begriff. Haben wir auch manchmal Schwierigkeiten dabei, aber es kommt sehr darauf an, wo die Demenz auftritt. […] Aber Grade in dem Sinne gibt es nicht so, Grade gibt's wirklich nur bei der Pflege, wo eingeschätzt wird, wie die Pflegebedürftigkeit ist.	Keine Unterteilung der Demenz in Grade oder Stufen	Demenzgrade	K4: Kognitive und körperliche Verfassung	S1: Individualität

1	6	A	Und von daher sind eben so viele Sachen unterschiedlich, die auf die, der eine kann sich das gut merken und der andere kann sich halt immer waschen. Während der Nächste dann schon nicht mehr so das Trinken akzeptiert.	Große Diskrepanz zwischen den unterschiedlichen Verfassungen der Pflegebedürftigen	Unterschiedliche Verfassungen	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	6	A	I: Wird anhand der Pflegegrade auch festgelegt, ob jetzt eine Person stationär oder ambulant? P: Nein.	Beurteilung der Gesamtsituation nicht anhand der Pflegegrade	Stationäre oder ambulante Pflege	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S4: Wohnsituation
1	6	A	Das hat damit gar nichts zu tun. Es kann auch jemand mit dem höchsten Pflegegrad, das ist die 5, zuhause versorgt werden, weil die Familie das gut managed.	Auch Leute mit der höchsten Pflegestufe können zuhause versorgt werden	Stationäre oder ambulante Pflege	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S4: Wohnsituation
1	6	A	Ich glaube, das wird schwierig. Wenn, dann würde ich ad hoc sagen bis zum Pflegegrad 3, ab Pflegegrad 4 oder 5 ist es dann meistens so, dass die körperlichen Einschränkungen so sind, dass sie zum Erliegen kommen, wo sie dann diese Sachen gar nicht mehr nutzen können.	Ab Pflegegrad 4 ist eine digitale Unterstützung wenig sinnvoll	Zeitpunkt der Unterstützung	K4: Kognitive und körperliche Verfassung	S2: Kognitive/Physische Fähigkeiten
1	7	A	Ja, also wenn Sie so eine Unterscheidung haben wollen, dann. Man kann nicht, wie soll man sagen, man kann nicht sagen, nach drei Jahren oder wenn sie sich nicht mehr das Gesicht waschen, ab da ist dann die Demenz anders. So ist es nicht. Das ist einfach nicht so. Weil der eine wäscht sich bis zum Schluss, kann aber, hat aber andere	Grad der Demenz unterscheidet sich und ist nicht standardisierbar	Individualität und Stufen der Demenz	K4: Kognitive und körperliche Verfassung	S1: Individualität

			Defizite. Kann sich halt nicht mehr artikulieren.				
4	7	A	Oftmals erlebt, dass im Frühjahr und im Herbst die Menschen einen Schub haben. Dann geht eine Weile gar nichts mehr. Und manchmal kommt das wieder. Und bei manchen bleibts auch weg.	Demenz kommt in Schüben, teilweise Verbesserung	Schubweise Erkrankung	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	7	A	Der Demenzerkrankte selber merkt zum Teil ja gar nicht, wo seine Defizite sind oder er kann sie gut verstecken und versucht die zu überspielen.	Selbsteinschätzung der Demenzerkrankten ist verzerrt	Selbsteinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
1	7	A	Und von daher ist die Familie dann meistens, derjenige die Ersten, die merken, da stimmt irgendwas nicht. Inwieweit die Möglichkeiten werden noch zu unterstützen mit den Zetteln am Kühlschrank, mit dem roten Punkt auf der Platte, so ist es.	Fremdeinschätzung erkennt Anzeichen der Demenz und unterstützt	Fremdeinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
5	7	A	Sie können z.B. 5 Leute im Pflegegrad 4 oder 3 haben und die sind alle unterschiedlich. Alle individuell.	Demenzerkrankung ist sehr individuell	Individualität und Stufen der Demenz	K4: Kognitive und körperliche Verfassung	S1: Individualität
5	7	A	Naja, so ist es ja, und der eine kann nur noch den linken Arm, der andere nur den rechten Arm. Also so ist es. Das kann man nicht so pauschalisieren und es ist auch Tagesform abhängig.	Pauschalisierung der Demenz nicht möglich und Tagesform-abhängig	Individualität und Stufen der Demenz	K4: Kognitive und körperliche Verfassung	S1: Individualität

3	8	A	Also das ist auch ziemlich individuell.	Tagesablauf ist recht individuell	Alltagsablauf	K1: Alltag von Pflegebedürftigen	S1: Allgemein
3	8	A	Ja, weil wenn ja z.B. jemand mal gerne bis um 9 schläft, dann wecke ich den halt nicht Punkt 7 und sage "So, jetzt geht es hier ja los. Wir starten in den Tag." Also ich bin dann eher so, ich gucke dann, wer jetzt schon so wach ist oder manchmal ruft auch schon jemand um 7, dann mache ich den natürlich eher als jemand anderen, der halt länger schläft.	Tagesablauf der Demenzerkrankten unterscheidet sich voneinander und ist nicht bei jedem gleich	Individualität Alltagsprozesse	K1: Alltag von Pflegebedürftigen	S2: Prozesse
1	8	A	Also es geht eigentlich normalerweise früh los mit der Körperpflege früh. Er wird wach und dann würde ich gucken, dass er sich wäscht, gewaschen wird, sich ankleidet. Das Bett macht […]	Körperpflege und Ankleiden sind die ersten Prozesse des Tages	Körperpflege und Ankleiden	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	8	A	Dann gegen 8:30 Uhr wird verteilt oder gemeinsam gefrühstückt oder halt auch bei Patienten das Essen gereicht.	Nach der Körperpflege gibt es Frühstück	Mahlzeiten	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	8	A	Da legen wir viel Wert drauf oder versuchen halt auch zu motivieren, dass sie halt auch mit eindecken oder mit anderen, also die halt wirklich in die Gemeinschaft zu integrieren.	Gemeinschaftsgefühl ist für Demenzerkrankte wichtig	Soziale Interaktion	K1: Alltag von Pflegebedürftigen	S3: Soziale Aspekte
2	8	A	Sie möchten ja eine Aufgabe haben und die versucht man dann auch zu geben, also zu integrieren.	Kognitiv eingeschränkte Personen benötigen Aufgaben	Aufgabenverantwortung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

5	8	A	Anleitung geben wir bei seiner Schnitte, jetzt zum Beispiel werden Koordination mit Messer und Hüter nicht mehr so richtig, dann ja wirklich durch Worte anleitet und weniger in Veruschung kommen zu sagen: "Komm, ich mache das mal schnell, dann geht es ganz einfach. Wirklich, das was ihr hier sagt, die Ressourcen zu erhalten [...]	Kognitiv eingeschränkte Personen benötigen Anleitung und werden motiviert/aktiviert um selbständig Aufgaben zu bewältigen	Aktivierung und Eigenständigkeit	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	8	A	[…] fördern. Genau.	Ressourcen der Pflegebedürftigen sollen gefördert werden	Kognitive Förderung	K4: Kognitive und körperliche Verfassung	S2: Kognitive/Physische Fähigkeiten
2	9	A	Also wir müssen dann schon animieren oder einen Lappen geben: "Möchten Sie vielleicht mal den Tisch abwischen?" Die freuen sich dann. Aber manche haben halt nicht mehr so die Eigeninitiative. Deswegen motivieren wir ja dann auch.	Motivation und Aktivierung spielen eine große Rolle	Motivation und Aktivierung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	9	A	Also bei mir oben, die räumen schon, die sehen, ich habe jetzt gegessen und jetzt wird der Tisch abgeräumt und die nehmen auch das Geschirr vom Nachbarn mit. Also die sind noch ein bisschen fitter.	Individuelle Prozesse, die auf die kognitive und körperliche Verfassung zurückzuführen sind	Individualität im Alltag	K4: Kognitive und körperliche Verfassung	S1: Individualität
3	9	A	Die Tabletten werden dabei noch mit verabreicht. Insuliner werden vorher versorgt, also die Diabetis-Patienten.	Tabletten werden zum Frühstück noch verabreicht	Tabletteneinnahme	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

3	9	A	Dann wird abgeräumt.	Abräumen des Geschirrs nach dem Frühstück	Abräumen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	9	A	Also bei mir oben ist es dann manchmal so, entweder sie gehen nochmal in ihre Wohnung oder wir bieten ihnen nochmal einen Toilettengang an, unterschiedlich.	Nach dem Frühstück entweder Wohnung oder Toilettengang	Individuelle Bedürfnisse	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	9	A	Da gibt's dann entweder, dass da irgendwie Spiele gemacht werden.	Spiele werden gespielt	Gesellschaftsspiele	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	9	A	Oder wir gehen raus oder eine Therapie findet statt.	Spaziergänge oder Therapie nach dem Frühstück	Therapie	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	9	A	Oder dafür sorgen, dass dann die Fußpflege kommt.	Fußpflege kommt regelmäßig	Fußpflege	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	9	A	Also Karten spielen, ja. Mensch ärgere dich nicht. Oder letztens haben wir irgendwie puzzelt, ja. Kreuzworträtseln, wer das noch kann, da haben wir zwei Damen oben, die sind noch recht fit.	Es werden oft unterschiedliche Spiele gespielt	Unterschiedliche Gesellschaftsspiele	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	9	A	Rummikub, spielt Gitte unten immer, mit denen wo es noch geht.	Rummikub wird ebenfalls gespielt	Unterschiedliche Gesellschaftsspiele	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

4	10	A	Viele Fragerunden hatten die auch. Was pflanze ich im Garten an oder […]	Fragerunden werden ebenfalls oft durchgeführt	Fragerunden	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	10	A	[…] so Gedächtnistraining, sowas wird gemacht oder so ähnlich.	Gedächtnistraining ist ebenfalls Teil des Alltags	Gedächtnistraining	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	10	A	Die Leute sind mit Sprichwörtern aufgewachsen. Sprichwörter kennen sie. Wenn man sagt: "Der frühe Vogel, ..."	Sprichwörter für das Gedächtnistraining	Gedächtnistraining	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	10	A	Sowas wird auch, also mache ich manchmal, wenn ich merke es kommt, es geht gerade beim Waschen. Dass man da einfach so die Kommunikation da drüber begleitet.	Spontane und dynamische Aktivierung, oft auch unbewusst	Dynamische Prozesse	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	10	A	Aber es wird nicht nur gespielt, es wird auch gebacken oder Salat vorbereitet.	Backen und Essen vorbereiten sind ebenfalls Prozesse des Tages	Kochen und Backen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	10	A	Genau, und dann suchen sie die Zutaten zusammen mit der Kollegin oder Obstsalat, kommt dann auch darauf an: "Was ist das für Obst oder was ist das für Obst?" Dann wird schnell mal aus einem Apfel eine Banane und umgedreht.	Aktivierung über alltägliche Prozesse und Gedächtnistrining	Aktivierung und Gedächtnistraining	K1: Alltag von Pflegebedürftigen	S2: Prozesse
5	10	A	Wäsche aufhängen, das kenne ich noch von früher. Das war	Wäsche aufhängen, bei denen es noch kognitiv und physisch geht	Wäsche aufhängen	K1: Alltag von Pflegebedürftigen	S2: Prozesse

			dann halt, als ich noch dort war.				
5	10	A	Und wiederum sind sie dann auch wieder in der Zeit, was soll ich sagen, Neunzehnhundert, 42. Ja und wollen wegrennen vor irgendwas, weil sie Angst haben. Und das ist immer die Schwierigkeit, gerade für die Pflegekräfte, dieses schlagartige Umdenken, in welcher Phase bin ich gerade.	Die Menschen befinden sich mental in unterschiedlichen Zeiten, was oft durch plötzliches Umdenken geschieht	Änderung kognitiver Zustände	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	10, 11	A	Da gibt es welche, die laufen die ganzen Tag auf und ab, auf und ab und setzen sich hin auf dem Fußboden und damit muss man umgehen können.	Unterschiedliche mentale Zustände und Verhaltensweisen sind herausfordernd	Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	11	A	Ja wir können den nicht stoppen, das geht einfach nicht, das ist so.	Verhaltensweisen oder kurze Phasen können nicht gestoppt werden	Abbruch von Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
4	11	A	Da hat einer das Essen in die Hand gekriegt und ist weiter gelaufen.	Pflegekräfte müssen sich den Verhaltensweisen anpassen	Umgang mit Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
2	11	A	Ich denke, es ist schwierig, dass sie so manche ihre Gedanken ordnen können. Also wir haben auch einen Bewohner, der läuft den ganzen Tag auf und ab. Ich hab da auch schon mal gefragt, wo er denn hin möchte oder warum er diesen Drang hat. Er hatte halt geantwortet: "Ich gehe jetzt die Kühe melken."	Problem, dass kognitiv eingeschränkte Personen ihre Gedanken nicht richtig ordnen können und scheinbar bizarre Dinge tun	Unerklärliche Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

2	11	A	Aber wenn man dann z.B. mal sagt: "Ach, kommen Sie. Setzen Sie sich jetzt kurz hin." Ja, dann macht er das kurz. Aber er steht dann wieder auf und dann weiß ich, gut, das ist jetzt einfach sein Bedürfnis. Also lasse ich dem freien Lauf.	Verhaltensweisen sollten nicht unterbrochen werden, wenn sie ein Bedürfnis stillen	Akzeptanz von Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
2	11	A	Und trotzdem geht man halt mal ab und zu hin und sagt: "Alles in Ordnung?" Oder: "Kommen Sie, wir gehen jetzt mal was trinken oder ich geb Ihnen mal was zu trinken." Da muss man dann halt auch mal drauf achten. Aber ansonsten, läuft derjenige dann halt.	Unterstützung und Assistenz bei der Handlung der Verhaltensweise	Unterstützung von Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	11	A	Ja weil sie da nicht hingehören. Weil sie das nicht richtig kennen dort.	Pflegebedürftige erkennen durch ihre mentale Verfassung ihr Zuhause nicht als solches und reißen aus	Flucht in andere Zeiten	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	12	A	Wir haben zu Unterstützung so einen Fieper an der Tür, das heißt es ist eine Lichtschranke oder was das ist, richtig? Wenn die Tür aufgeht, dann piept das halt so, dass die Kollegen vor Ort irgendwie merken: "Okay jetzt ist jemand an der Tür."	Technische Unterstützung, um die Verhaltensweisen besser erkennen und betreuen zu können	Türsignal	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	12	A	Ja, dann muss man den halt abholen an der Stelle und sagen: "Komm doch mit, ich begleite sie mal. Wir gehen aber vorher noch..." Ja, das ist ganz viel Fingerspitzengefühl. "Ich will aber ein Boot holen." "Ja, wir gehen gleich los. Wir gehen	Ablenkung um nicht zielführende Prozesse zu unterbrechen und den Menschen ein neue(s) Aufgabe/Ziel zu geben	Ablenkung	K1: Alltag von Pflegebedürftigen	S2: Prozesse

			vorher noch schnell einen Kaffee trinken, "Oh ja, Kaffee." Zack. Und dann habe ich ihn am Arm und wir gehen wieder zurück.				
4	12	A	Wir haben auch Demenzerkrankte, sehr, sehr aggressiv. Die uns gehauen haben, alles. Dann kann man halt nur noch die Ärzte einschalten, weil wir als Pflegepersonal können ja nichts mehr machen.	Aggressivität bei Demenerkrankten kann ein großes Problem werden und bedarf externer Hilfe	Aggressivität Demenzerkrankter	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
4	12	B	Man muss halt dann gucken, in was für einem Maß man diese Tabletten nehmen kann, oder geben kann, dass man sagt: "Gut der erlebt den Alltag noch ordentlich" und liegt nicht den ganzen Tag im Bett und schläft.	Medikation bei aggressivem Verhalten sollte vorsichtig dosiert werden	Medikation bei Aggression	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
3	12	B	Na ja, da gibt's jetzt Mittagessen. Ist eigentlich im Prinzip dasselbe Prozedere. Aber die Medikamente, Insulingabe. Dann wird der Tisch abgeräumt.	Auf Beschäftigungsphase folgt das Mittagessen, Medikamenteneinnahme und das Abräumen	Prozess Mittagessen	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	12,13	B	Manchmal noch gefegt, gemacht, getan. Und dann Mittagsruhe. Und dann wird noch ein Toilettengang durchgeführt, wer Mittagsruhe im Bett machen möchte, geht zu Bett. Es gibt auch manche, die setzen sich vor den Fernseher, schauen RTL. Es gibt auch welche, die lesen Zeitung.	Nach dem Mittagessen folgt die Mittagsruhe, welche individuell gestaltet werden kann, etnweder mit Bettruhe, Fernsehen oder Zeitunglesen	Individuelle Bettruhe	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	13	B	Genau wie bei den Kindern.	15 Uhr gibt es Vesper, ähnlich wie im Kindergarten	Vesper	K1: Alltag von Pflegebedürftigen	S2: Prozesse

4	13	B	Und wenn jemand nicht ruhen möchte, dann läuft er auf dem Flur, dann ist es halt so. Und da geht ma zusammen den Müll runterbringen oder holt noch die Post nach oben. Also da findet sich schon was.	Akzeptanz und das Eingehen auf individuelle Bedürfnisse ist im Kontext der Tagesstruktur wichtig	Akzeptanz von Verhaltensweisen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	13	B	Im schönsten Fall kommen die Angehörigen nachmittags nochmal vorbei, wenn es die Zeit erlaubt und nehmen ihren Angehörigen mit ins Kaufland, das kann schön aufregend sein oder gehen eine Runde spazieren.	Soziale Interaktion mit den Angehörigen ist sehr wichtig	Angehörige	K1: Alltag von Pflegebedürftigen	S3: Soziale Aspekte
5	13	B	Richtig, die Unterstützung der Agehörigen fehlt. Momentan, das denke ich, ist auch eine Überlastungsanzeige. Also die haben Schwierigkeiten, Berührungsängste, es handelt sich jaum ihre Mütter und Väter. Und da kommt man als Kind dann schlecht damit zurecht. Oder man will es schlicht einfach nicht. Man muss sich nicht darum kümmern und das muss man halt auch einfach akzeptieren.	Angehörige scheinen überlastet oder überfordert mit der Situation zu sein und können/wollen damit nicht richtig umgehen	Überlastung der Angehörigen	K1: Alltag von Pflegebedürftigen	S3: Soziale Aspekte
5	13	B	Dann gibt's Kaffee, ja, selbst gebackenen Kuchen, mal gekauften und dann nachmittags die Beschäftigung wie immer.	Am Nachmittag gibt es Vesper und anschließend Beschäftigung für die Pflegebedürftigen	Beschäftigung	K1: Alltag von Pflegebedürftigen	S2: Prozesse
3	13	B	Genau. Im Prinzip leiten wir dann auch schon wieder langsam das Abendessen ein. Da wird nochmal Salat vorbereitet und wer was essen möchte.	Anschließend geht es in die Vorbereitung des Abendessens	Vorbereitung Abendessen	K1: Alltag von Pflegebedürftigen	S2: Prozesse

3	13	B	I: Und so medizinische Sachen oder Therapie-Sachen dann eher am Vormittag? P: Der Arzt kann auch manchmal nachmittags kommen. Das ist schon unterschiedlich.	Arztbesuche zu unterschiedlichen Zeiten, vormittags und nachmittags	Arztbesuche	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	13,14	B	Die Ergotherapie. Also wir haben z.B. eine Bewohnerin gehabt, die sich immer so ab um 1 bis um 2, die hatte das Bedürfnis, sich halt ständig zu beschäftigen. Aber das hat ihr halt nicht gereicht. Wenn wir zum Beispiel mal eine halbe Stunde mit ihr saßen oder mit ihr erzählt haben. Da haben wir dann auch die Ergo gefragt, ob sie z.B. in diesem Zeitraum kommen kann. Und das hat sie auch gut aufgenommen. Weil das ist ja immer auch nochmal ein neuer Mensch, der einmal die Woche reinkommt. Das ist natürlich auch für die was anderes.	Individuelle Beschäftigung, die auf die Personen angepasst wird. So werden Therapien, etc. danach geplant, wie die Personen ihren Tag verbringen	Tagestruktur	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	14	B	[…] Und das hat sie auch gut aufgenommen. Weil das ist ja immer auch nochmal ein neuer Mensch, der einmal die Woche reinkommt. Das ist natürlich auch für die was anderes […]	Neue Dinge, Abläufe, etc. sind schwer einzuführen und müssen akzeptiert werden	Akzeptanz neuer Strukturen	K1: Alltag von Pflegebedürftigen	S2: Prozesse
2	14	B	Und da versuchen wir dann halt auch zu gucken, dass das vielleicht auch mal nachmittags ist, wenn wir halt merken, da ist jemand der jetzt dieses dringende und lange Bedürfnis hat, irgendwas zu machen	Neue Strukturen oder Abläufe werden individuell auf die Person abgestimmt	Individuelle Bedürfnisse	K1: Alltag von Pflegebedürftigen	S2: Prozesse

			oder zu erleben. Da sprechen wir das dann auch individuell ab.				
2	14	B	Also bei uns ist das auch manchmal nachmittags. Also früher Nachmittag natürlich nicht zur Kaffeezeit.	Feste und routinierte Struktur ist für Pflegebedürftige enorm relevant	Feste Strukturen	K1: Alltag von Pflegebedürftigen	S2: Prozesse
4	14	B	Ich glaube, man kann halt keinen festen Plan erstellen. Kann man nicht, für keinen. Für Demenz sowieso nicht.	Keine standardisierten Pläne bei Demenz möglich	Standardisierung	K4: Kognitive und körperliche Verfassung	S1: Individualität
4	14	B	Also bei uns steht nur mal drauf: Anfangsstadium Demenz, mittelschwere Demenz. Ja, Alkoholdemenz, solche Diagnosen kriegen wir dann. Aber ja, trotz alledem auch wenn ich zwei Männer Alkoholdemenz habe, kann der eine leichter betroffen sein, der andere schwerer. Man kann da kein Schema oder so errichten. Gibt es nicht.	Keine Schemata oder Grenzwerte der Einteilung für Demenzerkrankung vorhanden	Standardisierung	K4: Kognitive und körperliche Verfassung	S1: Individualität
5	14	B	Dabei sein ist alles.	Demenzerkrankte wollen eingebunden werden, wollen nicht einsam sein	Mitwirkung	K1: Alltag von Pflegebedürftigen	S3: Soziale Aspekte
4	14	B	Genau. Und Spaß haben. Ja, ganz viel Spaß und selten Mensch ärgere dich nicht. Ja, der eine kann das kleine Männchen gar nicht festhalten. Da muss man ganz individuell, fällt es einem mal um. Also man muss da so ein Feingefühl einfach entwickeln.	Spaß steht im Vordergrund, aber auch das Feingefühl in bestimmten Situationen richtig zu reagieren	Spaß und Feingefühl	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

5	14,15	B	Der andere kann nicht sehen, der Andere macht das in die andere Richtung, der Andere ist richtig gut drauf. Und da ist die Präsenz gefordert. Die stellt sich dann hinter die Leute und sagt: "Kommen Sie Frau XY oder Herr XY, wir probieren es jetzt mal. Nehmen sie doch mal das Gelbe." Und dann geht es schon wieder los. Schwierigkeiten mit Farben, und dann machen wir mal das hier mit Festhalten, 1, 2, 3. Es ist aber ganz individuell.	Individualität und Tagesform ermöglichen immer wieder neue Situationen und Herausforderungen, die gelöst werden müssen	Herausforderungen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	15	B	Aber dadurch, dass Sie täglich Kontakt mit denen haben, wir sind ja teilweise mehr auf Arbeit als zu Hause, ist das dann, kann man sagen, schon die Familie und man kann den anderen einschätzen.	Einschätzung der Pflegebedürftigen ist wichtig, um reagieren zu können	Einschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
5	15	B	[...] wenn dann schlagartig mal so ein Wechsel kommt. Im Frühjahr oder Herbst. Das fällt einem dann gravierend auf. Das kommt, das weiß keiner. Und es ist uns immer unerklärlich. Man kann aber wirklich sagen, Frühling und Herbst. Da bekommen die meisten einen Schub, wo man sich denkt: Oh Gott was ist denn jetzt passiert? Von heute auf morgen.	Wechsel des Grades der Demenzerkrankung kann gravierend sein und plötzlich kommen. Kognitive und körperliche Verfassung schwankt ohne Anzeichen	Verfassung der Pflegebedürftigen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	15	B	Ja, wenn er nicht mehr aufsteht oder sie können nicht mehr sprechen. Oder reagieren einfach nicht. Da muss man sich wieder mal darauf einstellen. Es ist für	Umstellung auf neue körperliche und mentale Verfassung stellt eine große Herausforderung dar	Umstellung auf neue Verfassung	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

			die Kollegen, die dort vor Ort sind, eine wahnsinns Herausforderung.				
4	15	B	Ja, also die von oben, die noch alleine vorkommen und so, ja.	Leute mit milden kognitiven Einschränkungen könnten sich an Technik gewöhnen	Technologiegewöhnung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
4	15	B	Aber die, die wirklich gar nichts mehr wissen, wo das Kurzzeitgedächtnis, das Kurzzeitgedächtnis komplett weg ist. Ja, also ich war da. Und die wissen das gar nicht, weil wenn ich weg bin ist das vergessen. Dann kann man nichts mehr lernen.	Menschen mit starken kognitiven Einschränkungen haben keine Lernkurve mehr und können es mental nicht greifen	Lernkurve	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
1	15	B	I: [...] mit Technik aufgewachsen ist. Das heißt, da gibt es ja, wahrscheinlich gibt's keine Erinnerungen an irgendwelche Technik, die bedient wurde. So kurz mal gelesen, springen die Gedanken ja doch eher zurück in z.B. die Kindheit und deswegen diese Frage nach der Akzeptanz. Ob es da in der derzeitigen Generation auch geht. P: Schwierig. Ganz, ganz, ganz schön schwierig.	Akzeptanz von Technik wird durch Erinnerungsverlust erschwert	Erinnerungsverlust Technik	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
5	15	B	Dieses erste Bild, was Sie hatten, hier mit dem Vorsicht heiß. Damit können die nichts anfangen. Also die Generation, die jetzt da ist. Dieses Schild, wenn ich mal dement werde, könnte ich vielleicht was damit anfangen.	Aktuelle Generation kann mit projektionsbasierter Technologie und optischen Signalen nicht viel anfangen, allerdings positiv für folgende Generationen	Visuelle Grenzen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale

			Heißt jetzt in Verbindung für mich, wenn ich hier draufgucken würde mit dem Herd Heiß.				
5	15	B	Wenn ich jetzt nur dieses Schild sehen würde, würde ich mir denken: Habe ich in der Fahrschule nicht aufgepasst, oder? Achtung dreispurig. Nein, keine Ahnung, aber das ist schwierig.	Aufforderungen und Signale sollten unmissverständlich, klar und einfach gehalten werden	Aufforderungen /Anweisungen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
5	15,16	B	Ein Demenzkranker, der in seinem eigenen häuslichen Umfeld noch ist, ja, in einer ganz normalen Wohnung, der zu Hause wohnt zum Beispiel, wird ja eine Gefahr für sich selbst und für andere. Das kriegt man meistens erst zu spät mit. Die Reaktionen kommen zu spät, von den Angehörigen oder von Drumherum.	Selbsteinschätzung eines Demenzerkrankten macht das selbständige Leben gefährlich, oft wird die Krankheit zu spät erkannt	Selbst- und Fremdeinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
5	16	B	Da brennt halt das Wasser an auf dem Herd. Das wird halt vergessen, dass ich das jetzt auf den Herd gestellt habe.	Beispielhaft wird Wasser auf dem Herd vergessen	Anwendungsbeispiel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	16	B	Oder der Kühlschrank geht nicht zu […]	Beispiel offener Kühlschrank	Anwendungsbeispiel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	16	B	Wiederum haben wir eine Erfahrung in der D3 draußen, diese Piktogramme. Da haben wir Piktogramme an dem Kühlschrank und der Schrank, wo die Gläser drin sind. Da war damals der Vermieter sehr hinterher. Man	Piktogramme (Bspw. Schrank, Kühlschrank, etc.) wurden in der Praxis gut angenommen von Pflegebedürftigen	Anwendungsbeispiel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S5: Anwendungsbeispiele Praxis

			hatte da auch ein Forschungsprojekt laufen und hat das mit angepackt. Das ist gut angenommen worden.				
5	16	B	Also die, die fit sind wissen, da kommen die Gläser rein. Erfahrungswerte haben dann gezeigt, es gab ein Piktogramm für die Dusche auf den Fußboden geklebt. Da laufen die nicht rüber. Kann ich hier in? Fall ich jetzt in ein Loch? Darf ich da drauftreten? Ja die bleiben davor stehen und starren das an und können das nicht verarbeiten.	Verarbeitung von manchen Signalen ist problembehaftet, allerdings können noch "fitte" Personen diese Signale verarbeiten	Signalverarbeitung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
2	16	B	I: Die Ansprache, welche ist die Verständlichste? Auch so, dass man es noch annimmt. P: Viele schreckt das halt auch teilweise ab.	Ansprache (egal ob visuell oder auditiv) kann abschreckend wirken	Ansprache	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
2	16	B	Da wird auch viel mit Licht gearbeitet. Das ist so ein Entspannungs-Raum. So, manche Demenzkranke nehmen das an, manche werden da ganz dolle nervös, möchten da nicht sein, weil das zu viel ist und dieses virtuelle wenn das zu grell ist. Oder Geräusche macht. Manche scheckt das ab, weil die Angst haben, weil die ja nicht sehen, was das ist, oder sein sollte.	Ansprache kann unterschiedlich auf Personen wirken, somit entweder angenommen werden oder abschreckend wirken. Daher sollte es nicht zu grell sein oder zu ungewohnte Geräusche machen	Anspracherezeption	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
4	16	B	Laute Knall Geräusche erinnern die an Krieg. Manche leben noch im Krieg. Und wenn die irgendwas knallen hören, da sind die sofort im Langzeitgedächtnis im	Laute Geräusche sollten in dieser Generation vermieden werden	Geräuschrezeption	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation

			Krieg wieder und dann ist es aus.				
5	16	B	Panik, Wegrennen, Schreien, haben wir alles mit dabei.	Unterschiedliche Reaktionen bei der Rezeption von Reizen	Anspracherezeption	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
4	16	B	Wie kleine Kinder.	Demenzerkrankte Menschen erinnern in ihrer Ansprache und dem Umgang an kleine Kinder	Umgang mit Demenzerkrankten	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
2	16	B	Oder können dann auch aggressiv werden: "Was ist denn das? Das Licht geht da nicht weg." Das kann man da auch nicht einfach so abwägen.	Aggressive Reaktion bei der Rezeption von Reizen	Anspracherezeption	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
5	16	B	Können halt Gefahren ganz schlecht oder gar nicht mehr einschätzen.	Demenzerkrankte können keine Gefahren mehr einschätzen	Gefahreinschätzung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	16,17	B	Wir hatten einen, der wollte seinen gelben Vogel vom Baum holen. […] Der ist vom Balkon gefallen. Er ist drauf geklettert und hat einen Vogel gesehen und wollte seinen gelben Vogel wieder holen. Ja, was macht man da?	Pflegebedürftige kommen auf die unvorhersehbarsten und bizarrsten Ideen, was den Umgang noch einmal erschwert	Bizarre Handlungen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	17	B	Also die sehen das nicht, entweder funktionieren die Augen nicht mehr richtig, die Brille war nicht auf oder mit den Gedanken ganz woanders gewesen. Kann ja nichts passieren. Also die sehen ja	Selbst- und Fremdeinschätzung der kognitiven/körperlichen Verfassung unterscheidet sich oft enorm, Ursache solcher Entscheidungen ist nicht wirklich greifbar	Selbsteinschätzung und Ursachen	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung

			wahrscheinlich auch noch ganz andere Bilder.				
1	17	B	I: Aber können Sie sich dann vorstellen in so einem Szenario, also der würde jetzt diesen gelben Vogel sehen und würde sich auf den Balkon aufmachen und würde dann aber vielleicht, weil jetzt ein Sensor an der Tür das mitbekommt, dass die Tür geöffnet wird. Also dann entweder so ein Audiosignal geben, um vielleicht so eine sanfte Stimme, die sagt irgendwas in die Richtung oder so was? P: Bei der Person definitiv nicht. Der hätte sich gefreut und wäre trotzdem weitergegangen.	Es scheint unmöglich Personen in einem solchen Szenario zu unterbrechen oder abzulenken, da sie in einer Art Tunnel sind und den unbedingten Willen haben ihr Ziel zu erreichen	Unterbrechung eines Prozesses	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	17	B	Naja, das ist einfach so, bei manchen muss man einfach auch die Biografie beachten. Und er ist es gewöhnt, war Sprengstoff-Meister, der ist es gewöhnt wegzurennen. Und wegzugehen und sich nicht aufhalten zu lassen von kleinen Stimmen.	Biografien sind enorm wichtig, um auf die verschiedenen Personalitäten eingehen zu können und diese zu verstehen	Biografie	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	17	B	Und von daher würde ich diesen Laufdrang bei ihm, das ist derjenige auch da einordnen, weil man kann ihn schlecht aufhalten, er ist es so gewöhnt, er ist Zeit seines Lebens gelaufen.	Biografien helfen, die Verhaltensweisen von Personen zu verstehen und sie einzuordnen	Biografie	K4: Kognitive und körperliche Verfassung	S1: Individualität
5	17	B	Setzt sich einfach in den Flur und kurze Zeit später steht er wieder auf und läuft weiter. Als wäre nichts	Freundlichkeit ist in diesen Situationen das beste Mittel	Freundlichkeit	K2: Herausforderungen im Alltag kognitiv	S1: Ansprache & Kommunikation

			gewesen, und man ist ganz freundlich.			eingeschränkter Personen	
3	17	B	Manchmal ist es nicht nur die Sprache, sondern man muss manchmal ja auch die Berührung dazu nehmen, auch mal einfach zu sagen: "Da ist kein gelber Vogel und irgendwie berühren und dann setzt vielleicht irgendwas anderes ein, wo man ihn ablenken kann.	Berührungen sind neben auditiven Signalen ebenfalls sehr wichtig, um Personen abzulenken und/oder zu "steuern"	Berührungen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
3	17	B	Aber wenn da, wie Pflegekraft 1 sagt das Männchen da einfach sagt: "Stopp, nö", dann vielleicht gerade doch, wie bei den Kindern.	Art und Weise der Kommunikation/Ansprache ist entscheidend um Trotzreaktionen zu vermeiden	Art und Weise der Kommunikation	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
3	18	B	I: Aber wenn da der Fernseher jetzt anspringen würde oder erst einmal eine Ablenkung schaffen würde? P: Schon, trifft nicht bei allen zu glaube ich.	Nicht alle Personen können mit denselben Mitteln abgelenkt werden	Ablenkung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
5	18	B	Das ist wie im Tunnel, Sie müssen sich das vorstellen, wie im Tunnel, da gibt's auch kein Rechts und kein Links, das ist dann fixiert auf einen Punkt. Da will ich jetzt hin und das mache ich jetzt auch.	Prozesse der Demenzerkrankten sind absolut und jene Leute durchlaufen dabei einen Tunnel, der viele Sachen ausblendet	Tunnelprozess	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	18	B	Und das ist die Schwierigkeit auch für die Kollegen, die Leute aus dieser Situation, wenn es gefährlich wird oder wenn sie weg wollen, die dann rauszuholen, mit ganz, ganz viel Feingefühl.	Es bedarf viel Feingefühl, um einen Prozess bei Demenzerkrankten zu unterbrechen	Feingefühl	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
3	18	B	Man kann da auch viel falsch machen. Wo sie dann böse werden. Oder ich mag das	Schmaler Grad zwischen einer richtigen und falschen Handlung	Feingefühl	K2: Herausforderungen im Alltag	S1: Ansprache &

			nicht oder ich muss jetzt aber.			kognitiv eingeschränkter Personen	Kommunikation
5	18	B	Also es ist ja eher die Generation, also ich gehe jetzt mal von meinem Sohn aus. […] Ja genau, der könnte was damit anfangen.	Akzeptanz von Technologie ist abhängig von der Generation	Akzeptanz von Technologie	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
5	18	B	Also geht nicht würde ich nicht sagen, aber ich glaube es ist schwierig.	Berührung durch bspw. Roboter würde Unbehagen auslösen und höchstwahrscheinlich nicht funktionieren	Berührung durch Technologie	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S3: Digitale / Haptische Signale
4	18	B	Man merkt auch oft die Stimmlage. Man muss in einer bestimmten Stimmlage an die Leute herantreten.	Stimmlage ist ebenfalls für die Akzeptanz von großer Bedeutung	Stimmlage	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
4	18	B	Also wir haben ja auch welche mit einer leichteren Demenz. Und die sagen auch, die kommen mit denen nicht klar, wo die Stimme sehr tief ist. Ja, das ist nicht so vertraut, als wenn man wie Pflegekraft 2 ein bisschen höher, ja, so piepsiger. Ja, das macht auch viel einen Unterschied.	Akzeptanz der Stimmlage ist hoch individuell, es kommt dabei immer auf die kognitiv eingeschränkte Person und deren Empfinden an	Unterschiedliche Stimmlagen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
5	19	B	Die werden ja als Kindern nicht mehr erkannt, auch ab einem gewissen Stadium. Oder die suchen ihre Mutter, wollen ihre Mutter besuchen. Wer war denn das letztens? Reißen dann aus und wollen ihre Mutter besuchen gehen, die ist aber vielleicht seit 40 Jahren tot.	Kognitiv eingeschränkte Personen verlieren den Bezug zu (oder die Erinnerungen an) ihren Angehörigen, was die Ansprache zusätzlich erschwert	Bezug Angehörige	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

1	19	B	I: Passiert das auch, dass sie sich dann vielleicht an eine bestimmte Person einfach zu dem Zeitpunkt nicht erinnern können, dass einfach die Leute auch mit der Stimme nichts anfangen können? P: Hm, ja.	Erinnerung an bestimmte Personen kann nicht präsent sein, wodurch Stimmen (oder andere erinnerungsbezogene Signale) nicht zugeordnet werden können	Erinnerungsbezug	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
1	19	B	I: Das ist auch bei Farben schon losgeht. Ist das wahrnehmungsseitig oder ist es wirklich vergessen, welche Farbe was ist? P: Sowohl als auch würde ich sagen. P: Das greift so ineinander.	Wahrnehmung und das dementielle Vergessen erschweren die Ursachenfindung und verschlechtern den kognitiven und körperlichen Zustand	Verschleiß und Erinnerungsverlust	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	19	B	So wie man es von Kleinkind auf lernt ja, das ist Grün, das ist Gelb. So ein Kind, mensch wann lernen die denn Farben Farben, mit 3? Okay, dann sagt man doch: "Was ist denn das für eine Farbe?" "Das ist Rot." "Nein, das ist Gelb." So müssen Sie sich das vorstellen. So wie es im Kindesalter, ich vergleiche das immer mit, vorwärtsgeht, geht es dann mit der Demenz wieder rückwärts. Nicht in allen Bereichen.	Prozess des Lernens ist bei derDemenz rückläufig und teilweise vergleichbar mit dem eines Kindes (nur andere Richtung), daher wird versucht viel zu aktivieren	Rückläufige Lernkurve	K3: Entwicklung kognitiv beeinträchtigter Menschen	
5	19	B	Finde ich das auch sehr schwierig. Die sind auch nicht mit Ampeln aufgewachsen.	Ampelsystem kann schwierig werden, wenn Personen bspw. nicht mit Ampeln aufgewachsen sind	Ampelsystem	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
2	20	B	Aber sie können es nicht umsetzen.	Verarbeitung meist einfacher Dinge/Prozesse gestaltet sich als sehr schwierig	Kognitive Umsetzung	K4: Kognitive und körperliche	S4: Herausforderungen

						Verfassung	
1	20	B	Genau. Die haben eine Grenze, aber wissen nicht, dass es die Ampel ist. [...] Oder wir [...] heute einen Kreisverkehr.	Alltägliche Dinge werden nicht also solche wahrgenommen oder erkannt	Kognitives Verständnis	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
3	20	B	Ich glaube Demente sind so clever und umgehen die Ampel. Die sehen die Ampel, aber die suchen sich dann schon einen Weg, dass sie vorbeikommen. Also das haben sie schon.	Demenzerkrankte versuchen die kognitiven Einschränkungen/Hürden/Blockaden/etc. zu umgehen	Cleverness	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
2	20	B	Oder wenn Sie dann fragen: "Ja, die Ampel oder so", dann würden die wahrscheinlich sagen: "Da war doch ein Zebrastreifen, da konnte ich doch rüberlaufen". Oder ein Fußgängerüberweg.	Demenzerkrankte suchen Ausreden, um sich nicht einzugestehen, dass etwas nicht stimmt oder sie mit bestimmten Dingen nichts anfangen können	Ausreden	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	20	B	Die Defizite werden ausgeglichen durch Umgehungsmöglichkeiten.	Ausgleich der Erinnerungsdefizite durch einfaches Umgehen	Ausgleich der Erinnerungsdefizite	K3: Entwicklung kognitiv beeinträchtigter Menschen	
3	20	B	Genau, dieses ertappt.	Das Gefühl des "Ertappt-Werdens" ist für jene Personen sehr unbehaglich und unangenehm	Ertappt-Werden	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	21	B	Nee, da muss man das Spiel einfach mitspielen. Also da ist man glaube ich auf der leichteren Seite.	Pflegebedürftige sollten nicht bloßgestellt werden	Bloßstellung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
4	21	B	Und seit gestern versuchen wir auf die SIS umzustellen. Ja genau, das hat aber nichts mehr mit	Pflege arbeitet neuerdings mit dem Strukturmodell SIS, welches Einschätzungen,	Strukturmodell Pflege	K1: Alltag von Pflegebedürftigen	S1: Allgemein

			Angelika Krohwinkel zu tun. Die SIS ist ja runter bis aufs Minimum. Und da sehen wir uns ab nächster Woche, wenn alles umgestellt wird.	Maßnahmenpläne und Hilfen beinhaltet			
4	22	B	Da wird dann halt die Maßnahme beschrieben, die man macht. [...] Ja, und wenn ich in dem Vertrag stehen habe, ich mache Frühstück, muss ich beschreiben, wie ich das Frühstück mit demjenigen mache. Also wenn ich Ihnen das jetzt in die Hand geben würde, Sie würden das lesen, wüssten Sie ganz genau, was Sie bei der Frau machen müssten. Um alles zu berücksichtigen. Das ist dann natürlich toll. Na ja, man kann einfach jemanden losschicken, der sich das durchgelesen hat und weiß ganz genau, das muss ich jetzt machen.	Genaue Beschreibung der Maßnahmen ermöglicht allen Personen, die Maßnahmen auf die jeweiligen Personen individuell zuzuschneiden, sodass jeder unterstützen könnte	Strukturmodell Pflege	K1: Alltag von Pflegebedürftigen	S1: Allgemein
3	22	B	Also es gibt Kalender, das haben wir.	Anwendung eines Kalenders zur Aktivierung	Kalender	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	22	B	Aber wir haben auch die Uhr.	Anwendung der Uhr zur Aktivierung	Uhr	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	22	B	Aber dass das jemand sagt, das nicht. Man kann immer fragen, was haben wir heute für einen Wochentag	Kalender oder Uhr sind keine digitalen Hilfsmittel oder interagieren selbständig mit den Pflegebedürftigen	Interaktion mit Technologie	K2: Herausforderungen im Alltag kognitiv eingeschr	S3: Digitale / Haptische Signale

			oder wie spät haben wir es denn jetzt, ja.			änkter Personen	
2	22	B	Also ich weiß, ein Patientin, die hat einen Wecker auf der 3, der spricht mit ihr. Ja, der spricht auch, der sagt jetzt, wenn sie da jetzt drauf drückt, sagt er es ist jetzt 15 Uhr oder so.	Anwendung sprechender Wecker mit Interaktion ist möglich	Sprechender Wecker	K2: Herausfor derungen im Alltag kognitiv eingeschr änkter Personen	S3: Digitale / Haptische Signale
1	22	B	Ja, das kennen wir. Was die D3 auch hat, finde ich sehr schön. Da ist in dem Gemeinschaftsraum, wo die Mahlzeiten eingenommen werden, eine Tafel und da wird das Datum eingetragen, der Wochentag, die Jahreszeit und früh, das weiß ich, wird es laut benannt quasi, also wird darüber gesprochen.	Aktivierung über gemeinschaftliches Eintragen des Datums, etc. und das Sprechen darüber	Kognitive Aktivierung über Kalender	K2: Herausfor derungen im Alltag kognitiv eingeschr änkter Personen	S2: Anwendung sszenarien
2	23	B	Und dann. Also versuchen wir halt, dass sie dann die Zahlen nochmal. Dann sagen wir: "So, welche Zahl?", wenn sie jetzt zum Beispiel gar nichts sagen, sagen wir: "Heute ist der Einundreißigste." Und dann wissen die halt "Okay, dann machen sie eins und drei. "Nee, das ist jetzt die 13. Nehmen Sie doch nochmal drei und eins." Und dann einen Monat. Das steht dann so als eine Walztafel, dass jeden Tag jemand anderes dran ist, zum Frühstück halt. Und dann, wenn die das fertig haben, wird zum Beispiel gefragt: "Und jetzt haben wir Mai. Wissen Sie, welche	Aktivierung über alltägliche Dinge wie Zahlen, Daten oder Jahreszeiten, bei denen die kognitiv eingeschränkten Personen unterstützt werden	Alltägliche Aktivierung	K2: Herausfor derungen im Alltag kognitiv eingeschr änkter Personen	S2: Anwendung sszenarien

			Jahreszeit ist?" Und dann kommt man so ins Gespräch.				
4	23	B	Wir haben eine Mitarbeiterin, die singt gern. Im Nachmittagsdienst und die singen mit wenn sie die Lieder noch kennen. Ja und manche kennen die Lieder, und fangen dann an mitzusingen.	Aktivierung über Singen und das Erinnern an Lieder	Lieder singen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	23	B	Das macht die Übung. Also ich muss mich ja auf denjenigen einlassen können, und Krankenbeobachtung, dann halt selber einschätzen, ob wir Kollegen mit ins Boot holen: "Wie ist das bei euch?" Dann halt entscheiden und gucken. Also das ist halt die Beobachtung.	Entscheidung ob autonom oder nicht mehr autonom Leben wird durch Beobachtungen und Einschätzungen getroffen	Grenze autonomes Leben	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
2	23	B	In die Demenzwohngruppe, die Bewohner die da einziehen, da haben die Angeörigen ja quasi schon gemerkt, dass die Defizite da sind […] .	Demenz wird meist durch Fremdeinschätzung erkannt	Fremdeinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
2	23	B	[…] im anderen privaten Wohnen. Und da muss dann geguckt werden, wenn jemand wirklich die Cip-Karte in den Kühlschrank legt oder wenn das Essen verschimmelt ist. Und es wird einfach nicht erkannt und will gegessen werden.	Im Privaten sollte nach Ursachen Asschau gehalten werden, um frühzeitig reagieren zu können	Erkennen von Demenz	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	23	B	Oder wenn die Wasserflaschen nicht abnehmen, weil eben nicht getrunken wird.	Nicht trinken ist ebenfalls ein Indikator	Trinken	K2: Herausforderungen im Alltag kognitiv eingeschr	S2: Anwendungsszenarien

						ränkter Personen	
2	23	B	[…] die Sachen. Wo dann Achtung geschrien wird oder wenn man wirklich als Angehörige oder Pflegedienstmitarbeiter kommt: "Heute riechts komisch, wo ist es?" Und man sieht dann den Abdruck, von dem Plastebecher auf dem Herd.	Komischer Geruch als Indikator, dass irgendetwas nicht stimmt	Geruch	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
2	23,24	B	Muss man dann einfach gucken, weil in der Häuslichkeit, jetzt nicht in der Wohngruppe, sondern in der Häuslichkeit ist es ja so, die Bewohner sind nicht den ganzen Tag unter Kontrolle. Hier wird ja sehr viel noch alleine und dann sieht man das Ausmaß einfach nicht, sondern man sieht das nur an solchen Bruchstücken, dass so die Krankheiten da ist oder fortschreitet. Und dann muss man reagieren.	Bruchstücke dienen als Indikator, wie weit die Krankheit fortgeschritten ist und wo unterstützt werden kann, um adäquat darauf zu reagieren	Reaktion auf Umstände	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
2	24	B	Für mich zu Hause geht es nicht mehr, wenn derjenige sich definitiv nicht mehr alleine versorgen kann. Also mit allein versorgen heißt, dass er diese Wartezeit des Tages überbrücken kann. Was anderes, Waschen und so, das können wir ja übernehmen. Aber die Wartezeit des Tages mit seinen alltäglichen Aufgaben, wenn die nicht gemeistert werden und einfach nicht geschafft werden. Das ist für mich schon eine	Indikator für nicht mehr autonomes Leben ist, wenn jene Person den Tag (und die Wartezeiten) nicht mehr selbständig überbtücken kann, also bspw. durch Fernsehen, Lesen, etc.	Grenze autonomes Leben	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung

			Gefahr für sich selbst, weil dann kommt er völlig aus dem Ruder.				
1	24	C	Nein, das meine ich nicht. Oder naja doch das meine ich auch. Wir als Pflegedienst gehen ja ungefähr drei, maximal viermal hin und können dann bei diesen Verrichtungen helfen. In der normalen Wohnung, ich rede nicht von der WG.	Pflegedienst hilft bei den absolut notwendigen Dingen des Tages wie Essen oder Waschen	Unterstützung	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	24	C	Und da ist es dann so, diese andere Zeit, diese Zwischenzeiten, wo wir in der Wohngruppe die Beschäftigung haben alles, da ist ja keiner dort. Da sind die Patienten alleine. Und diese Zeit, da die, wie soll ich sagen, nicht besonders sinnvoll nutzen, dann ist das für mich der Punkt wo ich sagen würde, jetzt muss einfach was anderes her.	Sinnvolles Nutzen der autonomen Zeit als Indikator für Zustand der/des Pflegebedürftigen	Indikator Beschäftigung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
1	24	C	Wir sind ja da nicht mit dabei. Und wenn sie sich selbst überlegen am Wochenende: Wie stehen sie auf? Was machen sie in der Zeit bis zum Mittag? Oder was machen Sie in der Zeit bis zum Abend? Diese Zeit. Nutzen Sie sinnvoll, weil Sie Aufgaben machen […] .	Strukturierung des Alltags, um den Tag sinnvoll zu überbrücken, dient meist ebenfalls als Demenz-Indikator	Alltags-Strukturierung	K1: Alltag von Pflegebedürftigen	S2: Prozesse
1	25	C	Ich meine eben da wirklich, dass derjenige in der Wohnung rumläuft, weil er einfach nicht weiß, in welchem Zimmer er seine	Wenn sich kognitiv eingeschränkte Personen planlos bewegen oder vergessen, was sie machen wollten,	Planloses Bewegen	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung

			Socken findet, weil er gerade nicht weiß, er gerade nicht weiß, wo der Herd ist. So ne Sachen meine ich.	sollten sie nicht mehr autonom leben			
4	25	C	Mir fällt dann gerade ein, ich könnte jetzt was essen, aber nehme das und packe das in den Wasserkocher. Weil er wird ja warm. Das wissen sie irgendwie. Aber dass ein Wasserkocher nicht zum Essen warmmachen da ist, ja.	Kognitiv eingeschränkte Personen finden keine Verbindungen mehr zu normalen Tätigkeiten und vermischen Handlungen	Vermischen von Handlungen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	25	C	Oder eben dass in der Nacht angerufen wird. Das ist so, das haben wir oft. Können die Angehörigen dann sagen, wir werden so oft angerufen in der Nacht. Wieso? Das ist ein ganz typisches Zeichen, dafür dass so eine Demenz einfach fortschreitet.	Das Verwechseln von Tag und Nacht ist ein großer Indikator für fortschreitende Demenz	Tag und Nacht	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	25	C	I: Da ist ja wahrscheinlich auch die Selbsteinschätzung dann der Demenzerkrankten... P: ...ist nicht da.	Selbsteinschätzung der Demenzerkrankten ist oftmals nicht existent	Selbsteinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
2	25	C	Das ist vergessen worden, dass angerufen wurde.	Kurzzeitgedächtnis ist oftmals sehr schlecht	Kurzzeitgedächtnis	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	26	C	Es wird eben so versucht Umwege zu finden. Wie hier mit der Ampel. Es wird eben nicht über die Apel gegangen. Da geht man einen Umweg. Aber nicht sagen, ne mit mir stimmt was nicht. Die merken das schon […] .	Demenzkranke merken teilweise ihre Erkrankung und das Vergessen, versuchen dann Umwege zu finden	Selbsteinschätzung	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung

1	26	C	Die merken das schon. Können zum Teil auch nicht mehr artikulieren, haben Angst das zu sagen, weil was passiert mir, sperren sie mich weg. Dieses, dieser Begriff Heim ist für diese Generation ganz schlimm.	Demenzkranke haben Angst bzw. keine Möglichkeit ihre Bedenken zu auszudrücken, wenn sie merken, dass etwas nicht stimmt	Angst	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
1	26	C	[...] oder dieses zugestehen und zu sagen, ich komme nicht mehr zurecht. Was passiert jetzt mit mir, mit mir? Ich kann nicht mehr zu Hause bleiben. Wer will das? Es gibt die wenigsten, die sagen, ich gehe freiwillig in eine Residenz in eine Wohngruppe, weil ich zuhause nicht mehr zurecht komme.	Demenzerkrankte gehen nur sehr selten den ersten Schritt und suchen sich freiwillig Hilfe bzw. gehen in ein Heim	Eingestehen	K4: Kognitive und körperliche Verfassung	S3: Selbst- und Fremdeinschätzung
3	26	C	Aber die wollen ja auch ihren Angehörigen nicht zur Last fallen. Das ist ja das, deswegen verstecken die ja alles mögliche und sagen nicht: "Ich habe jetzt das Brot im Wasserkocher warm gemacht." Keine Ahnung, was die schon wieder da gemacht haben. "Nee, war ich nicht. Ich weiß nicht, wer das war. Es war jemand da, aber ich war es nicht." Aber immer wieder diese Angst.	Demenzerkrankte haben Angst und wollen ihren Angehörigen nicht zur Last fallen, daher werden Sachen versteckt oder versucht Ausreden zu finden	Vertuschen und Angstgefühl	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	27	C	Ich suche was und ich suche was für fünf Minuten und das macht micht wahnsinnig. Und ich hab es eilig. Und mein Gott, ich hab's doch gerade noch. Und dann hab ich es in der Hand. Zweimal ist mir das glaube ich schon	Suche von Gegenständen ist nicht nur ein Problem bei Demenzerkrankten sondern ein alltägliches Phänomen	Suche von Gegenständen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

			passiert. Wo ich mir dann dachte, was ist denn jetzt nicht in Ordnung? Ja, oder man hat was in Hand gehabt, hat es hingelegt. Man ist sich da auch absolut sicher. Ja, und dann sagt man "Wer war's? Wer hat das jetzt da hingelegt? Das war ich nicht."				
5	27	C	Wir hatten eine Bewohnerin, die ist eingezogen, da war der Mann noch klar im Kopf. Sie war dement und als er sie damals in der WG gegeben hat, hat er gesagt, er hat die Wohnung nochmal komplett renoviert. Also die alte, wo sie gemeinsam drin gewohnt haben. Er hat die Bilder von der Wand gemacht und hat die Bohrlöcher, in den Bohrlöchern zusammengerollte Geldscheine gefunden. Also so gut versteckt, da muss man erstmal drauf kommen. Ja, das ist das Sparen. Es darf keiner sehen, das muss gut versteckt sein und zusammengerollt und in die Bohrlöcher rein.	Demenzerkrankte verstecken oft Sachen, die dann von niemandem mehr gefunden werden (weil es keiner weiß und der oder die Demenzerkrankte es schlichtweg vergisst)	Verstecken von Gegenständen	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
5	27	C	Aber das mit der Technik, um Gottes Willen, ich bin ja immer jemand, der für sowas total ist. Aber ich stelle mir das echt schwer vor, wie man sowas unterstützen und begleiten kann.	Technologie-Akzeptanz bei Demenzerkrankten eher schwierig	Technologiegewöhnung	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
1	27	C	Also ich denke, es gibt vereinzelt Menschen, die Technik-affin sind, ob Männlein oder Weiblein. Da wird das	Vereinzelte Technologie-Akzeptanz ist denkbar, ist aber von	Technologiegewöhnung	K4: Kognitive und körperliche	S1: Individualität

			bestimmt was bringen, weil die sich dann damit abfinden können oder das akzeptieren können.	Technik-Affinität abhängig		Verfassung	
5	27,28	C	Aber wer jetzt in einem betreuten Wohnen wohnt, wo auch 24 Stunden, also unten sitzt ein Concierge über Nacht und da könnte ich mir das gut vorstellen. Wenn die noch selber kochen, als Unterstützung, ich gehe jetzt nur von diesem Piktogramm aus, wäre das nicht schlecht. Oder für eine Gemeinschaftsküche. Wenn die gemeinsam kochen, wäre das auch nicht schlecht.	Anwendung eines digitalen Assistenzsystems im betreuten Wohnen (oder bei Leuten, die zuhause leben) denkbar und könnte die Menschen dort unterstützen	Anwendung eines digitalen Assitenzsystems	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S4: Wohnsituation
5	28	C	Haben Sie den Kühlschrank richtig zugemacht? Ja, das stört mich einfach.	Kühlschrank als potentielles Anwendungsszenario	Kühlschrank	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
3	28	C	Also sagen wir mal so, wenn Sie am Anfang der Demenz zu uns in die WG einziehen, hat man wahrscheinlich noch eine Chance.	Bei milden kognitiven Einschränkungen oder anfänglicher Demenz erscheint der Einsatz eines digitalen Assistenzsystems realistisch	Zeitpunkt Unterstützung durch Assistenzsystem	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen
3	28	C	Aber wenn Sie zu spät und die Leute kommen ja leider meistens erst, wenn es schon eigentlich passiert ist mit der Demenz. Dann finden die sich mit allem nicht mehr zurecht. Das ist mit diesem Lernbedarf, was Sie vorhin gesagt hatten. Kann dieser Demente noch etwas lernen? Das glaube ich einfach nicht. Am Anfang ja. Aber wenn es zum Endstadium, wo man	In einer fortgeschrittenen Demenz ergibt der Einsatz eines digitalen Assistenzsystems wenig Sinn, da die Leute es nicht mehr verarbeiten oder begreifen können. Zudem gibt es keinen Lerneffekt mehr	Fortgeschrittene Demenz und Technologieakzeptanz	K4: Kognitive und körperliche Verfassung	S4: Herausforderungen

			sich komplett verliert im Kopf. Da kann man nichts ändern.				
1	28	C	Dann für Sehbehinderte könnte ich mir so eine Sache gut vorstellen. Nicht unbedingt das Virtuelle. Das Sehen, aber auch vom Hören her. Da denke ich, kann man viele Möglichkeiten schaffen, dass es mich mal vor so einer Schwelle warnt oder sowas.	Für Sehbehinderte wird der Einsatz von auditiver Kommunikation als sinvoll empfunden	Auditive Kommunikation	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
1	28	C	Und ja, für Demenzkranke, also für schon fortgeschrittene Demenzerkrankte auf keinen Fall. Auch in der Wohngruppe ist es in dem Sinne bedingt notwendig, sage ich jetzt mal. Für die Balkontüren vielleicht, für die Fenster vielleicht.	Für fortgeschrittene Demenz eignet sich im Extremfall eine Unterstützung bei Fenstern und Türen	Fenster und Türen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	28	C	Aber ich würde dann eher den Bedarf echt sehen in den Haushalten, wo sie wirklich allein leben, ohne ein Umfeld.	Einsatz sollte im häuslichen Umfeld geschehen, wo Leute noch autonom leben	Häusliches Umfeld	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S4: Wohnsituation
1	28	C	Also wenn derjenige das möchte und mitmacht, dann ja.	Technikakzeptanz ist individuell	Technologieakzeptanz	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	29	C	Man muss gucken, weil die Generationen ändern sich jetzt sicherlich und von daher wird es dann, also Pflegekraft 2 wächst ja jetzt schon damit auf, und für sie	Technikakzeptanz wird sich beim Generationswechsel erhöhen und einen Einsatz eines digitalen Assistenzsystems ermöglichen	Generationswechsel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

			ist es dann schon selbstverständlich, wenn sie die Küchentür aufmacht, dass gesagt wird: "Bitte den Herd ausschalten, wenn du raus gehst." Sowas.				
5	29	C	Oder Siri, ja da verstehen die ja die Welt nicht mehr. Meine Oma, 85, die fällt vom Glauben ab, wenn die Foto auf das Handy kriegt. Die kommt auch nicht damit klar. Also nur diese Taste zu drücken und das andere wieder rüber zu schicken. Diese Verbindungen sind nicht da. Bei der anderen Oma wurde das. Du musst es wollen.	Technikakzeptanz hängt vom Individuum ab und ob die Bereitschaft (bzw. auch die kognitive Leistung) da ist, um es lernen zu wollen	Lernbereitschaft	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	29	C	Deine andere Oma hat oft genug gefragt, ich saß oft da und hab gesagt: "Gucken Sie, so." Oder die hat mich angerufen "Können Sie mal schnell kommen? Ich wollte mal eine Nachricht schreiben, die geht nicht raus." Aber irgendwann hat sie es dann auch gewollt. Sie müssen es akzeptieren.	Akzeptanz und Wille, sich neuen Sachen/Dingen hinzugeben und diese zu akzeptieren	Akzeptanz	K4: Kognitive und körperliche Verfassung	S1: Individualität
3	29	C	Aber das ist ja, wo geht das Interesse hin? Die einen wollen und die anderen wollen eben nicht. Und es gibt im Dorf Frauen und Männer, die noch nie in der Küche gestanden, weil es eben der Partner gemacht hat oder die Partnerin. Und da fängt es ja eben schon an, ja?	Nicht nur die Akzeptanz der Technik, sondern das Ausführen von Prozessen, die sonst immer übernommen wurden, ist problematisch	Ungewohnte Prozesse	K4: Kognitive und körperliche Verfassung	S1: Individualität

1	29	C	Das hat aber nichts mit der Demenz zu tun, sondern ist dann einfach nur die Individualität des Einzelnen.	Individualität des Einzelnen steht im Vordergrund	Individualität	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	29	C	I: […] vielleicht wäre es dann auch eher sinnvoller bei positiven Sachen zu bleiben? Es wurde ja jetzt auch schon gesagt, so dieses Ermahnen kann richtig schlimm sein... P: Ja. P: Genau.	Ermahnen hat keine positive Wirkung auf die kognitiv eingeschränkten Personen	Ermahnen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
5	30	C	Navigationsgerät ist bei uns nur stumm. Also wir gucken drauf, wo wir langfahren und so weiter. Diese Dame, so nett wie diese Stimme auch ist. Biegen Sie rechts ab. Die nächste rechts abbiegen. Bitte biegen Sie jetzt rechts ab. Bist du wirklich abgebogen? Ach halt doch deinen Mund. Das ist anstrengend. Für mich ist das anstrengend.	Bestimmte Aufforderungen können ebenfalls einen negativen Effekt haben und bevormundend wirken	Aufforderungen /Anweisungen	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
4	31	C	Ja überall wo Wasser herauskommt. Wenn dann die Wohnung unter Wasser gestellt ist.	Wasser ist eine Gefahrenstelle	Wasser	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
5	31	C	Aber was ich vielleicht, was Sie so meinen, wo Sie hinwollen von diesem Herd weg. Hilfsmittel. Rollator, Rollstuhl, Gehbank.	Physische Hilfsmittel werden in der Pflege bevorzugt	Hilfsmittel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	31	C	P: Wenn die Tür aufgeht […] P: […] irgendein Signal oder so.	Signale im Öffnungsbereich von Türen sind sinnvoll	Türen	K2: Herausforderungen im Alltag kognitiv eingeschr	S2: Anwendungsszenarien

						änkter Personen	
5	32	C	Schlüssel vergessen. Und dir Tür klappt zu.	Vergessen des Schlüssels als Anwendungsszenario	Schlüssel	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien
1	32	C	Ich würde das nicht auf Demenz spezialisieren, sondern alte Menschen.	Zielgruppe eher ältere Menschen und nicht Demenzerkrankte	Zielgruppe	K4: Kognitive und körperliche Verfassung	S1: Individualität
4	32	C	"Bitte Schlüssel mitnehmen."	Klare, eindeutige, aber nicht zu fordernde Ansprache/Kommunikation	Klare Ansprache	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S1: Ansprache & Kommunikation
1	32	C	Das kann ich mir gut vorstellen. Ich glaube, das würden viele annehmen, weil sie in ihrer Selbstständigkeit bleiben und das ertappt werden merkt keiner.	Akzeptanz eines digitalen Assistenzsystems ist gegeben, um die Selbständigkeit und Autonomie zu stärken	Akzeptanz und Selbständigkeit	K4: Kognitive und körperliche Verfassung	S1: Individualität
2	32	C	Vielleicht ist auch diese Richtung, dass man sagt, die Dinge, die eigentlich alle betreffen, die dann auch vermehrt vorkommen, dass man da die Autonomie erhält. Schlüssel vergessen. Was gibt es denn noch? Naja, aber vielleicht auch diese Abläufe, so was mache ich, bevor ich die Tür zumache, hinter mir oder sowas.	Abläufe/Prozesse, die häufig auftreten, sollten abgebildet werden	Häufigkeit von Prozessen	K4: Kognitive und körperliche Verfassung	S1: Individualität
1	33	C	[…] weiß ich nicht, wie das dann, dann müssen Sie immer am selben Platz essen, damit dann die Stimme spricht und	Betroffene Personen sollten nicht immer an der gleichen Stelle sitzen, stehen oder liegen müssen, damit	Benachrichtigungsrichtung	K4: Kognitive und körperliche	S1: Individualität

			sagt: "Deine Tabletten. Hast du die genommen?" Also ich esse nicht immer an derselben Stelle, bei mir würde das nicht funktionieren.	sie eine Erinnerung o.Ä. bekommen		Verfassung	
1	33	C	Aber wenn die Tablettenbox vielleicht den Ton abgibt, weil sie nicht berührt wurde in einem bestimmten Zeitraum, das könnte ich mir dann auch vorstellen.	Tablettenbox, die sich eigens meldet, wenn keine Medikamente entnommen wurden	Medikamenteneinnahme	K2: Herausforderungen im Alltag kognitiv eingeschränkter Personen	S2: Anwendungsszenarien

Appendix D

The following questionnaire was used to evaluate the design theory and reference architecture summatively in the first design cycle (i.e., Chapter 3.4). This appendix also includes the detailed results of the conducted questionnaire.

Note: The term 'Augmented Living Spaces' was amended to 'Enhanced Living Environments' to ensure a double-blind peer review procedure.

Questionnaire on the Performance Expectancies and Effort Expectancies of a Design Theory and a Reference Architecture for Enhanced Living Environments

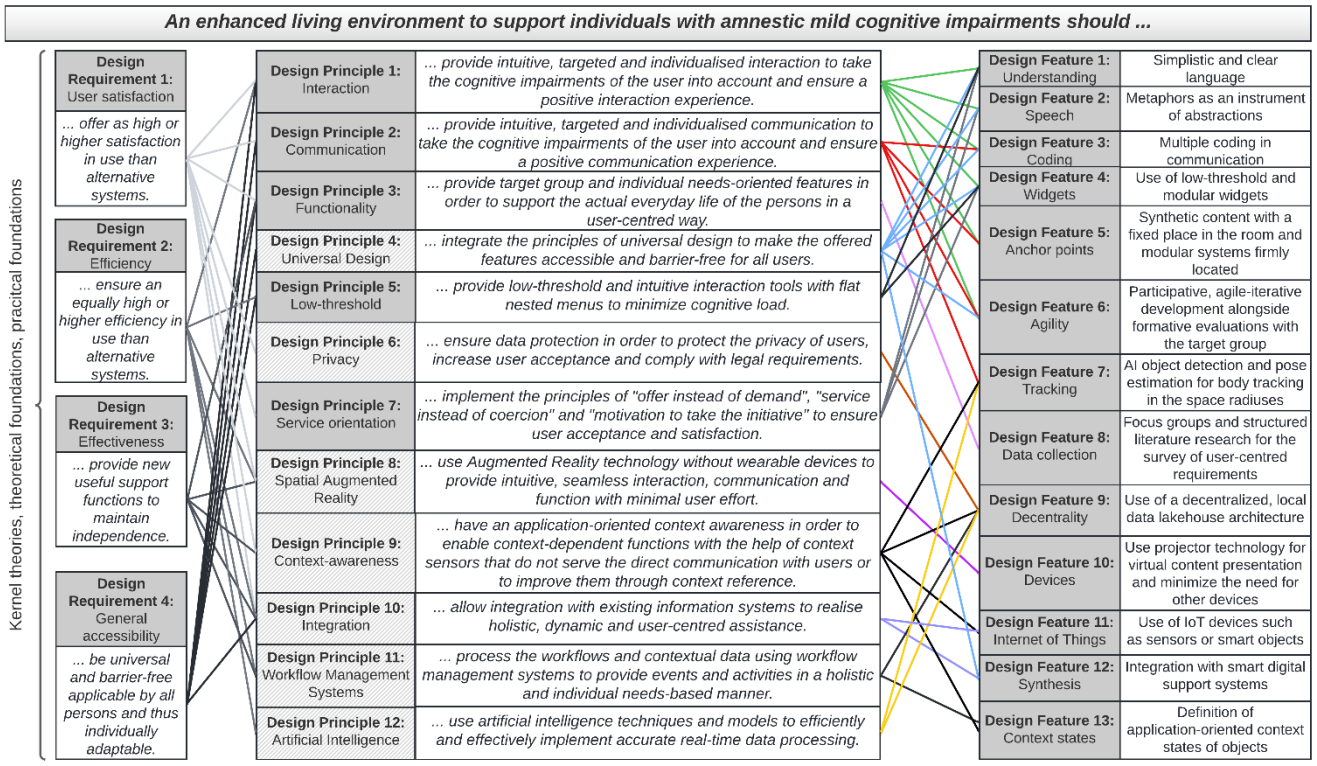
Note: Introductory sentences and paragraphs have been removed to ensure a double-blind peer review process

The respective questionnaire components can be found on the following pages.

Questionnaire #1: Design Theory

1. Design Theory

The following graphic represents the design theory of an ELiE for the extended autonomy of cognitively impaired persons. Please consider the design theory from the perspective of a theoretical/conceptual researcher or developer who, for example, aims to design/develop application-specific ELiE systems. The focus of this summative evaluation should be more on the perceived usefulness and adaptivity for theory as well as the transfer of theoretical concepts to other research areas. It is not aimed at the perception of the target group. For explanations of the DRs, DPs, and DFs, see the attached graphic. The following description is irrelevant to the evaluation but serves for a better understanding in case of arising questions.



Theoretically grounded on the ISO 9241-11:2018 standard for “usability” we derived the DRs user satisfaction (**DR1**), efficiency (**DR2**), and effectiveness (**DR3**). The DT was now expanded by the addition of the general accessibility (**DR4**) requirement, theoretically underpinned by the ISO 9241-171 standard for ergonomics of human-system interaction and the ISO/TR 22411 report for corporality that helps us to apply a universal design according to Connell (1997) and the Center of Universal Design (CUD). We aim to make ELiE generally accessible to everyone which requires principles like “equitable use”, “flexibility in use”, “simple and intuitive use” or “low physical” effort. Moreover, the ISO standards enable us to design human-centered augmented living spaces that address the needs of elderly and cognitively impaired persons.

DP1 addresses a user-centered, personalized, and intuitive interaction with the ELiE serving the need for individuality within digital assistance systems. With **DP2** we further ensure that the communication with the ELiE is individual, adapted to the specific impairments, and provides a satisfactory experience as emerged from the MFG and literature. **DP3** implements modularity which enables the system to allocate individual needs-oriented features and be vastly flexible at the same time. **DP4** was introduced to establish the principles of UD and general accessibility. **DP5** proposes the need for low-threshold user interfaces to reduce the cognitive load which is a key technology acceptance and comprehension factor. Privacy-related, **DP6** ensures personal data protection which further fosters user acceptance. An ELiE shall not be seen as a mandatory burden but rather as supporting and service-oriented which is addressed with **DP7**. Subsequently, we specify the use of SAR with **DP8** which reduces cognitive load via non-wearable devices and ensures minimal user effort. **DP9** addresses the context-awareness and reasoning of ELiE as a novel component that is based on the RAs for context-aware systems and uses context modeling techniques as well as the concept of Pervasive AR. With **DP10** a seamless integration with existing IT systems is proposed to provide a dynamic, flexible, and holistic

user experience with user-centered features. Moreover, **DP11** focuses on the novel WFMS component of the revised DT and is closely connected to the WFMC (1995) reference architecture which enables ELiE to adequately process sensory data, and contextual states, and triggers the projection respectively auditory information. **DP12** adds artificial intelligence (AI) as a component to enable real-time object detection, pose estimation, and body tracking due to precise context reasoning.

2. Statements on the Performance Expectancy and Effort Expectancy of a Design Theory for an Augmented Living Space

Please rate the performance expectancy and effort expectancy of the design theory above presented by reporting your level of agreement or disagreement with the statements (DT PE 1 – DT PE 8) on the verbal-numeric seven-point Likert-style interval scales.

Scenario:

Imagine that you're tasked with theoretically designing and engineering an augmented living space, which should enable elderly people to live autonomously for longer, is context-aware, and neglects wearables. You are at the very beginning of your design and engineering process. To support your design and engineering process, you can use all your existing prior knowledge. Additionally, you're provided with the design theory above.

Based on this scenario, how would you rate the following statements?

	Statements	Strongly disagree			Partly agree			Strongly agree	Not specified
DT 1	I would find the design theory useful in my job. (i.e., for designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 2	Using the design theory enables me to accomplish tasks more quickly (i.e., designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 3	Using the design theory increases my productivity (i.e., while designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 4	If I use the design theory, I will increase my chances of getting a raise (i.e., in your professional role as a designer and engineer of an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 5	My interaction with the design theory would be clear and understandable. (i.e., while utilizing it for designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 6	It would be easy for me to become skillful at using the design theory (i.e., for designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 7	I would find the design theory easy to use (i.e., for designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
DT 8	Learning to operate the design theory is easy for me (i.e., for the task of designing and engineering an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐

3. Conciseness, Extendibility, and Explanatory Power of the Design Theory

In addition to the performance and effort expectancies, we would also like to get your rating of conciseness, extendibility, and explanatory power of the design theory. Please ignore the scenario described above for this part, i.e., rate the statements as the expert you are. This part is also surveyed on verbal-numeric seven-point Likert-style interval scales.

	Statements	Strongly disagree			Partly agree			Strongly agree	Not specified
DT 9	**Conciseness** Does the number of design requirements, design principles, design features, and their relationships allow the design theory to be meaningful without being unwieldy or overwhelming?	☐	☐	☐	☐	☐	☐	☐	☐
DT 10	**Extendibility** Can a design requirement, design principle, design feature or a relationship be easily added to the design theory?	☐	☐	☐	☐	☐	☐	☐	☐
DT 11	**Explanatory Power** Are the design requirements, design principles, design features, and their relationships sufficiently self-explanatory within the design theory?	☐	☐	☐	☐	☐	☐	☐	☐

Part 3: Sociodemographic Data

For data analysis, we require a few individual sociodemographic data. Therefore, we would be very pleased to receive answers from you.

SD 1) What industry or industries do you work in?

- ☐ Consulting
- ☐ Finance
- ☐ Research and Development
- ☐ IT services
- ☐ Education
- Other: ____

SD 2) Which category does the company or institution you work for belong to?

- ☐ Micro enterprise (fewer than 9 employees and up to 2 Mio. Euro annual revenue)
- ☐ Small enterprise (fewer than 9 employees and up to 10 Mio. Euro annual revenue)
- ☐ Medium-sized enterprise (fewer than 249 employees and up to 50 Mio. Euro annual revenue)
- ☐ Large enterprise (more than 249 employees and more than 50 Mio. Euro annual revenue)

SD 3) What is or are your current job role(s) and how much experience do you have in these roles? Please write in the format *Role (n)* for n years of experience.

_____

SD 5) You are welcome to leave further comments on the design theory, the questionnaire, or the research project.

Thank you for your participation in the survey!

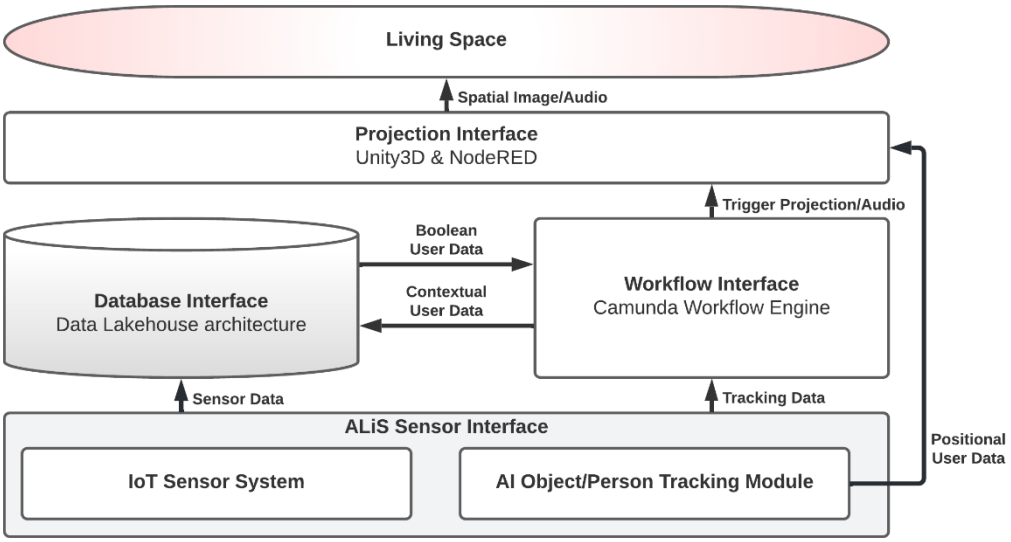
Questionnaire #2: Reference Architecture

4. Reference Architecture for ELiE

The purpose of ELiE is to enable elderly and cognitively impaired persons to live autonomously for longer:

- to provide guidance and cognitive support in everyday life
- to point out dangers
- to interact with the user
- to connect relevant information systems (e.g. healthcare data, etc.)

These relevant functions are provided through several sub-systems and components, which are composed of either hardware or software. The components here are simplified and visualized in the following graphic:



In general, the simplified component diagram depicts the structure and relationships between the different components of ELiE. Here we have four interfaces that represent stand-alone components at a higher level of granularity, consisting of more profound components. These high-level interfaces include (1) *sensor interface*, (2) *database interface*, (3) *workflow interface*, and (4*) projection interface*.

Sensor interface. The sensor interface of ELiE is the component that bundles all sensory hardware as well as machine learning-powered tracking. Thus, all sensors (e.g., heat sensors, water level sensors, fall detection sensors, etc.) are included and send their semi-structured or unstructured data to the data pre-processing unit that we realized with *NodeRED*. Here, the data is parsed and every sensor is given a static ID for further processing. The data pre-processing unit then specifies where, what, and in which format data will be sent, enabling higher efficiency (**DR2**). The sensor components are further able to process data in *parquet* format, enabling fast processing of unstructured data. On the other side, we have a synthetically trained machine learning model to track people with 360-degree fisheye cameras to adequately project information in the user`s gaze direction (**DP12**). This data will be pre-processed and sent to the messenger workflow as well as directly to the projection interface, allowing fast process time for real-time information delivery, which is essential for the conceptualization of RAs for AAL and the realization of **DR1** and **DR2**.

Database interface. The database interface is structured in the form of a data warehouse, enabling near real-time data storage, processing, and retrieval. Hence, data can be structured or unstructured upon storage. Furthermore, the database interface creates context variables through the incoming and pre-processed data from the sensor interface, e.g., storing the stove temperature at a specific time with a defined ID. This specific context data is sent as a variable to

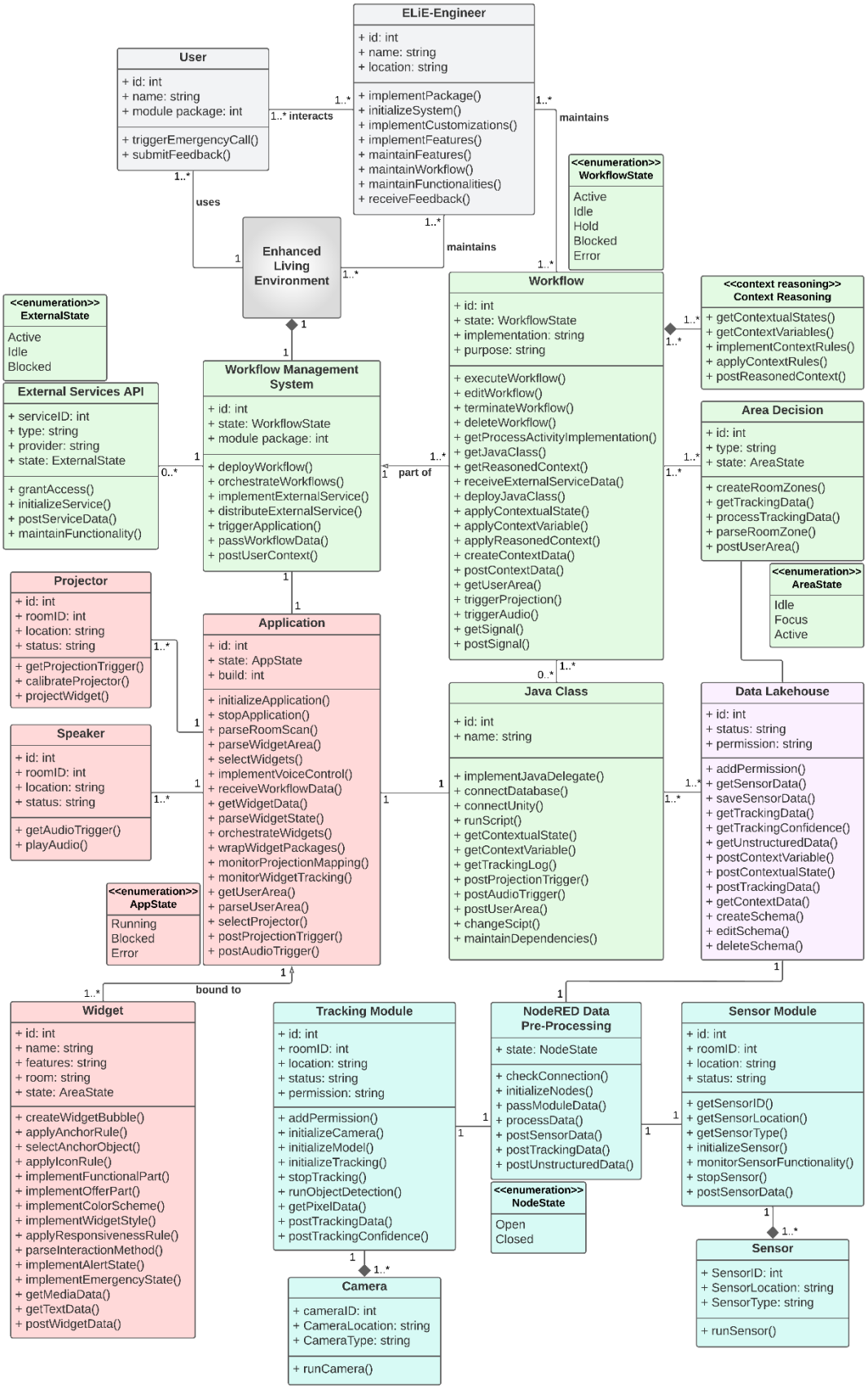
the workflow interface, which then reasons the data. Nonetheless, the database interface also includes contextual states that come from the workflow interface, storing context states (e.g., *stove is hot, door is open*) based on the context variables (**DP9**).

Workflow interface. Moreover, the workflow interface can be seen as the brain of ELiE, establishing contextual connections between raw sensory data and its implications for the user, and thus, following the RA for context-aware as well as addressing **DP11**. Our WFMS defines, interprets, instantiates, and manages the execution of workflows with software, integrates external applications, and interacts with human workflow participants according to the definition of the Workflow Management Coalition. Moreover, it manages and controls the sequences. Hence, it is responsible for creating, reasoning, and combining context (**DP9**). For example, a raw temperature context variable from the database interface is not quite meaningful. However, if the WFMS "knows" that after 10 pm the stove plates should be off, but detects a hot temperature there, we created a reasoned context for the raw variables and added value. Furthermore, the WFMS also integrates external services such as the user's phone, personal health applications, smart home systems, or health insurance services via a secured API (**DP7**, **DP10**). Lastly, the workflow interface triggers projection or auditive communication, which is implemented through the application (e.g., triggering and augmenting the information of a hot stove plate).

Projection interface. The projection interface is represented through a spatial augmented reality application that parses the sent information to project or communicate a certain widget or widget bubble (**DP8**). With pre-defined widget appearances, it is possible to flexibly assemble certain widgets as well as orchestrate them. This allows the application to change color schemes or data composition according to the individual needs of the user and hereby accounts for individual impairments (**DR4**, **DP3**, **DP4**). Since the application also gets the positional user data, suitable projection mapping is enabled and the right projector or speaker can be selected.

Moreover, we developed a **UML class diagram** based on the design theory and simplified component architecture. This artifact is intended to serve as guidance and blueprint for the practical implementation of the theoretical/conceptual design theory. The class diagram for ELiE clearly maps out the structure of the particular system by modeling its classes, attributes, operations, and relationships between objects (components) on a deeper level of granularity. It documents the software architecture and describes what must be present in the system being modeled, thus concentrating on and extending the simplified component architecture. For convenient practical implementation of ELiE systems, the classes in the diagram represent the classes that will actually be programmed by an engineer or developer.

The class diagram is depicted as follows:



5. Statements on the Performance Expectancy and Effort Expectancy of a Reference Architecture for ELiE

Please rate the performance expectancy and effort expectancy of the reference architecture above presented by reporting your level of agreement or disagreement with the statements (RA 1 – RA 8) on the verbal-numeric seven-point Likert-style interval scales.

Scenario:

Imagine that you're tasked with designing and implementing an ELiE-system, which should enable elderly people to live autonomously for longer, is context-aware, and neglects wearables. To support your design and implementation process, you can use all your existing prior knowledge. Additionally, you're provided with the reference architecture above.

Based on this scenario, how would you rate the following statements?

	Statements	Strongly disagree			Partly agree			Strongly agree	Not specified
RA 1	I would find the reference architecture useful in my job. (i.e., for designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 2	Using the reference architecture enables me to accomplish tasks more quickly (i.e., designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 3	Using the reference architecture increases my productivity (i.e., while designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 4	If I use the reference architecture, I will increase my chances of getting a raise (i.e., in your professional role as a designer and engineer of an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 5	My interaction with the reference architecture would be clear and understandable. (i.e., while utilizing it for designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 6	It would be easy for me to become skillful at using the reference architecture (i.e., for designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 7	I would find the reference architecture easy to use (i.e., for designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐
RA 8	Learning to operate the reference architecture is easy for me (i.e., for the task of designing and implementing an ELiE).	☐	☐	☐	☐	☐	☐	☐	☐

6. Conciseness, Extendibility, and Explanatory Power of the Reference Architecture

In addition to the perceived usefulness, we would also like to get your rating of the conciseness, extendibility, and explanatory power of the reference architecture. Please ignore the scenario described above for this part, i.e., rate the statements as the expert you are. This part is also surveyed on verbal-numeric seven-point Likert-style interval scales.

	Statements	Strongly disagree			Partly agree			Strongly agree	Not specified
RA 9	**Conciseness** Does the number of diagrams and the elements and relationships within allow the reference architecture to be meaningful without being unwieldy or overwhelming?	☐	☐	☐	☐	☐	☐	☐	☐
RA 10	**Extendibility** Can an element or a relationship between elements be easily added to all the reference architecture diagrams?	☐	☐	☐	☐	☐	☐	☐	☐
RA 11	**Explanatory Power** Are the diagrams, i.e., their elements and the relationships between them, sufficiently explained or self-explanatory?	☐	☐	☐	☐	☐	☐	☐	☐

Part 3: Sociodemographic Data

For data analysis, we require a few individual sociodemographic data. Therefore, we would be very pleased to receive answers from you.

SD 1) What industry or industries do you work in?

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- ☐ Small enterprise (fewer than 9 employees and up to 10 Mio. Euro annual revenue)
- ☐ Medium-sized enterprise (fewer than 249 employees and up to 50 Mio. Euro annual revenue)
- ☐ Large enterprise (more than 249 employees and more than 50 Mio. Euro annual revenue)

SD 3) What is or are your current job role(s) and how much experience do you have in these roles? Please write in the format *Role (n)* for n years of experience.

_____

SD 5) You are welcome to leave further comments on the design theory, the questionnaire, or the research project.

Thank you for your participation in the survey!

Questionnaire Responses & Results

Design Theory (n = 12)

Subject	Design Theory												
	DT 1	DT 2	DT 3	DT 4	DT 5	DT 6	DT 7	DT 8	DT 9	DT 10	DT 11	SUM	SUM
	PE1	PE2	PE3	PE4	EE1	EE2	EE3	EE4	CON	EXP	EXT	PE	EE
DT-S1	7	6	7	4	7	7	7	7	6	7	6	24	28
DT-S2	7	6	7	5	6	7	7	6	5	7	7	25	26
DT-S3	7	6	7	6	6	6	7	6	6	7	7	26	25
DT-S4	7	7	7	4	6	7	6	6	7	7	6	25	25
DT-S5	7	5	7	4	7	6	7	7	6	5	7	23	27
DT-S6	4	3	7	5	5	5	4	6	5	7	4	19	20
DT-S7	7	7	7	6	6	6	7	6	6	7	7	27	25
DT-S8	7	7	7	6	6	7	7	7	5	7	6	27	27
DT-S9	7	6	7	5	5	6	7	6	6	4	7	25	24
DT-S10	4	6	7	5	7	7	7	7	5	7	7	22	28
DT-S11	7	7	7	6	6	7	7	7	5	7	6	27	27
DT-S12	3	4	3	3	6	7	7	7	7	6	5	13	27

Reference Architecture (n = 12)

Subject	Reference Architecture												
	RA 1	RA 2	RA 3	RA 4	RA 5	RA 6	RA 7	RA 8	RA 9	RA 10	RA 11	SUM	SUM
	PE1	PE2	PE3	PE4	EE1	EE2	EE3	EE4	CON	EXP	EXT	PE	EE
RA-S1	7	6	7	5	7	7	7	7	6	7	7	25	28
RA-S2	7	6	6	4	6	7	7	6	6	7	5	23	26
RA-S3	6	7	6	4	6	6	6	6	7	7	6	23	24
RA-S4	7	7	7	5	7	7	7	6	5	7	5	26	27
RA-S5	7	6	7	4	7	6	6	7	6	6	6	24	26
RA-S6	7	7	7	4	7	6	7	6	7	5	5	25	26
RA-S7	7	7	7	6	6	6	5	6	3	4	6	27	23
RA-S8	7	6	6	4	7	6	6	6	7	4	6	23	25
RA-S9	6	7	7	6	7	6	7	7	7	7	7	26	27
RA-S10	7	7	7	6	6	7	7	7	6	5	7	27	27
RA-S11	7	7	6	5	7	6	7	7	6	4	3	25	27
RA-S12	4	5	5	3	4	5	5	5	5	7	7	17	19

Appendix E

Author's statement on the work shares in the Article: "Too Hard to Handle: Empowering People with Amnestic Mild Cognitive Impairment through Innovative Human-Computer Interaction and Innovative Interfaces"

The article "*Too Hard to Handle: Empowering People with Amnestic Mild Cognitive Impairment through Innovative Human-Computer Interaction and Innovative Interfaces*" was co-authored. The following table gives an overview of the authors' contributions to the article.

Authors

Martin Böhmer	MB
Philip Massler	PM
Stephan Kuehnel	SK
Johannes Damarowsky	JD
Stefan Sackmann	StS

Aspekt	**Autor(en)**
Research concept	MB
Research methodology	MB, SK
Problem definition and objective	MB, PM, SK, StS
Literature review	MB
Conceptualization of the topic	MB, PM, SK, JD, StS
Conceptualization of the idea and the AI model	MB, PM
Development and improvement of the AI model	MB, PM
Conceptualization and development of synthetic data	MB, PM
Development of the interaction design	MB, PM
Definition & conceptualization of the components	MB, PM
Conducting the benchmark evaluation for the AI model	MB
Conducting the think-aloud evaluation	MB, PM
Test and validation of the AI model values	MB, PM
Visualization of the research methodology	MB
Visualization of the interaction design	MB
Theoretical & practical implications	MB
Discussion of limitations and further research	MB
Conclusion	MB
Preparation of the manuscript	MB

Revision of the manuscript and the argumentation	MB, SK, JD, StS
Review and revision before submission	MB, SK, JD, StS
Revision after review	MB, SK

Appendix F

Full text of the Article: “Too Hard to Handle: Empowering People with Amnestic Mild Cognitive Impairment through Innovative Human-Computer Interaction and Innovative Interfaces”

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Too hard to handle: empowering people with amnestic mild cognitive impairment through innovative human–computer interaction and innovative interfaces

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ABSTRACT

Global demographic shifts have led to more cases of cognitive impairment, such as amnestic mild cognitive impairment (aMCI), which typically involves memory loss and disorientation. While digital health tools offer support for users, their complex design often hinders adoption and usability by people with aMCI. Therefore, this study focuses on improving human–computer interaction design for people with aMCI using spatial augmented reality and deep learning. We present a novel interaction design and innovative interface that uses deep learning with synthetic image data to enable intuitive digital health interactions by detecting and responding to the spatial positioning of people with aMCI, projecting relevant reminders and warnings without wearable devices. The study demonstrates that this approach can provide an accessible, inclusive, and low-threshold digital health solution with high usability and usefulness for people with aMCI. Bridging theory and practice in digital health, it adds to the theoretical discourse on social cognitive theory in deep learning with synthetic image data and spatial augmented reality in digital health, and provides a possible way to leverage these technologies for the development of effective, user-centered, and symbiotic AI/SAR tools for aMCI individuals.

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KEYWORDS
Spatial augmented reality; human-computer interaction; amnestic mild cognitive impairment; deep learning; synthetic image data

1. Introduction

Pervasive global demographic changes and an aging population intensify healthcare challenges (Bloom and Canning 2008). As neurodegenerative diseases, including forms of dementia, become more prevalent, individuals with Mild Cognitive Impairments (MCI) increasingly face difficulties in daily activities such as cooking, therapy, socialising, and dressing through memory loss, disorientation, or anxiety (Flicker, Ferris, and Reisberg 1991). Among these conditions, multi-domain amnestic MCI (aMCI) affects memory and at least one other cognitive domain (e.g. forgetting to turn off the oven and struggling with executive functions such as planning or organising), making it harder to follow complex instructions or consistently use digital tools. While people with aMCI can often live independently, they may need more intuitive and less cognitively demanding technological support (Petersen 2016; Petersen et al. 2018; Yu, Lam, and Lee 2017). In parallel, the proliferation of digital health applications to support patients, caregivers, and healthcare professionals highlights a persistent challenge: low user confidence and limited adoption, particularly among vulnerable populations (Böhmer, Kendziorra, and Kuehnel 2024; Ienca et al. 2021; Mathews et al. 2019). For aMCI individuals, concerns about privacy, ethics, and usability persist, exacerbated by complex interfaces, cognitive load, and non-user-centered Human–Computer Interaction (HCI) design (Blass et al. 2022; Chignell et al. 2023; Vines et al. 2015). Thus, this study focuses on the rehabilitative and supportive potential of novel HCI designs explicitly designed to increase autonomy and reduce cognitive load for individuals with aMCI rather than diagnostic applications. We explicitly address cognitive rather than emotional targets to maintain a focused evaluation and to ensure that the design and assessment processes remain aligned with the primary rehabilitative goals of the study.

In this context, Augmented Reality (AR) and Artificial Intelligence (AI)-based approaches, especially those using deep learning, offer promising avenues for

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more accessible and context-aware digital health solutions (Dhiman et al. 2022; Maedche et al. 2019). However, traditional wearable AR devices have significant usability issues, such as restricted fields of view, limited battery life, and high interaction complexity, that fail to address the nuanced needs of aMCI individuals (Biocca et al. 2007; Margrett et al. 2022; Seifert and Schlomann 2021). Spatial Augmented Reality (SAR), using projections rather than head-mounted displays, could alleviate these burdens by reducing cognitive load and enhancing everyday usability (Baumeister et al. 2017; Mousavi Hondori et al. 2013; Raskar, Welch, and Fuchs 1998; Yang et al. 2018). Meanwhile, synthetically generated image data for deep learning models has shown promise for improving predictive performance and efficiency in computer vision settings but remains underexplored in digital health contexts (Aranjuelo et al. 2021; Hinterstoisser et al. 2019; Kucharski and Fabijańska 2023; Scheck, Seidel, and Hirtz 2020).

As a result, innovative, intuitive, and AI- and SAR-driven HCI approaches may help bridge the digital divide for the elderly by providing useful digital health support (Lee et al. 2023) and engaging them in the HCI design process to facilitate technology adoption (Vines et al. 2015). While various (AI-driven) HCI approaches have been explored in digital health (Ando et al. 2022; Iversen and Joshi 2015; Mavropoulos et al. 2021; Prakash and Das 2020; Williams, Jenkins, and Valacich 2016), these approaches still face challenges in terms of accessibility, affordability, and usability for the aMCI population (Böhmer, Kendziorra, and Kuehnel 2024). Bridging these gaps by integrating SAR with AI-driven, synthetically trained deep learning models can result in user-centered interfaces tailored to the needs and abilities of aMCI individuals. Such solutions can provide context-aware, location-based information without constant reliance on cumbersome wearables and potentially build user trust by addressing privacy and ethical concerns. However, to the best of our knowledge, theoretical and practical insights on how to effectively integrate these technologies for intuitive, indirect, and user-centered HCI that supports aMCI autonomy are lacking, especially for projecting timely warnings and daily guidance in real-world settings, given that wearable AR has significant limitations because people cannot wear it preventively or in anticipation of a warning, let alone for more than 1–2 h to retrieve relevant information.

In this study, we address this gap to develop a novel SAR-based, AI-driven interaction approach that provides aMCI users with intuitive, context-aware support free from the limitations of conventional wearables. This leads us to the following research question:

> **RQ:** How can synthetic image data be leveraged with deep learning methods for a novel contextual, user-centered, and intuitive SAR approach to human–computer interaction for people with amnestic mild cognitive impairments?

To this end, we conducted a full *DASC-PM* cycle (Kuehnel et al. 2023) that develops an intuitive interaction design for aMCI individuals based on a synthetically trained deep learning model and context-aware location-based SAR projections, which we term *ConZones*. In this study, we position ConZones as a novel interaction paradigm within the broader discipline of HCI, offering a rethought approach to intuitive interaction design that aims to empower individuals with aMCI through practical, solution-oriented methods. We explicitly focus on SAR over other AR approaches because it enables interaction without the need for constantly worn devices, which, in their complexity, are 'too hard to handle' and can be cumbersome for people with aMCI due to their physical and cognitive limitations. We may empower people with aMCI through innovative SAR-based interfaces based on a synthetically trained deep learning model for intuitive interaction design that enables location-based information projection. Thus, we can guide aMCI individuals through daily tasks while they are free to move about, free from time-restricted and cumbersome wearables, and free from direct interaction with technology. The primary audience for this study is researchers and practitioners in HCI, digital health, and AI, particularly those developing user-centered and accessible solutions for people with (a)MCI. The findings may also be relevant to assistive technology developers, policymakers, and advocates for ethical and inclusive digital health systems.

In general, this study contributes to the theoretical understanding of HCI in digital health by demonstrating how AI and SAR-driven systems enhance self-efficacy and autonomy for individuals with aMCI through intuitive, context-aware interactions grounded in Social Cognitive Theory. Operationalising the concept of reciprocal determinism shows how adaptive technologies can create positive feedback loops between individual capabilities, environmental affordances, and desired behaviours, providing a new lens for theorising the design of healthcare IS. By leveraging synthetic data and deep learning, the ConZones system addresses data scarcity and privacy challenges to provide scalable, non-intrusive solutions that reduce cognitive and technological barriers, promote independence, and improve quality of life. By expanding the application of SAR beyond entertainment into therapeutic contexts, this

research positions SAR as an innovative technology for accessible, user-centric digital health solutions, paving the way for innovative cognitive support and care approaches.

2. Theoretical foundations

The impulse for our problem-focused research stems from a real-world challenge: providing sufficient digital healthcare to people with aMCI so that they can maintain their independence in daily life while accommodating their impairments. Exact definitions of MCI may vary according to cultural, medical, or legal contexts. Consistent with the medical literature, MCI represents an intermediate stage between the expected cognitive decline of normal aging and the more severe decline of dementia (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen 2016; Petersen et al. 2009). It is characterised by cognitive changes that are noticeable to the individual or others but not severe enough to significantly interfere with daily life. These changes include declines in memory, reasoning, judgment, and the ability to plan and complete complex tasks. As a result, individuals with MCI are at higher risk of developing Alzheimer's disease or other dementias compared to the general population (Anderson 2019; Gauthier et al. 2006).

As noted above, aMCI specifically affects memory. While individuals with aMCI show significant memory impairment, they generally maintain other cognitive functions (Petersen 2016; Petersen et al. 2018; Yu, Lam, and Lee 2017). This form of MCI is more likely to progress to Alzheimer's disease because memory loss is an early hallmark of the disease (Anderson 2020). People with aMCI often face daily challenges such as forgetting recent conversations, misplacing personal items, having difficulty remembering the names of new acquaintances, and struggling with tasks that require detailed instructions or multiple steps. While these problems may not always require outside care, they can significantly impact daily activities and social interactions. Recent studies (e.g. Manenti et al. 2020; Gu et al. 2022) have advanced our understanding of MCI, including the effects of Transcranial Direct Current Stimulation (tDCS), which improved recognition sensitivity in individuals with aMCI. This suggests that targeted interventions may improve the accessibility of newly learned information. Although individuals with aMCI can still manage their daily lives, their autonomy is at risk. Thus, they could benefit substantially from IS-based support to preserve their independence. We have observed these challenges in prior focus group and observational studies (Böhmer et al. 2022). As the worldwide demographic shift continues (Bloom and Canning 2008), a growing body of literature has examined HCI with aMCI-affected individuals and explored deep learning-based solutions in recent years.

2.1. Theoretical lens

In the context of our research, we draw upon the Social Cognitive Theory (Bandura 2001) as our main foundational theory, and to adequately and theoretically-conceptually orient our research approach, we incorporated the sub-foundational-theories of user-centered design (Abras, Maloney-Krichmar, and Preece 2004), value-sensitive design (Friedman et al. 2013), and HCI research with elderly people (Dickinson, Arnott, and Prior 2007), which serve as underlying theoretical lenses. We adopt the school of thought regarding foundational theories in IS and use them as our lens that shapes and guides our methodological approach. Social Cognitive Theory (Bandura 2001) posits that behaviour is influenced not only by personal factors, such as physical and mental conditions or individual beliefs and attitudes, but also by social and environmental factors. Adopting Social Cognitive Theory as foundational theory allowed us to examine the complex interplay between individual cognition and external influences on technology adoption and use among aMCI people, who often struggle with complex instructions (e.g. using technology) and multiple steps (Petersen 2016; Petersen et al. 2018; Yu, Lam, and Lee 2017). Therefore, this theory provided a framework for understanding how people with aMCI's beliefs and attitudes about technology, as well as social and environmental factors such as physical accessibility and interaction, influenced their technology adoption and use behaviours. Consequently, we identified three sub-foundational-theories that shaped the methodical, user-centered, and moral-ethical orientation of our research approach. First, user-centered design (Abras, Maloney-Krichmar, and Preece 2004) presents key principles in the context of interactive system design and aims to create systems that are usable, useful, and desirable. We adopted the paradigm of participatory design and used the methods of usability testing and questionnaires for evaluation with our target group, which helped us to tailor the system interaction to the specific needs of aMCI people. Since designing interactive systems for these people is highly complex and we are working with an AI-driven approach, we used the paradigm of value-sensitive design (Friedman et al. 2013) as the second underlying sub-theory to account for the values and ethical considerations of our target group.

Value-sensitive design involves a structured, iterative process and, among a range of methods and approaches, particularly participatory design and ethical principles, to identify, articulate, and incorporate values into the design process. We explicitly chose this paradigm because people with aMCI are a vulnerable population for whom the design of assistive IS should be particularly careful and sensitive. Third, Dickinson, Arnott, and Prior (2007) provide a framework for conducting research on HCI with older adults, proposing a stringent understanding of their unique needs, abilities, and preferences. The rationale for utilising this foundational theory is relevant because aMCI predominantly affects older and aging individuals. The theory's insights into methodological adaptations, inclusive design considerations, and user-centered approaches can be instrumental in framing HCI research tailored to the cognitive challenges of aMCI patients. While not specific to aMCI, its principles for accommodating diverse cognitive abilities are highly applicable and support the design of effective, accessible HCI tools for aMCI individuals. We have adopted the framework and used its suggested methods of thinking aloud and questionnaires for our system evaluation and ultimately to accommodate the physical, sensory, cognitive, and emotional changes that occur with aging and impairment.

Not necessarily one of our foundational theories, the *Unified Theory of Acceptance and Use of Technology* (UTAUT) proposed by Venkatesh et al. (2003) serves as a foundational framework of our study, guiding the evaluation of key constructs related to technology acceptance and use among our aMCI target group, validating measurement models, offering a comprehensive approach for empirical validation, and integrating with the aforementioned theories to shape the overall research methodology. Due to its comprehensive assessment of technology acceptance and relevant constructs such as *Performance Expectancy* (PE) and *Effort Expectancy* (EE), the UTAUT model seems appropriate for our study and for assessing aMCI user acceptance of digital health solutions. Its empirical validity and reliability, demonstrated in various studies, provide a robust framework for predicting user behaviour toward technology, and its holistic approach, integrating both qualitative and quantitative aspects, aligns well with the study's focus on digital health, taking into account the nuances of user interaction with technology.

Table 1. Relevant research streams in the context of our study.

	Research stream 1 STD	Research stream 2 OFT	Research stream 3 I-HCI
Bird et al. (2020)	X		
Chen et al. (2021)	X		
Hinterstoisser et al. (2019)	X		
Krump, Ruß, and Stütz (2020)	X		
Seib, Lange, and Wirtz (2020)	X		
Valtchev and Wu (2021)	X		
Aranjuelo et al. (2021)	X	X	
Scheck, Seidel, and Hirtz (2020)	X	X	
Yang et al. (2020)		X	
Tezcan et al. (2022)		X	
Ahmed et al. (2021)		X	
Zorin and Barr (1995)		X	
Duan et al. (2020)		X	
Tezcan et al. (2022)		X	
Yu, Seidel, and Hirtz (2019)		X	(X)
Colantonio et al. (2018)		X	X
Chignell et al. (2023)		X	X
Maedche et al. (2019)		X	X
Mallas, Xenos, and Katsanos (2022)			X
Dickinson, Arnott, and Prior (2007)			X
Vines et al. (2015)			X
Kriglstein et al. (2016)			X
Chen and Levkoff (2015)			X
Blass et al. (2022)			X
Our proposed approach	X	X	X

Legend: *STD*: Synthetic training data with transfer learning and domain adaptation for real image setting; *OFT*: Overhead fisheye and distorted top view object tracking; *I-HCI*: aMCI-suitable human-computer interaction approaches and requirements for an innovative and easy usability; (X): Implicit application.

2.2. Research streams and gap

The prevalence of intelligent assistants is on the rise, encompassing a diverse spectrum of forms and intricacies within the realm of IS and digital health (Dhiman et al. 2022). In this context, computer vision and natural language modelling techniques are being used to intelligently monitor patients (Mavropoulos et al. 2021), characterise behaviour (Al-Ma'aitah, Alwadain, and Saad 2022), or support cognitive processes (Gao 2019; Preum et al. 2021). Furthermore, the scarce utilisation of synthetic training data in the context of deep learning shows great promise for healthcare applications, as highlighted by, for example, Bidani, Gouider, and Travieso-González (2019), Herzog and Magoulas (2021), or Taleb, Likforman-Sulem, and Mokbel (2020). To offer a comprehensive overview of HCI research involving deep learning within the scope of our study, we analyzed three pertinent research streams: synthetic training data with transfer learning and domain adaptation for real image setting (STD), overhead fisheye and distorted top view object tracking (OFT), and aMCI-suitable human–computer interaction approaches and requirements for innovative and easy usability (I-HCI). The corresponding results are displayed in Table 1. Since this study uses the AI-driven

approach as a means to an end for the SAR-based projection IS and intuitive interaction assisting aMCI individuals, and therefore delves into the intricacies of synthetic image data and deep learning rather than SAR, a thorough literature review on SAR-based digital health solutions and their characteristics can be found in the study by Böhmer et al. (2022).

2.2.1. Synthetic training data and domain adaptation

Since state-of-the-art deep learning models for computer vision consist of millions or even billions of parameters, training such models typically requires an enormous amount of training data, which is often unavailable or unbalanced (Alzubaidi et al. 2021). In recent years, several studies have investigated the use of synthetic data to train deep learning models in various domains to minimise training cost, dataset generation and inference time, and improve model performance. Synthetic image data is becoming increasingly important in digital health, especially for improving AI algorithms in medicine and healthcare. This data can be categorised into three types: fully synthetic, partially synthetic, and hybrid synthetic (Gonzales, Guruswamy, and Smith 2023). Fully synthetic data is completely artificial and does not include real data (e.g. a video game scene instead of a real photograph), providing strong privacy control but less analytic value. Partially synthetic data contains original values with certain sensitive variables replaced by synthetic versions, providing some risk of re-identification. Hybrid synthetic data combines both original and synthetic data, balancing privacy control with high utility. Synthetic data generation, especially in deep learning for medicine and healthcare, is gaining attention for its potential to improve AI algorithms through data augmentation. For example, synthetic histology images of rare subtypes of renal cell carcinoma can improve the detection accuracy of Convolutional Neural Networks (CNN). However, there are challenges to the use of synthetic data, such as the need for clinical quality measures and evaluation metrics, assessing whether the synthetic data mimics the correct phenotype, and the practical barriers to visually evaluating large amounts of synthetic data (Chen et al. 2021). From a more practical application perspective, Bird et al. (2020) used transfer learning with synthetic data to improve scene classification, training a convolutional neural network on a large synthetic dataset generated by the *Unreal Engine* and then fine-tuning the model on a real-world dataset. Respectively, Krump, Ruß, and Stütz (2020) used synthetic data to improve the performance of vehicle detection algorithms on unmanned aerial vehicle platforms. They generated a large number of synthetic images using the Unity3D engine and tested the trained models on real-world images. Moreover, Hinterstoisser et al. (2019) explored the use of synthetic data and pre-trained image features for deep learning, proposing a method for generating synthetic images that can be used to augment real-world datasets and investigating the use of pre-trained image features as a form of transfer learning. The results of these papers show that transfer learning and synthetic data can significantly improve the algorithm and model performance. Valtchev and Wu (2021) proposed domain randomisation for neural network classification and presented a method for training neural networks on synthetic data containing random variations of various parameters such as lighting, textures, and camera angles, showing promising results in terms of model robustness. Regarding domain gap and adaptation, Seib, Lange, and Wirtz (2020) reviewed the use of mixed real and synthetic data to improve neural network training, discussing different methods for combining real and synthetic data and the advantages and disadvantages of each method. The review showed that the use of mixed real and synthetic data can improve the performance of neural networks in various applications, depending on how well the domain gap is filled. In the context of synthetic data in digital health, this *domain gap* refers to the differences or discrepancies between synthetic data (artificially generated data) and real-world data. This gap can present challenges in terms of how well models trained on synthetic data perform when applied to real-world scenarios, which is their *domain adaptation*.

2.2.2. Overhead fisheye object detection and tracking

As our solution should apply to enhanced living environments for aMCI individuals, we generally envision overhead fisheye cameras as part of our solution as they can cover a large area and enable 360-degree coverage of the living space. Since people with aMCI have problems using wearables due to their complex interaction, display, and handling, which does not match their reduced cognitive performance (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen 2016; Petersen et al. 2009), a focus on wearable-based AR would not be reasonable and meaningful. In essence, the use of overhead fisheye tracking and SAR addresses an issue of practicality for people with aMCI, who cannot wear a head-mounted display all day due to comfort and convenience, as well as battery and immersion issues. Overhead fisheye cameras for detection and tracking offer a non-invasive and intuitive approach that minimises the

physical and cognitive burden on aMCI individuals, enabling continuous monitoring and assistance without requiring the individual to interact with or even be aware of the device's presence. The use of SAR in conjunction with these cameras can provide contextual and environmental cues that seamlessly integrate into the home environment to assist with activities of daily living, enhancing safety and independence. This approach aligns with the needs and abilities of people with aMCI, providing seamless integration into their living environments without adding complexity to their daily routines. In a hypothetical scenario where aMCI individuals are assisted by receiving contextual information (e.g. warnings if they leave the stove on or a medication reminder), it would make little sense to have them prophylactically wear AR glasses in case a potential alert occurs at some point. If aMCI individuals choose not to wear these wearables, they would immediately stop receiving these valuable alerts and information, not to mention forgetting to put them on. In addition, the overhead fisheye component allows for complete coverage from one perspective, whereas wearables would have different angles for each perspective if objects were tied to visual detection. Key strategies for synthetic data generation to train intelligent systems in overhead fisheye object detection of people are provided by Aranjuelo et al. (2021). They proposed a novel synthetic data generation approach that combines domain adaptation and adversarial learning, showing that the proposed approach can effectively improve the performance of the people detection system. Correspondingly, Scheck, Seidel, and Hirtz (2020) developed a synthetic omnidirectional top-view indoor dataset for deep transfer learning. The dataset contains synthetic images generated by the *Unreal Engine*, and results showed that the use of the synthetic dataset can improve the performance of deep learning models for indoor object detection and fine-tuning on real images. Since the distortion in these imagery settings distinguishes them from conventional image alignments and characteristics, Zorin & Barr (1995) proposed a correction method to mitigate geometric distortions in pictures. This work provides a foundation for subsequent research that leverages image data to train deep learning models. Specifically, Yu, Seidel, and Hirtz (2019) used an omnidirectional camera to capture top-view images and proposed a deep learning-based approach for person detection in indoor environments. Similarly, Ahmed et al. (2021) adapted a Gaussian computer vision model for human detection in smart cities and societies, leveraging transfer learning to improve performance for surveillance. Additionally, Yang et al. (2020) proposed an intelligent video analysis method for pedestrian trajectory extraction without blind areas, calculating the trajectory points of pedestrians according to the detected head position. Duan et al. (2020) proposed a rotation-aware people detection method based on a CNN that can handle fisheye images using arbitrarily oriented bounding boxes. Building on that, Tezcan et al. (2022) introduced the WEPDTOF dataset and benchmark algorithms for people detection and tracking from overhead fisheye cameras, which can facilitate the development of deep learning models for human detection in complex indoor environments.

2.2.3. Appropriate and intuitive HCI approaches for aMCI people

Addressing the intersection between overhead fisheye object detection/tracking and intuitive HCI approaches for aMCI individuals, Colantonio et al. (2018) discussed computer vision systems for personalised healthcare and wellness, highlighting the benefits for aMCI individuals. Maedche et al. (2019) investigated AI-based digital assistants, which can provide a more natural way of interacting with technology, especially for individuals with cognitive impairments. The study emphasises that the use of AI-based digital assistants is increasing in various domains such as healthcare, finance, and smart homes, with user acceptance and trust being critical factors for the success of AI-based digital assistants, requiring careful design of user interfaces. The authors note that the potential benefits of AI-based digital assistants for aMCI individuals include improved accessibility, social engagement, and independence. In addition, Chignell et al. (2023) explored the evolution of HCI and the integration of humans and AI, which is particularly relevant to the development of technologies that can assist individuals with aMCI. The authors recommend a deeper integration between HCI and human factors to promote trust and situational awareness. They revisit the concept of human augmentation, which is particularly relevant to inclusive design and AI, and explore how HCI and human factors engineering can work together to address the challenges posed by human-AI technology. As such, they contrast the different approaches of HCI and human factors in AI research and advocate for more collaboration between these fields to address the challenges of data science and AI. Key aspects include trust, situation awareness in human-AI interaction, and potential paths for the future development of HCI approaches. Focusing more on the aging population and associated cognitive impairments, Dickinson, Arnott, and Prior (2007) emphasised the importance of considering the abilities and limitations of older people in the design of HCI systems and suggested appropriate methods

for conducting research with this target group. The study focuses on user-centered design approaches and methodological adaptations that are essential for developing effective HCI solutions for people with cognitive impairments such as aMCI. These insights are invaluable for creating interfaces and technologies that are accessible, intuitive, and tailored to the unique needs of aMCI patients. Mallas, Xenos, and Katsanos (2022) built on this work and proposed a descriptive model of passive and natural passive HCI, presenting requirements for passive interaction to qualify as natural passive interaction, paving the way for the development of a more intuitive interaction experience for aMCI individuals. Here, passive interaction is defined as a system-initiated interaction triggered by changes in the user's physical or mental state to adapt the system to provide a consistent user experience. Natural passive interaction is a subset where the system response remains undetected by the user. The paper presents a descriptive model for these interactions, discusses their effectiveness in terms of system response time, and provides examples of real and envisioned scenarios where such interactions may occur, aiming for system invisibility and a non-intrusive, distraction-free user experience. Kriglstein et al. (2016) focused on evaluation methods in process-aware information systems research with a perspective on human orientation. They highlighted the importance of taking into account the user's perspective when evaluating HCI systems. Furthermore, Chen and Levkoff (2015) proposed design recommendations for delivering telemonitoring care to digitally disadvantaged older adults, emphasising the importance of designing a user-friendly and accessible human–computer interface. Lastly, Blass et al. (2022) examined the concerns of professionals and patients associated with digital healthcare. They found that concerns regarding technology's complexity, usability, privacy, and reliability could hinder the adoption of digital healthcare services, reinforcing the importance of designing a user-friendly and intuitive HCI approach for older adults with cognitive impairments.

2.2.4. Research gap

To the best of our knowledge, no intuitive SAR-driven HCI approach for aMCI individuals based on a synthetically trained deep learning model has yet emerged (Table 1). Recent work has shown that synthetic data can be used to train deep learning models in various domains, but domain gap and adaptation remain a significant challenge (Bird et al. 2020; Hinterstoisser et al. 2019; Krump, Ruß, and Stütz 2020). Although there have been contributions proposing strategies for efficient synthetic data training in omnidirectional camera settings or providing synthetic datasets for overhead fisheye object detection, these have not yet been applied to digital healthcare or linked to HCI (Aranjuelo et al. 2021; Scheck, Seidel, and Hirtz 2020), let alone their application to SAR. Overhead fisheye or omnidirectional camera settings for object detection and tracking are primarily used in surveillance, and real imagery datasets for such applications remain scarce (Ahmed et al. 2021; Duan et al. 2020; Tezcan et al. 2022; Yang et al. 2020). At the intersection of AI-based approaches and research on computer vision and deep learning methods, there has been a focus on conceptualising AI assistance, its framing principles, and exploring how such applications can benefit users (Chignell et al. 2023; Colantonio et al. 2018; Maedche et al. 2019). However, there has been less emphasis on exploring the potential connections and synergies between the research streams themselves. Given the scarcity, unavailability, and high cost of omnidirectional real-world image datasets and their error-prone labelling, it seems reasonable to generate scalable, photorealistic, and highly accurate synthetic images for training deep learning models and applying them in digital health IS. Coupled with the innovative and intuitive nature of SAR, this approach can pave the way for a novel, intuitive, accessible, and inclusive HCI approach that has yet to emerge in digital healthcare for aMCI individuals (Seib, Lange, and Wirtz 2020; Valtchev and Wu 2021) and help address their cognitive challenges related to interaction complexity, information reception, memory decline, and daily life organisation (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen 2016; Petersen et al. 2009; Petersen et al. 2018; Yu, Lam, and Lee 2017). In the following, we demonstrate the viability of this approach by utilising a synthetically trained deep learning model for positional reasoning and SAR-based projections to enable an intuitive, context-aware, and user-centered interaction within enhanced living environments.

3. Research methodology

In general, we followed a multi-method research approach (Mingers and Brocklesby 1997), focusing on various qualitative research methods but incorporating quantitative evaluation metrics regarding the deep learning model. By way of explanation, our approach could be described as sequential mixed methods (Venkatesh, Brown, and Bala 2013), as we used the quantitative deep learning model results to inform the system application and interaction. However, we see the quantitative deep learning metrics on a different meta-level, as they do not allow for a direct evaluation with the

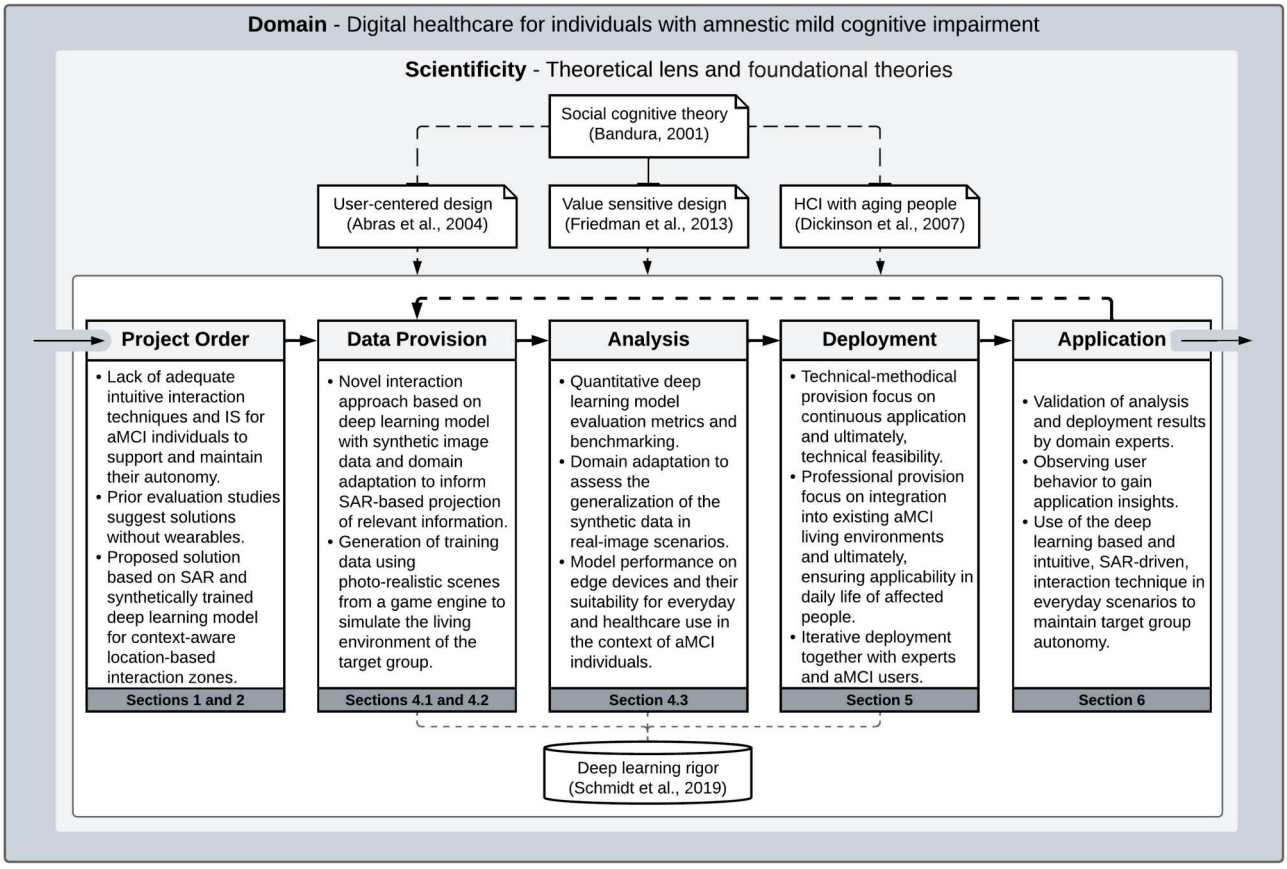


Figure 1. Research approach following the DASC-PM (Kuehnel et al. 2023).

target audience and our final IS artifact, epitomising an ambiguous mixed-methods approach where we cannot presume to have used a fully quantitative method. As shown in Figure 1, our multi-method research approach is based on the data science process model *DASC-PM* (Kuehnel et al. 2023), which aims to overcome isolated problem solving and focuses not only on a phase-oriented flow of a data science research project, but also includes other key areas, such as the application domain, scientific rigour (scientificity), and the required IT infrastructure.

Our application domain is the provision of digital healthcare for aMCI individuals who are struggling to maintain their autonomy in everyday life as they age. To ensure scientific rigour, traceability, and comprehensibility, our research approach holds the aforementioned foundational theories of *user-centered design* (Abras, Maloney-Krichmar, and Preece 2004), *value sensitive design* (Friedman et al. 2013) as well as *HCI research with aging people* (Dickinson, Arnott, and Prior 2007) under the guise of *Social Cognitive Theory* (Bandura 2001) which formed the theoretical lens of our methodology (e.g. thinking aloud sessions, questionnaires).

The *Project Order* phase describes the starting point of our data science project and describes our specific problem: the lack of intuitiveness in HCI approaches for aMCI individuals from the aforementioned application domain. The purpose of the proposed solution is defined, and requirements are described, ensuring feasibility and project structure. As shown in Figure 1, this phase has been explained in detail in Sections 1 and 2.

The *Data Provision* phase focuses on the appropriate data selection and target-oriented analysis, primarily covering the process of data preparation. Since we are working with synthetically generated image data, the data preparation and generation are motivated by a technical but content-related domain adaptation impulse to inform the subsequent SAR-based projection of relevant information. A detailed explanation of the content of this phase is provided in Sections 4.1 and 4.2.

The *Analysis* phase focuses on the appropriate use of analytical methods to evaluate the validity, robustness, and generalisation of the data and model results, respectively. Since we are working with a deep learning model, the quantitative training, test, and validation

results should provide a sound foundation for evaluating the analytical deep learning method, which is thoroughly explained in Section 4.3.

Moreover, the *Deployment* phase aims at making the analysis results usable, focusing on the implementation and feasibility in the context of our SAR-based projection approach. In our case, the implementation is thereby twofold: (1) the deployment of the synthetically trained deep learning model within the novel HCI approach, and (2) the deployment of the novel HCI approach in the SAR-environment itself, opting for a continuous application, thoroughly explained in Section 5.

Subsequently, the *Application* phase addresses the need for permanent monitoring of the proposed and deployed SAR- and AI-driven application, checking whether the initial assumptions are still met. Herein, user observations and validations should be performed, which we did via various evaluation methods in Section 6. Given the often experimental rather than methodical nature of deep learning research, we aimed to establish a rigorous and reproducible deep learning procedure by adhering to the supervised learning workflow and process model proposed by Schmidt et al. (2019). As illustrated in Figure 2, to ensure the highest level of stringency and reproducibility, we followed their approach closely, applying further application-oriented rigour to the *DASC-PM* process steps of *Data Provision, Analysis,* and *Deployment*.

In general, the study scope, data collection, and evaluation processes were explicitly designed to assess the cognitive impact and perceived usefulness/easiness of the proposed SAR-based HCI approach for individuals with aMCI, with a focus on supporting autonomy and reducing cognitive load/complexity. Data were collected through three iterative evaluation episodes using usability tests, think-aloud sessions, and structured questionnaires targeting constructs such as cognitive support, usability, and system intuitiveness. Emotional outcomes, such as participants' mood, were not directly measured because the study prioritised cognitive targets to ensure a focused evaluation of the system's rehabilitative potential and the cognitive influence of the HCI approach. However, user feedback on emotional aspects such as confidence and frustration was captured when apparent during think-aloud sessions, providing indicative insights into the interplay between cognitive and emotional factors. This explicit focus on cognitive targets ensures that the design and assessment processes remain aligned with the primary rehabilitative goals of the study while minimising complexity and scope that could dilute the clarity of the results.

4. Deep learning approach

Given the promise of deep learning models trained on synthetic data (Alzubaidi et al. 2021), for this study, we view them as a means to achieve our overarching goal of providing innovative and intuitive interaction designs for people with aMCI. Our approach employs a deep learning model trained on photorealistic synthetic living room scenes that accurately detects people in real-world environments and generates a spatial understanding of the room. This enables the projection of location-based information tailored to the specific needs of people with aMCI.

4.1. Model and architecture

Given the focus of our study on computer vision as a means of SAR-driven assistance for people with aMCI, we deliberately chose CNN as the algorithmic architecture of choice, given its widespread use and prominence in the field (Alzubaidi et al. 2021). CNNs excel in computer vision tasks, especially object detection, due to their ability to learn relevant features from local input patterns, their efficient parameter utilisation through weight sharing, and their hierarchical feature learning approach, which allows for a high degree of translation invariance (Alzubaidi et al. 2021). Our model is based on the well-known *YOLO* (v4-v8) architecture but with unique combinations of existing neural network techniques tailored for optimal performance on synthetic image data. The model incorporates anchor-free object detection, feature extraction, and cross-stage partial connections. Figure 3 illustrates our ConZones model, which uses a *CSPDarkNet-53* (Bochkovskiy, Wang, and Liao 2020) backbone derived from the *EfficientNet* architecture to extract features from the input image, which is critical due to the synthetic nature of our input data.

The model includes shortcut links and a spatial pyramid pooling module that generates feature maps at multiple scales, which are then concatenated to capture objects of different sizes. The neck architecture processes the feature maps through convolutional layers and upsampling operations to produce detection maps, with each map predicting objects of specific scales and aspect ratios at different locations in the synthetic image. Multiple fusion blocks within the neck architecture fuse feature maps from the backbone architecture to produce more discriminative features. The head architecture performs object detection and classification on the synthetic images, using convolutional layers to generate a set of detection maps that indicate the presence of a particular class of objects. To improve

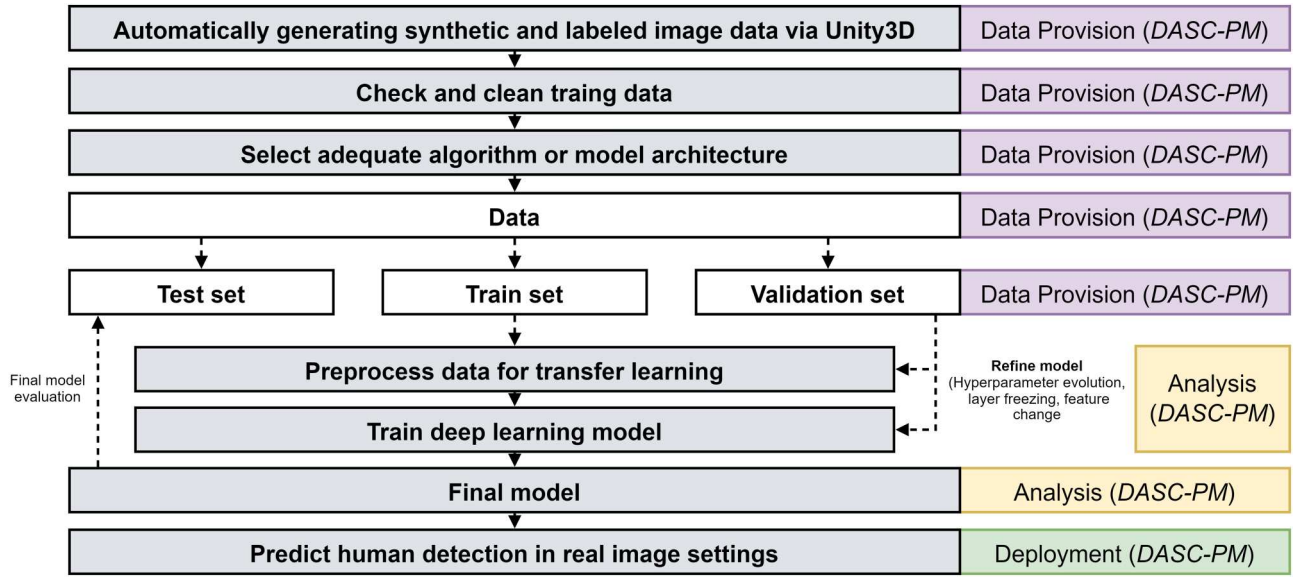


Figure 2. Deep learning research methodology following Schmidt et al. (2019).

performance and convergence, we pre-trained the ConZones model on the *MS COCO* dataset (Lin et al. 2014), following the consensus in deep learning research and mitigating the risk of overfitting. To fine-tune the model with synthetic data, we adopted a transfer learning strategy (Bozinovski and Fulgosi 1976), enabling rapid retraining with novel data without the need to retrain the entire network. Layer freezing was employed on the model backbone, a technique that keeps some layers' weights fixed during the fine-tuning process of a pre-trained neural network. This approach is particularly advantageous when adapting synthetically trained models to real image data (Hinterstoisser et al. 2019), as the lower layers of the network (model backbone) capture general features that are useful across different tasks. By freezing these layers, we utilise their learned

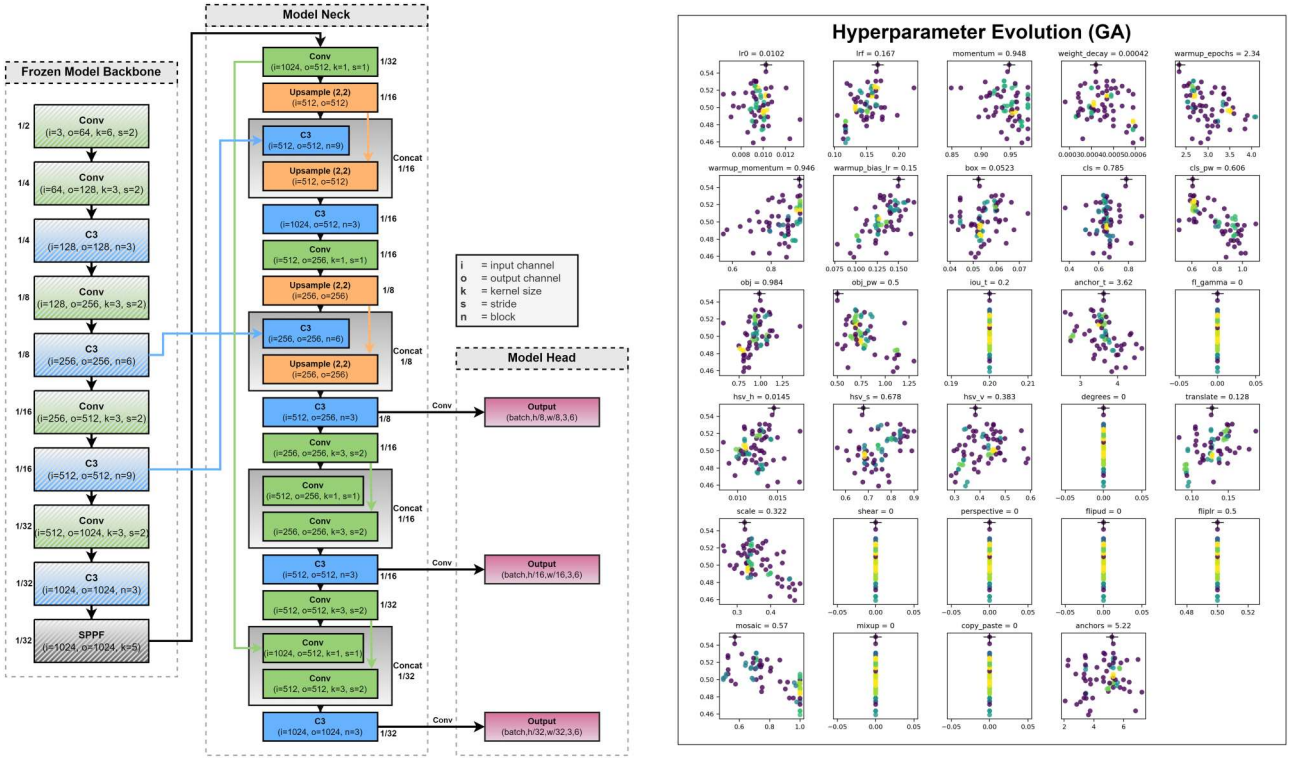


Figure 3. Model architecture and hyperparameter evolution via genetic algorithm.

representations to enhance the higher layers' performance on the new task, preventing overfitting and reducing training time.

Additionally, layer freezing stabilises the training process, mitigating catastrophic forgetting, which is particularly relevant for synthetic data by limiting gradient propagation during fine-tuning. Figure 3 further depicts our adoption of a genetic algorithm, following established deep learning procedures (Griebel, Dürr, and Stein 2019) and the *Refine Model* process step (Schmidt et al. 2019) to discover optimal hyperparameter values for training the ConZones model. Our model employs a population-based search strategy (mutation, crossover), where multiple neural networks evolve concurrently as potential solutions, increasing the likelihood of discovering optimal hyperparameters for the algorithm.

4.2. Domain adaptation

Domain adaptation is a technique in deep learning computer vision that involves adapting a model trained on one domain of data to perform well on a different but related domain (Venkateswara, Chakraborty, and Panchanathan 2017) and is often used in synthetic data setups (Lahiri, Agarwalla, and Biswas 2018; Wilson and Cook 2020). In our case, the source domain is synthetic (photorealistic game engine scenes), whereas the target domain is real (real images, video frames). In the context of synthetic image data, domain adaptation can be used to improve the performance of a deep learning model trained on synthetic data when it is applied to real-world images. Since the synthetically generated images may slightly differ in terms of features and characteristics (e.g. lighting conditions, textures, etc.), these differences can result in a performance gap when applying the model to real-world images. Nonetheless, domain adaptation techniques aim to reduce this performance gap and catastrophic forgetting by leveraging a small amount of real-world data to modify the model trained on synthetic data, which we did through our fine-tuning and transfer learning approach.

To achieve the best possible domain adaptation, we generated photorealistic living room scenes using *Unity3D*, enabling us to easily set up an omnidirectional, fisheye overhead camera setting. As shown in Figure 4, the scenes contained differing persons and objects, lighting conditions, textures, room setups, and levels of messiness, which was aimed at recreating homes of people with aMCI to the best possible scale and, thus, achieving high model generalisation. In our case, and to account for higher model generalizability, we randomly and automatically modified scenes in Unity3D as proposed by Scheck, Seidel, and Hirtz (2020), opting for high domain randomisation (Tobin et al. 2017; Tremblay et al. 2018). As such, image generation is infinitely scalable and can be modified according to specific environments or scene preferences, further proving that the creation of such synthetically generated datasets is fast, effortless, and economical. The often tedious process of labelling real-world image datasets becomes obsolete, as all synthetically generated images are automatically labelled with their corresponding bounding boxes, reducing labelling errors that could potentially hinder model performance. In addition, we applied data augmentation techniques to better generalise our fine-tuned ConZones model (Takahashi, Matsubara, and Uehara 2018; Tobin et al. 2017).

4.3. Model evaluation

Following the DASC-PM *Analysis* process step and the deep learning rigour procedure (Schmidt et al. 2019), we conducted experiments to assess the efficacy of our deep learning methodology. The experiments spanned different datasets, validation settings, and evaluation metrics. Our training set consisted of 6,500 scene images (as shown in Figure 4), divided into 5,000 train and 1,500 validation images. The training was performed on an NVIDIA GeForce RTX 3080 within a virtual Python (Version 3.12.1) environment. The ConZones model was trained for 150 epochs until we decided to conclude training due to the absence of additional gains in model performance and to forestall potential overfitting. To evaluate the effectiveness of our deep learning approach, we computed precision, recall, average precision, mean average precision, and corresponding model losses for class (*cls*), objectness (*obj*), and location (*loc*) (see Table 2). Looking at the formulas, and since we are only predicting one class in our specific use-case scenario, i describes the class 'person.' Therefore, the true positives for class i (tp_i) represent the number of individuals correctly classified as belonging to 'person,' while false positives (fp_i) indicate the number of individuals incorrectly classified as 'person.' Moreover, false negatives (fn_i) represent the number of individuals incorrectly classified as not belonging to 'person.' Based on these metrics, *Precision* determines how many individuals were correctly classified as 'person,' given all predictions of that class. *Recall* is the ratio of the number of correctly identified objects to the total number of ground truth objects in the image, measuring the proportion of all actual positive instances that were correctly identified by our model. In addition, *Average Precision* (AP) measures how well the model can precisely identify all relevant objects in an image while

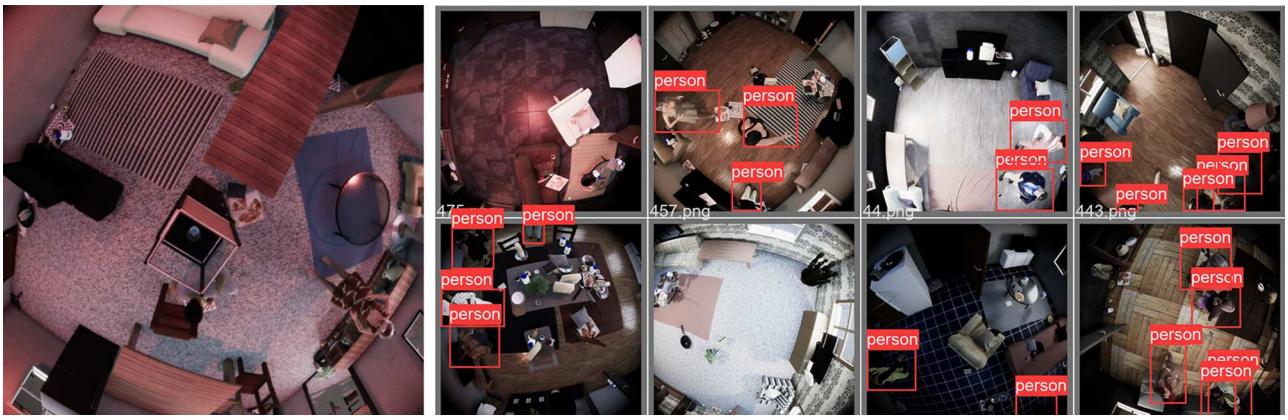


Figure 4. Synthetic and photorealistic training data generated with video game engine.

also minimising the number of false positives. Subsequently, *mAP* as the most meaningful and current benchmark evaluation metric embodies the essential balance between precision and recall while simultaneously maximising their impact. By evaluating the overlapping surface area between the predicted bounding box and the ground truth, which is the intersection over union (IoU),, *mAP* provides a robust measure of the model's efficacy. Thus, the greater the intersection between the two bounding box surfaces (ground truth and prediction), the higher the *mAP*, signifying a prediction that closely approximates the true object location. The classification loss penalises the model for misclassifying an object, the objectness loss ensures that the model detects the presence of an object, and the localisation loss penalises the model for inaccurate predictions of the object's location.

Table 2 presents the evaluation results of the ConZones model training for the 'person' class, demonstrating robust performance during training with considerably high precision, recall, and *mAP* scores. These results indicate that our model has effectively learned from synthetic image data and can make accurate predictions on unseen data. The high *mAP* score suggests that the model performs consistently well across all thresholds, which is crucial for its generalisation capabilities. Here, the recall score indicates that the model can identify a large proportion of instances of the 'person' class, which is important for our later application of location-based and intuitive interaction that forms the basis for the SAR-driven and contextual projections. To bridge the domain gap between synthetic training data and real-world application scenarios, we validated and tested the ConZones model on real image data. Real-world overhead fisheye datasets are scarce and not uniform, making comparative analyses and benchmarking challenging. We chose to benchmark our model against Scheck, Seidel, and Hirtz (2020)'s *FES* dataset, which contains real-world omnidirectional overhead fisheye images. Table 3 shows our ConZones model's *mAP* results compared to different model architectures used for validation by Scheck, Seidel, and Hirtz (2020). Our model architecture outperforms Scheck, Seidel, and Hirtz (2020) by a small but significant margin, using 18.5k fewer synthetically generated images. While differences in that category of computer vision analysis are hardly recognisable at inference, they embody significant improvements for the theoretical development of deep learning architectures and models. The validation of the ConZones model demonstrates its accuracy on real-world overhead fisheye images, providing evidence

Table 2. Quantitative evaluation metrics, formulas, and train/validation results.

Metrics	Formula	Results
Precision	$\frac{1}{n}\sum_{i=1}^{I}\frac{tp_i}{tp_i+fp_i}$	0.966
Recall	$\frac{1}{n}\sum_{i=1}^{I}\frac{tp_i}{tp_i+fn_i}$	0.885
AP*	$\int_0^1 prec(rec)d(rec)$	*was only used as an intermediary for mAP calculation
mAP 0.5	$\frac{1}{n}\sum_{i=1}^{I} AP_i$	0.937 (*mAP 0.5:0.95* = 0.607)
Loss	$Loss = \lambda_1 L_{cls} + \lambda_2 L_{obj} + \lambda_3 L_{loc}$	0.021 (*train box loss*); 0.019 (*train obj loss*); 0.030 (*val box loss*); 0.018 (*val obj loss*)

Table 3. Quantitative model validation on FES dataset for 'person' class.

Model	mAP 0.5
ConZones	**0.921**
SSD (Scheck, Seidel, and Hirtz 2020)	0.904
R-FCN (Scheck, Seidel, and Hirtz 2020)	0.849
Faster R-CNN (Scheck, Seidel, and Hirtz 2020)	0.873

that synthetic data can be a valuable supplement to real-world data, especially when acquiring real-world data is difficult or scarce. Moreover, the results show that our model can keep up with current state-of-the-art deep learning models in omnidirectional overhead settings, even outperforming leading approaches. The small but significant margin by which the ConZones model outperformed the other models suggests that even minor improvements in object detection accuracy can have a meaningful impact on real-world applications and the domain use case (e.g. reducing false alarms in healthcare settings).

We further tested the model's performance in our own overhead fisheye setup. As can be seen in Figure 5, individuals are being detected and recognised consistently while also achieving considerably high detection rates for near-border and cut-off bodies. As our test scenario shows, multiple-person detection is realised swiftly in differing environments, indicating its potential to be used in a variety of settings. Consequently, the domain adaptation and shift from synthetically generated images to a real-world imagery setting succeeds well through the ConZones model. The shown scenario was deployed in real time and confirmed the proposed model architecture.

5. Context-aware interaction zones

As aforementioned, our synthetically trained deep learning model serves as a means to ultimately introduce an intuitive, user-centered, and SAR-driven interaction approach in digital healthcare. With the promising model evaluation results and guided by our theoretical lenses, a seamless integration into the everyday life of people with aMCI is envisioned. Hereby, our aim is twofold: First, to demonstrate the translation of conceptually developed deep learning approaches into real-world applications; Second, to propose a novel and SAR-driven HCI approach for digital health and provide practical implementation, thereby bridging the gap between theory and practice. For a better understanding, we present and apply the novel HCI approach in a context that precedes this research (Böhmer et al. 2022) yet is generally applicable in different domains depending on the intended use.

5.1. Enhanced living environments with spatial augmented reality

SAR-driven enhanced living environments were introduced by Böhmer et al. (2022), using SAR to immersively project relevant information directly into the user's living environment and eliminate the aforementioned need for difficult and cumbersome wearables (e.g. tablets, headsets) for people with aMCI. Based on their individual needs, impairments, and preferences, these people are supported holistically in the areas of perception, mobility, organisation, and medicine, enabling them to live autonomously for longer without relying on wearable technology. This involves visually enhancing certain objects in the home environment (e.g. stove, calendar, medicine box) with a projected widget consisting of a functional component and an offer component, addressing areas where people with aMCI experience reduced cognitive performance (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen 2016; Petersen et al. 2009). For example, the stove widget would project the stove plates and their temperature (*functional*) as well as provide recipe suggestions (*offering*) (see Figure 7). Figure 6 shows an example of the SAR display compared to conventional AR approaches. Although the SAR-based projection has less contrast, it achieves a considerably high display in broad daylight, making it suitable for everyday use in residential environments.

The widgets and their variety are designed to maintain and promote independence for people with aMCI in a more abstract way than tDCS (Gu et al., 2022; Manenti et al. 2020) while mitigating potential dangers. In other words, these SAR-driven enhanced living environments are designed to provide a digital health IS that ensures a low-threshold, unobtrusive, yet effective and individualised needs-based service while addressing the lack of intuitive HCI approaches suitable for people with aMCI. To operationalise low-threshold and accessible HCI approaches with the SAR-based widgets, we propose a context-aware and location-based HCI approach termed ConZones, which describe zones (invisible to the user) in the living environment that are monitored by an AI-driven IS for people entering them. This system employs a deep learning model that has been trained on synthetic image data to recognise and comprehend the environment and the individuals within it. The system can detect objects (such as people) in the room, understand their geographic location, and infer their context. Then, when a person enters a particular zone (see Figure 7), it uses this information to project useful and contextual data directly into their living space at their current location. When this happens, the widget is presented to the user, e.g. by zooming in from a minimised icon, and when all people have left the zone, the widget is minimised again. For example, it could highlight a potential hazard in their immediate environment or guide them through a daily task without the need for wearable devices. The



Figure 5. Domain adaptation and real-time model deployment with real image data.

system is designed to be intuitive and easy to use, requiring minimal direct interaction from people with aMCI as it responds naturally to their location and actions without the need for explicit commands or complex interfaces.

5.2. Intuitive and indirect interaction via ConZones

According to Social Cognitive Theory (Bandura 2001), people's cognitive processes are strongly influenced by their interactions with their environment, and they develop beliefs about their ability to perform certain daily activities, called self-efficacy beliefs. These beliefs can have a powerful influence on their behaviour, as people are more likely to engage in activities that they believe they can perform successfully, thus maintaining or even enhancing their autonomy (Bandura 2001). Our ConZones interaction approach focuses on the needs, disabilities, and preferences of people with aMCI and is tailored for accessibility and inclusivity (Abras, Maloney-Krichmar, and Preece 2004) while simultaneously aiming for the most intuitive and natural HCI approach (Dickinson, Arnott, and Prior 2007).

As aforementioned, digital healthcare solutions and services have to be designed as user-friendly and intuitive in the HCI context since they otherwise hinder adoption (Blass et al. 2022), especially in the case of aMCI individuals who have to deal with reduced cognitive performance (Petersen 2016; Petersen et al. 2018; Yu, Lam, and Lee 2017). By addressing these aspects of reduced cognitive performance, our proposed approach of combining synthetic deep learning with SAR has the potential to assist people with aMCI in their daily lives without requiring them to either wear head-mounted displays or directly operate complex technologies. Our goal is to make the context-aware

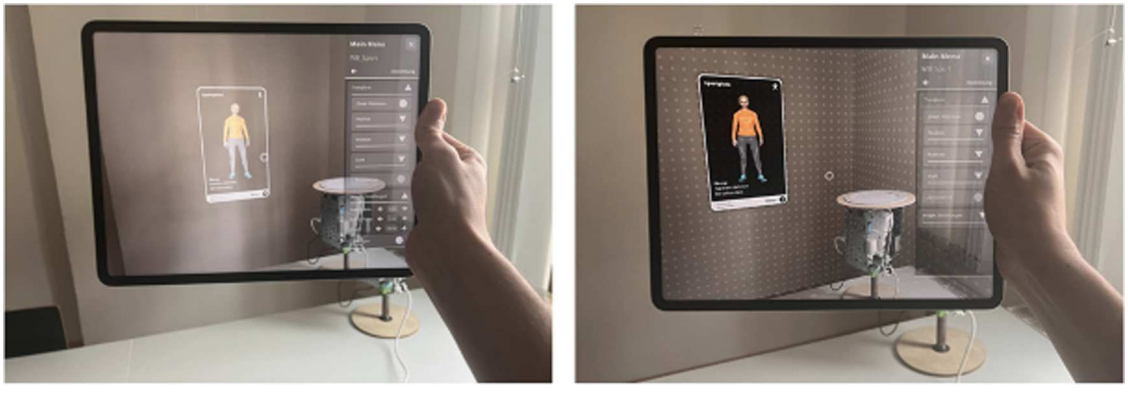


Figure 6. Comparison between spatial AR projection (left) and conventional AR visualisation (right).

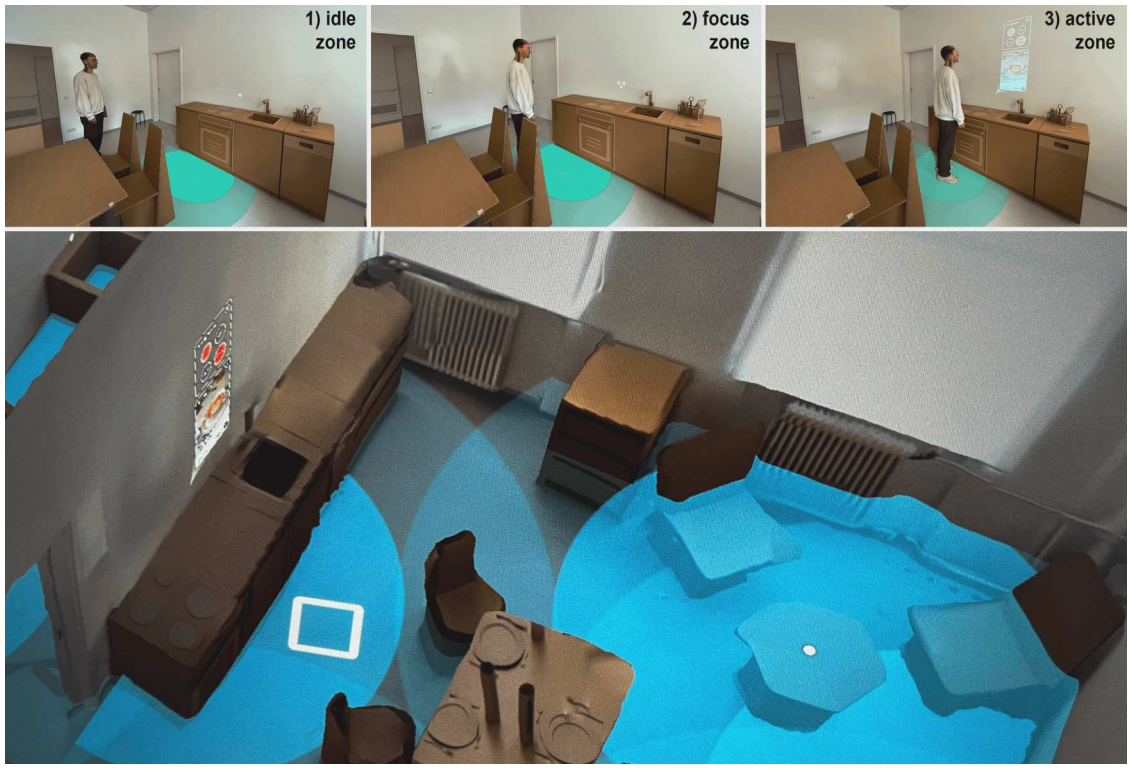


Figure 7. Context-aware zones and location-based projection.

technology of AI- and SAR-driven IS as accessible as possible, where aMCI individuals can move freely, and relevant information is projected at the right place and time to be not only visible but also helpful. In this way, we can support this vulnerable population in the areas of daily life (i.e. memory, daily life structuring, medicine, socialisation) that are primarily affected by their impairments (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen 2016; Petersen et al. 2009) and could potentially help them achieve a higher quality of life. Within our SAR-driven enhanced living environment for people with aMCI (Figure 7), we can structure each room into spatial zones that are attached to the anchor points of certain objects (e.g. stove, calendar, phone). To overcome technostress and cognitive overload, we decided not to show the whole widget presentation at all times, as the projected information is either not relevant to be projected permanently or would unnecessarily change the appearance of the living room. Nastjuk et al. (2023) found that technostress creators are more effective in a private setting, and psychological outcomes are often neglected. We targeted the technostress creators of *techno-complexity*, *techno-overload*, and *techno-invasion* (Nastjuk et al. 2023) with our novel HCI approach to best address the impairments of our target group. As depicted in Figure 6, we subdivide our spatial zones into three categories that specify the context-aware information representation of the respective widget: (1) *idle zone*, (2) *focus zone*, and (3) *active zone*. Based on the omnidirectional overhead fisheye camera and the deep learning positional reasoning module, we are not only able to detect people in the enhanced living environment but also to obtain precise positional data of the user calculated based on the pixels of the image. In other words, the bounding boxes described in Section 4 represent a rectangle with the corresponding pixel data (see Figure 7 and the small white rectangle that represents a bounding box). Consequently, this bounding box or positional user data can then be used to identify overlaps/intersections with the three context-aware spatial zones (idle, focus, active). A workflow management system component then processes this positional data and triggers the maximisation or minimisation of the projected widget

Table 4. Mathematical formulas of the bounding box and pixel mapping.

	Formula	
Top-left corner of the rectangle bounding box in image pixels	$image_x = \frac{(x \times W)}{image_{width}}$	$image_y = \frac{(y \times H)}{image_{height}}$
Width and height of the rectangle bounding box in image pixels	$image_w = \frac{(w \times W)}{image_{width}}$	$image_h = \frac{(y \times H)}{image_{height}}$

Legend: (x, y) coordinates of the top-left corner of the rectangle bounding box; Width (w) and height (h) of the rectangle bounding box; Width (W) and height (H) of the image in pixels.

accordingly. The positional data can be used in other reasoning workflows and combined with other sensors in the AI- and SAR-driven IS to provide real-time, context-aware, and relevant information to an aMCI user. The mathematical foundations of our approach are shown in Table 4.

Here, $image_x$ and $image_y$ represent the top-left corner of the rectangle bounding box in the image's pixel coordinates. Similarly, $image_w$ and $image_h$ represent the width and height of the rectangle in the image's pixel units. By scaling the rectangle's coordinates and dimensions concerning the image size, we can map the rectangle to the appropriate region within the image. These formulas assume that the rectangle's coordinates are given relative to the image size, where (0,0) represents the top-left corner of the image and ($image_{width}$, $image_{height}$) represents the bottom-right corner. This mathematical procedure enables us to precisely and efficiently track the users or, rather, their bounding box throughout the living environment, creating context-awareness and utilisable positional data. By specifying the widget (and information) size depending on the user's position, we reduce the technostress creator of *techno-overload* (Nastjuk et al. 2023). As a result, users are not exposed to large amounts of information when it is not necessary in their daily lives, also targeting techno-complexity (Nastjuk et al. 2023). Our goal with ConZones is to provide an environment and use of technology that aMCI individuals are comfortable with, reducing the amount of effort required to learn and understand the system. Our novel SAR-based HCI approach is thereby an intuitive application where users can move freely around, and relevant information is directly projected into their field of view – without having to actively go through complex operating processes or operate any wearables. In terms of the classification by Mallas, Xenos, and Katsanos (2022), ConZones can be understood as *Natural Passive Interaction*, providing a consistent user experience that maintains the same conditions for the user and is independent of changes in the user's physical or cognitive state. We provide a more natural way of interacting with technology for individuals with cognitive impairments, as proposed by Maedche et al. (2019), incorporating a low-threshold user interface. In doing so, we are further aligned with the design recommendations for telemonitoring care proposed by Chen and Levkoff (2015) and adhere to the technology acceptance model as well as the digital divide perspective. In other words, with ConZones, we can customise the system to the user's needs, increase functionality and flexibility, provide integrative APIs, use audio-visual presentation, provide clear instructions, reduce the burden of data entry, and promote a culture of self-care and self-efficacy that aMCI patients can potentially benefit from, thus promoting their independence and improving their quality of life.

To illustrate an exemplary use-case for ConZones, let's take *Gisela,* who is 85 years old, has aMCI, and still lives autonomously in her home, as shown in Figure 7 and Figure 8. She was about to cook a meal, where she used the offering component of the stove widget which gave her clear, precise, and relevant instructions on the cooking process. As all the work had to be done at the stove, she stood in the action zone with the widget and its information being ubiquitous and visually enhanced. Gisela was relieved that she no longer had to use cumbersome wearables, her complex smartphone, or fumble through her already half-decayed recipe book – the relevant information was projected directly and swiftly onto her wall behind the stove. After she finished cooking her meal, she remembered her medicine intake (which she also had a widget for) and went to another part of her apartment to get her medicine. When she came back from the living room and decided to put the medicine directly on top of the stove, the widget visually enhanced as she approached the stove and showed her that the stove places she used were still hot, thus visualising a potential hazard warning. If Gisela had a declining vision, this information would also have been provided additively to accommodate individual needs, preferences, and impairments. Subsequently, if she had forgotten to turn off the hot plates, all other widgets (e.g. medication intake, social activities, memorisation) would have received a warning overlay to inform her accordingly. As can be seen in Figure 8, the widgets can be placed anywhere in her living environment, addressing all possible use cases, with our ConZones enabling the system to adequately and holistically support people with aMCI without having to sacrifice their freedom in everyday life activities.

5.3. Ethical considerations

If not already, the ethical or moral question of using computer vision techniques in digital healthcare, and specifically in our use case, would have come up sooner or later – and rightly so. Ethical, or more precisely, privacy-intrusive approaches can not only hinder the adoption of digital health solutions (Blass et al. 2022) but also leave users with a bad and 'spied on' feeling (Schak, Blum, and Bomsdorf 2022). Therefore, Spiekermann et al. (2022) suggest designing and developing more ethical systems, for which we have adopted foundational theories that guided us in this research approach. In



Figure 8. Gisela within an exemplary AI- and SAR-driven enhanced living environment.

addition, Nastjuk et al. (2023) identified *techno-invasion* as a crucial technostress creator, which is described as invading users' personal and private space through constant connectivity, monitoring, and surveillance. Through our theoretical lens under the guise of Social Cognitive Theory (Bandura 2001), we have closely involved our target group of people with aMCI from the beginning of our research approach (cf. Böhmer et al. 2022). Hereby, the idea of tracking people (or rather their rectangles) circulated for longer and has been discussed in every moderated focus group, think-aloud session, and evaluation episode. As expected, it was by far the most discussed and equivocal aspect. Nonetheless, through our user-centered approach and the close involvement of our target group, we were able to ensure high transparency, eliminate prejudices, and include user feedback, establishing user-centric privacy controls (Chhetri and Motti 2022). Therein, a major concern was directed at the image processing of the omnidirectional fisheye camera, which our target group of aMCI individuals felt was intrusive. However, our image processing by the ConZones deep learning model runs completely locally on an edge device, which does not store any image data and only sends the positional user data as vector coordinates of the bounding box. Any image predicted by the deep learning model is immediately deleted and not saved since pixels are being processed, not a reasoned image. The following reasoning and calculation of the context-aware image data are not based on the image itself but rather on the extracted bounding box rectangle and pixel coordinates. As can be seen in Figure 8, the person being tracked is not actually represented as a person but as a bounding box, thus ensuring privacy, anonymity, and abstraction. Consequently, the enhanced living environment aligns the user's positional data with the ConZones by the bounding box, effectively abstaining from tracking and monitoring additional activities. Our tracking can be seen as more on a higher meta-level that does not allow any conclusions about intimate and privacy aspects where people do not have to worry about a drastic invasion of their privacy. We, therefore, refrain from using the terms *tracking* or *monitoring* and suppose using *positional reasoning* instead, which not only better describes the process but also sounds less intrusive and was widely accepted by our target group evaluation.

6. Evaluation

Given that the lower-level but necessary deep learning model evaluation was successful (cf. Section 4.3), a close and thorough evaluation of the novel HCI approach seems reasonable. Under our theoretical guidance of Social Cognitive Theory (Bandura 2001), we identified the assessments of *self-efficacy, performance expectancy,* and *outcome expectancy* as the key evaluation measures that can be measured either quantitatively or qualitatively. Subsequently, value-sensitive design theory (Friedman et al. 2013) classifies two sets of stakeholders that are relevant for our evaluation episodes and, ultimately, the system application: (1) our target group as direct stakeholders, and (2) researchers, developers, and practitioners (referred to as *experts*) from the IS and digital health field as our indirect target group. While prioritising the usability and inclusiveness of our intended target group of aMCI individuals, it is crucial to obtain a more comprehensive assessment by seeking validation from domain specialists regarding the proposed ConZones HCI approach. This procedure

aims to ensure that the evaluation encompasses a broader perspective, both in terms of the specific needs and challenges faced by the target group as well as the expertise and insights of professionals working in relevant domains, which is an established procedure in HCI research with aging individuals (Dickinson, Arnott, and Prior 2007). To gauge the effectiveness, intuitiveness, and usability of our proposed deep learning-based HCI approach, we conducted a total of three evaluation episodes with different experimental settings, subjects, and evaluation purposes as recommended by Kriglstein et al. (2016), epitomised by system use tests, questionnaires, and think aloud sessions. Regarding the sample sizes, our iterative evaluation episodes and user-centered design align with the principles of meaning and theoretical saturation (e.g. via tailored sampling approaches), ensuring that all nuances and contextual meanings of HCI interactions for aMCI individuals are thoroughly captured (Wutich, Beresford, and Bernard 2024).

Table 5. Definition of relevant evaluation constructs.

Aspect	Definition	Construct	Evaluation Method
Usability	The extent to which the system is effective, efficient, and satisfying in achieving goals (ISO 9241-11).	Holistic (not tied to UTAUT directly)	Usability tests, think-aloud sessions, and qualitative feedback.
Usefulness (PE1)	The degree to which ConZones enhances task performance or facilitates goal achievement.	Performance Expectancy	Survey item on perceived usefulness of ConZones in daily tasks.
Quickness (PE2)	The degree to which the system allows users to complete tasks faster.	Performance Expectancy	Survey item on perceived speed improvements in completing tasks.
Productivity (PE3)	The extent to which ConZones increases overall productivity in daily activities.	Performance Expectancy	Survey item on perceived impact on productivity in enhanced living environments.
Health Benefits (PE4)	The potential benefits (e.g. reduced therapy costs, free courses) associated with system use.	Performance Expectancy	Survey item adapted to reflect perceived health-related advantages of using ConZones.
Clarity (EE1)	The degree to which the system's functions are clear and understandable.	Effort Expectancy	Survey item on clarity of interaction paradigms.
Easiness to Master (EE2)	The ease with which users can master ConZones functionalities.	Effort Expectancy	Survey item on how easily users felt they could master the system after initial exposure.
Easiness to Use (EE3)	The perceived simplicity of interacting with the system.	Effort Expectancy	Survey item on overall ease of use.
Easiness to Learn (EE4)	The ease of learning to use ConZones effectively (synonymous with 'learnability').	Effort Expectancy	Survey item on how quickly users understood and adapted to ConZones in a natural setting.

Evaluation episodes 1 & 2 were characterised by a similar experimental setting but included different subjects and different evaluation purposes. While the first evaluation episode aimed to assess the usability and intuitiveness perceived by our target group of people with aMCI, the second evaluation episode applied the same system evaluation setting to a group of IS and digital health experts. To determine usefulness and intuitiveness as a form of *self-efficacy*, *performance expectancy*, and *outcome expectancy* (Bandura 2001) that are not explicitly measurable, we evaluated *performance expectancy* (PE) and *effort expectancy* (EE), which are embedded in the *Unified Theory of Acceptance and Use of Technology* (UTAUT) model (Venkatesh et al. 2003), by surveying the target group and experts after using the system. Subsequently, to rigorously assess PE and EE, we drew on the well-known scale items by Venkatesh et al. (2003). These are, for PE: *usefulness* (PE1), *quickness* (PE2), *productivity* (PE3), and *increased chance of getting a raise* (PE4); for EE: *clarity* (EE1), *easiness to master* (EE2), *easiness to use* (EE3), and *easiness to learn* (EE4). Since PE4 would not be meaningful in the context of our research, we changed it to *increased chance of receiving health insurance benefits* for the questionnaires, which implies that using such a digital health application could yield potential healthcare benefits (e.g. reduced therapy costs, free courses, etc.).

Our evaluation framework distinguishes between usability (effectiveness, efficiency, and satisfaction) and various aspects of performance and effort expectancy. Because these terms are often used interchangeably with technology in various fields of social science, Table 5 presents our definition of these constructs based on their intended use within the UTAUT framework (Venkatesh et al. 2003) to ensure comprehensive coverage of user experience dimensions.

In the first step, both the target group and experts were asked to use the system in a semi-natural setting (Abras, Maloney-Krichmar, and Preece 2004) with three active widgets that offered the novel interaction approach. In selecting the sample size for health pilot studies, we adhered to the minimum of n = 12 subjects suggested by Julious (2005) based on feasibility rationale, precision of mean and variance, and regulatory concerns. This approach is further supported by Wutich,

Beresford, and Bernard (2024), who emphasise that small but carefully chosen sample sizes are appropriate for capturing rich, meaningful data in iterative, context-specific qualitative research designs. In evaluation episode 1, n = 12 subjects with aMCI used the system, while evaluation episode 2 consisted of n = 14 domain experts. Subjects were then asked to move freely and use/test the SAR-based system by pretending to perform activities of daily living such as cooking, taking medication, and socialising via video telephony. Subsequently, the study participants were asked to complete the questionnaire, which included (1) an introductory text about the research project, (2) the description of the *ConZones* HCI approach, (3) the statements on the PE and EE, and (4) some socio-economic questions. For data collection, we used interval-scaled verbal-numeric 7-point Likert-style scales. The questionnaires were anonymized before being analyzed. Subjects of our aMCI target group were aged older than 60 years (some over 80 years old), lived autonomously or with their partners at home, and already retired from their professional roles. Moreover, the domain expert respondents partially fulfilled multiple professional roles and included two senior IS researchers, two senior digital health researchers, 1 HCI senior researcher, 2 IS research associates, one digital health research associate, four digital health project leads, one usability engineer, and one health insurance manager, all possessing 2–19 years of experience in their respective roles.

Figure 9 illustrates the boxplots representing the responses, which exhibit high agreement levels across all items, displaying medians of m = 6 for both the target group and field experts. Consequently, the cumulative scores of the PE and EE, with medians of m = 24 for the target group and m = 25 for domain experts on a 7–28 scale, effectively capture the overall positive evaluation. Subjects indicated that the novel HCI approach would enable them to accomplish tasks (e.g. cooking in an AI- and SAR-driven enhanced living environment) more quickly while increasing their overall productivity in daily activities. In particular, the high level of agreement on the EE constructs suggests a high level of user-centeredness, system usability, and learnability.

To validate the quality of the constructs PE and EE, we examined individual item reliability (loadings), composite construct reliability (CCR), and average variance extracted (AVE) (Hulland 1999). Item reliability is examined by evaluating the loadings of the measured items on their respective construct, for which we performed a confirmatory factor analysis in *R* (Table 6). It is generally known that items with low loadings (rule of thumb: < 0.4) should be carefully scrutinised as they offer little additional explanatory power but attenuate (and thus bias) parameter estimates (Hulland 1999; Nunnally 1978). As shown in our models in Table 6, all item loadings exceed the 0.4 limit. In addition, the AVE is a measure to assess the amount of variance captured by the construct, compared to the variance due to measurement error, and should be above 0.5, which is given for all our constructs and artifacts, indicating that the variance captured by the construct is greater than the measurement error (Fornell and Larcker 1981). Subsequently, CCR measures the overall reliability of items loading on a construct and, therefore, the internal consistency of a construct. It should exceed the threshold of 0.7 (Hulland 1999; Nunnally 1978), which is given for all our items and artifacts. Discriminant validity was assessed by comparing the AVE and the squared correlation among the constructs, following the framework established by Fornell and Larcker (1981). To calculate the correlation, we employed Kendall's Tau coefficient, which is specifically designed for Likert-style scales, as recommended by Jamieson (2004). The comparison reveals that the average variances extracted for PE and EE (see Table 6) are both higher than the squared correlations (cor) between PE and EE for both the target group ($cor^2 = 0.246$) and experts ($cor^2 = 0.022$). Based on these validity criteria, our measurement models, consisting of four items each for the constructs PE and EE, are deemed suitable for evaluation.

Despite the overall positive system use and questionnaire evaluation, we observed a minor portion of whisker outliers (see Figure 9), especially within the target group evaluation episode. We decided to perform another qualitative ex-post analysis to ensure high system usability and resolve ambiguities (e.g. system use issues, cognitive load, misconceptions), which further aligns with our multi-episode evaluation strategy (Kriglstein et al. 2016). Particularly in the context of aMCI, where the assessment of technology complexity, low-threshold interaction, and intuitiveness are most relevant, we decided to follow the techniques of *behavioral rehabilitation* for aMCI discussed by (Greenaway et al. 2008), which typically focus on improving daily living skills, memory attention, and problem-solving skills. Here, computerised and augmented/virtual reality cognitive training to stimulate cognitive functions embody interventions for people with aMCI tailored to improve specific cognitive skills that are often qualitatively evaluated (Jean et al. 2010). Hence, in pursuit of a summative and naturalistic HCI approach assessment for people with aMCI and to ensure the necessary scientific rigour, evaluation episode 3 drew on our

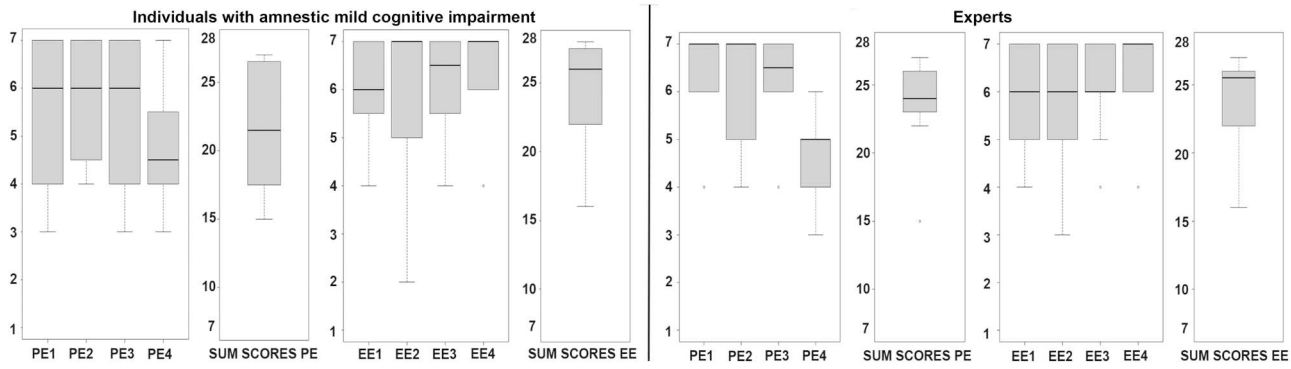


Figure 9. Boxplots for ConZones interaction evaluation with scale items.

foundational theories and theoretical foundations that consider think-aloud sessions to be a valid qualitative evaluation method (Abras, Maloney-Krichmar, and Preece 2004; Dickinson, Arnott, and Prior 2007; Friedman et al. 2013; Kriglstein et al. 2016). Accordingly, we adhered to the *Concurrent Think-Aloud* approach (Van Den Haak, De Jong, and Jan Schellens 2003) as a means of our qualitative analysis and conducted our session using the '10±2 rule' for think-aloud evaluation sample size (Hwang and Salvendy 2010) with n = 12 aMCI subjects. In this method, participants were instructed to use the system or complete a series of tasks while articulating their thoughts, allowing for evaluation of system design and implementation. To ensure qualitative rigour during and after these sessions, we followed the well-established methodology outlined by Gioia, Corley, and Hamilton (2013), which involved formulating *first-order concepts*, *second-order themes*, and *aggregate dimensions* based on the subjects' expressed thoughts. These details can be found in Table 7, where positive aspects, as well as potentials for improvement, are outlined. Overall, the results of the think-aloud sessions show promising results as the subjects felt comfortable, confident, and easy with the novel HCI approach. As the second-order themes 'Easy information access and tangibility,' 'Intuitive use through indirect interaction,' 'Easy to understand and operate,' and 'Information complexity and comprehensibility' show, we were able to effectively address the technostress creators of *techno-complexity* and *techno-overload* (Nastjuk et al. 2023), minimising cognitive load while simultaneously increasing user-centered usability. Subjects emphasised that they felt more comfortable with the SAR-based HCI approach than with wearable or direct HCI technologies because it was more intuitive, easier to learn, and swiftly integrated into their daily lives. Participants in the think-aloud session expressed great satisfaction with the provided information, its content, and pleasantness, especially valuing the transformation and user-location dependency of widgets, as well as the division into functional and offering parts.

The subjects found the system user-friendly, intuitive, and easy to use, with low entry barriers, where they quickly understood the context-aware zones and voice control and considered it to be useful. Participants experienced cognitive relief from minimised complexity and easy-to-understand information and reported the benefit of not having to actively search for information yet receiving relevant and personalised data immediately. The different widget states, particularly the idle state, were found useful for reducing information overload, where subjects positively assessed the system's location-based information provision. Most importantly, the think-aloud session provided valuable insights into the system usage by individuals with aMCI, especially addressing the whisker outliers from the first evaluation episodes. Nonetheless, since evaluation episode 3 provided a more in-depth and detailed user experience, these outliers can be attributed to the

Table 6. Construct validation for elderly and expert groups.

Performance Expectancy		Elderly/MCI	Experts	Effort Expectancy		Elderly/MCI	Experts
Loadings	Usefulness	.900	.630	Loadings	Clarity	.872	.740
	Quickness	.878	.649		Easy to Master	.423	.815
	Productivity	.906	.998		Easy to Use	.998	.695
	Chance of Raise*	.436	.743		Easy to Learn	.562	.776
AVE		.648	.591		**AVE**	.563	.574
CCR		.874	.848		**CCR**	.823	.843

Note: MCI = mildly cognitively impaired, AVE = average variance extracted, CCR = composite construct reliability.

Table 7. Think-aloud evaluation results.

Aggregate Dimensions	2nd Order Themes	1st Order Concepts
Information Representation	Useful and adequate widget transformation	+ Subjects reported sufficient and pleasant content of information. + Subjects positively assessed the transformation and user-location dependency of widgets as well as their changing information content. + Subjects highlighted the widget division into a functional part and an offering part as very positive.
	Easy information access and tangibility	+ Subjects perceive the colour representation as highly recognisable and could easily access and understand the communicated information. + Subjects valued the connection between a widget and its anchored augmented real-world object.
	Realistic and abstract information visualisation	+ Subjects perceived the realistic representation and augmentation of the real object (e.g. number of stove plates) as highly useful. o Some subjects rather preferred text to illustrations.
Usability	Highly user-friendly and user-centric	+ Subjects highlighted the high level of user-friendliness. + Subjects highlighted the high level of user-centeredness.
	Intuitive use through indirect interaction	+ Subjects found the system and interaction process easy to use. + Subjects reported high intuitiveness and low entry barriers. + Subjects preferred the indirect interaction over wearable approaches (i.e. tablet, smartphone).
	Easy to understand and operate	+ Subjects were able to understand and use the context-aware zones quickly and without further instructions. + Subjects assessed the voice control as highly useful.
	Setup process	o Some subjects reported fears about the initial setup and instruction process.
Cognitive Relief	Information complexity and comprehensibility	+ Subjects experienced cognitive relief both from minimised complexity and from the use of easily comprehensible and object-oriented information. + Subjects reported high cognitive relief as they did not have to actively seek information and were provided with individual, relevant, and useful data. + Subjects found the different widget states to be very useful, with the idle widget showing only a small anchor point, reducing information overload.
	No need for additional devices and constant reorientation	+ Subjects were relieved to not have to reorient themselves to gather information (e.g. recipe on smartphone and cooking area in different locations). + Subjects positively assessed the information provision based on their location since it gave them relevant information at the respective object/location. + Subjects highly valued the hands-free and indirect interaction which reduces cognitive effort and the need for handling wearable devices.
Daily Routines	Holistic approach to autonomy support	+ Subjects assessed the holistic assistance approach as highly useful, expressing their need for cognitive augmentation.
	System versatility and context-awareness	+ Subjects reported high consent for having different widgets for different daily routines. + Subject positively highlighted the widget context-awareness and their real-time as well as object-dependent occurrence.

Note: + = positive aspect; o = potential for improvement.

daily form of aMCI participants, misconceptions in the task/questionnaire description, or personal reasons. It would also be presumptuous to think and expect that our re-thought HCI approach with ConZones will benefit all users equally.

Overall, the three evaluation episodes positively assessed usability and intuitiveness by qualitatively addressing *self-efficacy, performance expectancy,* and *outcome expectancy* of Social Cognitive Theory (Bandura 2001) via various methods, models, and constructs. Our multi-episode evaluation strategy aimed at evaluating the proposed AI- and SAR-based HCI approach in the most naturalistic way possible, directly involving our target group of aMCI individuals as well as IS and digital health field experts – guided by our foundational theories and theoretical foundations. While the first two evaluation episodes made these positive results somewhat quantifiable (without quantitative/empirical claims), the think-aloud session allowed for a deeper understanding of the user's thoughts and feelings, where the room for improvement does not require a system or approach overhaul.

7. Discussion

This study explored the use of synthetically generated image data to train deep learning models for implementing ConZones, an innovative SAR-driven interaction design for aMCI individuals. By enabling context-aware, location-based zones, ConZones facilitate intuitive, indirect interaction without the need for wearables, addressing the physical and cognitive challenges associated with aMCI. We argue that by supporting natural and passive interactions (Mallas, Xenos, and Katsanos 2022), ConZones enable aMCI individuals to maintain autonomy in everyday life. These SAR-driven systems provide low-threshold access to digital health solutions by projecting contextually relevant information, such as medication reminders or entertainment, directly into the user's environment. Evaluation

episodes highlighted the usefulness and usability of ConZones for behavioural rehabilitation of aMCI individuals. Participants appreciated the seamless integration of the system, which facilitated effortless access to information while reducing *techno-complexity* and *techno-overload* (Nastjuk et al. 2023). This implies that the potential intrusiveness of AI applications must be carefully evaluated to strike a balance between convenience and the preservation of personal freedoms as epitomised by the technostress creator *techno-invasion* (Nastjuk et al. 2023). Characterised as an *Intelligent Assistant* (Dhiman et al. 2022), our proposed HCI approach further addressed the individuals' concerns associated with digital healthcare, especially *technical-related* (unreliability of technology, user competence, data quality) and *privacy- & security-related* (invasion of privacy, data manipulation, super-powerful health insurance) concerns (Blass et al. 2022), that affect digital technology adoption. Thus, with our proposed HCI approach utilising SAR, we aimed at reducing digital health adoption concerns as well as technostress creators, contributing to intuitive and accessible digital health solutions for individuals with aMCI.

7.1. Theoretical implications

From a theoretical perspective and given our theoretical lens of Social Cognitive Theory (Bandura 2001), our study demonstrates that the proposed AI- and SAR-driven HCI approach can influence self-efficacy by providing intuitive and low-threshold access to digital health solutions among people with aMCI. As individuals with such cognitive impairments interact with the system and experience successful outcomes, their self-efficacy may increase. Increased self-efficacy can empower individuals by instilling a sense of confidence in their ability to independently engage with digital technologies and their environment (Bandura 2001), for which our study demonstrates one possible way to reduce the burden of technology entry and the complexity of operation and interaction for individuals with aMCI (Anderson 2019; Böhmer, Kendziorra, and Kuehnel 2024; Petersen et al. 2009; Petersen et al. 2018; Yu, Lam, and Lee 2017). In addition, the concept of *reciprocal determinism* (Bandura 2001) was addressed, and our proposed HCI approach considers the specific needs and capabilities of aMCI individuals through contextual awareness. By providing relevant and personalised information in real-time through ConZones and SAR-based projections, the environment is structured to support and facilitate desired behaviours (Bandura 2001). This reciprocal determinism between technology, individual capabilities, and environmental affordances can create a positive feedback loop in which the technology enhances the individual's ability to engage with it, leading to improved outcomes and increased motivation to continue using the system and maintain their autonomy in everyday life. Thus, we argue that the theoretical concept of reciprocal determinism can be used to some extent as a theoretical underpinning that shapes the design of future healthcare IS.

Building on this, we would also like to discuss the potential role of emotional factors in enhancing the effectiveness and adoption of digital health solutions, extending the theoretical implications of Social Cognitive Theory to include emotional dimensions. While our primary focus was on cognitive targets, research has demonstrated the critical interplay between emotional and cognitive factors in technology adoption and usability. For example, findings from Zoccarato et al. (2024) suggest that emotional trust in continuous glucose monitoring systems is positively correlated with perceived usefulness and intention to use such tools. Similarly, research by Siepmann and Kowalczuk (2021) shows that positive emotional responses, such as enjoyment, significantly influence perceived usefulness and continued use of smartwatches for health monitoring. These findings resonate with Bandura's (2001) emphasis on the interaction between cognitive and environmental factors and suggest that emotional responses to technology are an integral part of this interaction. Incorporating these perspectives, we argue that although emotional targets were not explicitly measured in our study, the perceived usefulness of the proposed system and its ability to reduce cognitive load may indirectly promote positive emotional responses such as increased confidence, reduced frustration, and improved mood. This interaction underscores a complementary pathway by which technology not only supports cognitive processes but also enhances emotional well-being (Steinert and Dennis 2022). From a theoretical standpoint, this may expand the scope of reciprocal determinism by incorporating the emotional outcomes of users' interactions with technology, creating a feedback loop in which emotional and cognitive benefits reinforce each other, leading to sustained engagement and improved autonomy.

Our study extends the theoretical discourse on cognitive interventions for individuals with aMCI by incorporating synthetic, data-driven deep learning and SAR to bring new dimensions to the field. Unlike traditional cognitive interventions using virtual reality (Jean et al. 2010; Kim, Pang, and Kim 2019; Migo et al. 2016), ConZones leverages SAR to create an intuitive, accessible, and low-threshold interaction environment. This approach moves SAR from entertainment and industrial

applications to a therapeutic context, providing novel cognitive support in areas such as memory, structuring, and participation (Petersen 2016; Petersen et al. 2018; Yu, Lam, and Lee 2017). By using synthetic data to train deep learning models, ConZones addresses the challenges of data scarcity and privacy in healthcare, providing an ethical and efficient foundation for AI-driven support systems. The system projects contextual information directly into the user's environment, providing intuitive, seamless, and immersive cognitive support that is less intrusive than traditional AR/VR wearable-based approaches. The stimulation of cognitive functions through AI-driven SAR is a largely unexplored area of research. Our study opens the door for future advances by demonstrating the potential of SAR in digital health, particularly for cognitive impairments. This expands SAR applications/theorising beyond entertainment and industrial settings (Baumeister et al., 2017; Mousavi Hondori et al. 2013; Yang et al. 2018) and demonstrates its ability to improve the quality of life for individuals with special needs. In addition, our work contributes to the digital health discourse by presenting a practical approach to using synthetic data and deep learning models to achieve symbiotic AI with innovative interaction designs.

7.2. Practical implications

By bridging the gap between theory and practice, we have expanded knowledge on the use of synthetically generated image data for digital health applications, as existing studies tend to focus on use in different domains (Krump, Ruß, and Stütz 2020; Scheck, Seidel, and Hirtz 2020; Seib, Lange, and Wirtz 2020), while digital health applications remain largely underexplored. By leveraging scalable synthetic data generation, realistic and diverse datasets can be created that comply with privacy regulations and mitigate the scarcity of real patient data. This opens up new opportunities to develop and test digital health solutions in a controlled manner while enabling user-centered system design. Our results demonstrate the technical feasibility of synthetic data with high visual fidelity and benchmark performance that surpasses existing studies, validating its potential as a resource for monitoring, diagnosis, and treatment advances.

We argue that the AI- and SAR-driven ConZones approach addresses the cognitive overload that individuals with aMCI often face when interacting with digital technologies (Anderson 2019; Gauthier et al. 2006; Jongsiriyanyong and Limpawattana 2018; Petersen et al. 2009; Yu, Lam, and Lee 2017). By providing visual cues and contextual information directly in the user's environment, the system simplifies interaction and makes digital health tools more intuitive and accessible. This has practical benefits for daily activities such as medication management and appointment reminders, promoting independence, and improving the quality of life for people affected by neurodegenerative diseases without the need for wearables. ConZones demonstrated real-time detection of multiple individuals, suggesting its potential for broader application in hospitals, nursing homes, and care facilities where monitoring activities are critical. This makes it valuable not only for promoting autonomy in aMCI individuals but also for assisting healthcare professionals and caregivers. As such, this study contributes to research on AI-based assistants (Maedche et al. 2019), HCI combined with personal factors (Chignell et al. 2023), computer vision in assisted living (Colantonio et al. 2018), and future HCI strategies for aging populations (Vines et al. 2015), providing both theoretical insights and practical application.

7.3. Limitations and future research

In light of the positive evaluation episodes, some limitations of this study should be noted. Firstly, the perspective of evidence-based data supporting our findings remains arguably the most obvious limitation of this study. While the small sample size of the questionnaire is a limitation in terms of generalizability, we argue that it served the intended purpose of providing indicative evidence-based data through the combination of questionnaire and think-aloud sessions, following the sample size guidelines proposed by Julious (2005) and Wutich, Beresford, and Bernard (2024). Through a combination of questionnaire data and subsequent think-aloud sessions, we gathered indicative, evidence-based insights that go beyond surface-level assessments. The think-aloud sessions provided a deeper qualitative layer of understanding, enriching the questionnaire results with nuanced perspectives on system use, user interaction, and areas for improvement. This approach ensured that the study captured not only indicative quantitative measures but also contextual and experiential data, which we believe are critical for evaluating systems designed for sensitive user groups such as people with aMCI. These data were not intended to provide definitive empirical conclusions but rather to provide a basic understanding and initial pilot impression of the system's use and how people with aMCI, as well as experts, rate the HCI approach. The goal here was not to conduct a large-scale empirical evaluation, which would have been neither feasible with the current system nor meaningful at this stage of development.

Rather, these pilot results are essential in guiding refining the system and informing future studies that can build on this work. Nonetheless, a quantitative perspective, such as the full use of the UTAUT, could validate our indicative findings more empirically, which is often challenging in such qualitative research areas, where even assembling a sample of aMCI individuals is not only challenging in itself but also costly.

Secondly, although our ConZones approach has demonstrated its potential for real-time detection and interaction design for multiple individuals, its performance and usability in different healthcare settings and with individuals with more severe cognitive impairments or specific medical conditions remain to be explored, e.g. people using walking aids or are connected to mobile medical devices like oxygen concentrators. Since our approach shall be regarded as a pilot study and we were evaluating only a few subject samples, the effectiveness of the approach in different contexts and with a broader range of individuals is still crucial to assessing its practicality and potential limitations in real-world digital health applications. Given these limitations, future research should focus on addressing these challenges and conducting extensive validation studies to ensure the reliability, generalizability, and ethical implications of using synthetically generated image data (which we acknowledge may not be appropriate for every use case) for novel HCI approaches in digital health. In addition, we strongly encourage researchers to conduct further research in the area of SAR in digital health and cognitive interventions or cognitive stimulation in individuals with aMCI to propose alternative approaches to tDCS. In this regard, we also acknowledge the potential diagnostic applications of the ConZones approach that remain underexplored in the current study. While our primary focus was on providing rehabilitative and supportive functionalities with a SAR- and AI-based HCI approach to enhance autonomy and reduce cognitive load for individuals with aMCI, we recognise that the system's ability to capture contextual and behavioural data could theoretically support diagnostic goals, such as early detection of cognitive decline or monitoring of disease progression. However, incorporating diagnostic applications would require significant modifications to the system design, including validation protocols, calibration for medical diagnostics, and adherence to strict regulatory standards for diagnostic tools. Future research could explore these possibilities by integrating diagnostic capabilities, such as tracking behavioural patterns or detecting anomalies that may indicate cognitive decline or health deterioration. Such extensions would require technical adaptations and interdisciplinary collaborations to ensure that the diagnostic results are clinically meaningful, ethically sound, and tailored to the unique needs of individuals with aMCI. By expanding the scope of SAR-based HCI tools into the diagnostic domain, researchers could bridge the gap between rehabilitation and early detection, creating a more comprehensive ecosystem of digital health solutions for vulnerable populations.

8. Conclusion

The ongoing global demographic shift requires innovative and inclusive digital health solutions for people with aMCI that enhance autonomy and cognitive facilitation while overcoming technology concerns and over-complexity. As we live in the digital (health) age with increasing solutions and applications, it is crucial to design user-centered, inclusive, and intuitive information systems that empower individuals to take control of their health and prioritise usability over complexity. By demonstrating how a SAR-driven approach based on synthetic image data computer vision can be used to ultimately propose a novel (or rethought) HCI approach for aMCI individuals, our study contributes to the field of digital health and paves the way for future applications. Based on the positive evaluation episodes, the proposed HCI approach has great potential to support these individuals in their daily lives. Therefore, the presented study not only contributes via its feasibility but also serves as a starting point for future research endeavours in the field of digital health solutions.

Authors' contributions

Each author has contributed significantly to the conception, design, execution, or analysis of this study.

Consent for publication

All individuals involved in this study have consented to the publication of identifiable details, which may include data and images.

Ethics approval and consent to participate

This received ethical approval by the Commission for Ethical Issues in Science at Martin Luther University Halle-Wittenberg and all participants gave informed consent.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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References

Abras, C., D. Maloney-Krichmar, and J. Preece. 2004. "User-centered Design." *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Sage Publications* 37 (4): 445–456.

Ahmed, I., G. Jeon, A. Chehri, and M. M. Hassan. 2021. "Adapting Gaussian YOLOv3 with Transfer Learning for Overhead View Human Detection in Smart Cities and Societies." *Sustainable Cities and Society* 70:102908. https://doi.org/10.1016/j.scs.2021.102908.

Al-Ma'aitah, M., A. Alwadain, and A. Saad. 2022. "Application Dependable Interaction Module for Computer Vision-Based Human-Computer Interactions." *Computers and Electrical Engineering* 97:107553. https://doi.org/10.1016/j.compeleceng.2021.107553.

Alzubaidi, L., J. Zhang, Amjad J. Humaidi, Ayad Al-Dujaili, Ye Duan, Omran Al-Shamma, J. Santamaría, Mohammed A. Fadhel, Muthana Al-Amidie, and Laith Farhan. 2021. "Review of Deep Learning: Concepts, CNN Architectures, Challenges, Applications, Future Directions." *Journal of Big Data* 8: 1–74. https://doi.org/10.1186/s40537-021-00444-8.

Anderson, N. D. 2019. "State of the Science on Mild Cognitive Impairment (MCI)." *CNS Spectrums* 24 (1): 78–87. https://doi.org/10.1017/S1092852918001347.

Anderson, N. D. 2020. "State of the Science on Mild Cognitive Impairment." *The Journals of Gerontology: Series B* 75 (7): 1359–1360. https://doi.org/10.1093/geronb/gbaa040.

Ando, T., T. Yamaguchi, T. Giovannetti, and M. Sakamoto. 2022. "A Recognition Model of Motion Primitives in VR-IADL Based on the Characteristics of MCI Patients and Elderly Adults. HCI International 2022, HCI for Health, Well-Being, Universal Access and Healthy Aging." *Lecture Notes in Computer Science* 13521:3–12. https://doi.org/10.1007/978-3-031-17902-0_1.

Aranjuelo, N., S. García, E. Loyo, L. Unzueta, and O. Otaegui. 2021. "Key Strategies for Synthetic Data Generation for Training Intelligent Systems Based on People Detection from Omnidirectional Cameras." *Computers & Electrical Engineering* 92:107105. https://doi.org/10.1016/j.compeleceng.2021.107105.

Bandura, A. 2001. "Social Cognitive Theory: An Agentic Perspective." *Annual Review of Psychology* 52 (1): 1–26. https://doi.org/10.1146/annurev.psych.52.1.1.

Baumeister, J., S. Y. Ssin, N. A. ElSayed, J. Dorrian, D. P. Webb, J. A. Walsh, T. M. Simon, A. Irlitti, R. T. Smith, M. Kohler and B. H Thomas. 2017. "Cognitive Cost of Using Augmented Reality Displays." *IEEE Transactions on Visualization and Computer Graphics* 23 (11): 2378–2388.

Bidani, A., M. S. Gouider, and C. M. Travieso-González. 2019. "Dementia Detection and Classification from MRI Images Using Deep Neural Networks and Transfer Learning." In *Advances in Computational Intelligence. IWANN 2019. Lecture Notes in Computer Science*, edited by I. Rojas, G. Joya, and A. Catala, 925–933. Cham: Springer. https://doi.org/10.1007/978-3-030-20521-8_75

Biocca, F., C. Owen, A. Tang, and C. Bohil. 2007. "Attention Issues in Spatial Information Systems: Directing Mobile Users' Visual Attention Using Augmented Reality." *Journal of Management Information Systems* 23 (4): 163–184. https://doi.org/10.2753/MIS0742-1222230408.

Bird, J. J., D. R. Faria, A. Ekárt, and P. P. Ayrosa. 2020. "From Simulation to Reality: Cnn Transfer Learning for Scene Classification." In *2020 IEEE 10th International Conference on Intelligent Systems (IS)*, 619–625. Varna, Bulgaria. https://doi.org/10.1109/IS48319.2020.9199968

Blass, M., H. Gimpel, C. Regal, and D. Waldmann. 2022. "Individuals' Concerns Associated with Digital Healthcare: Professionals' and Patients' Hindrances to Adopt Digital Healthcare Services." In *Proceedings of the 30th European Conference on Information Systems (ECIS)*. Timişoara, Romania.

Bloom, D., and D. Canning. 2008. "Global Demographic Change: Dimensions and Economic Significance." *Population and Development Review* 34:17–51.

Bochkovskiy, A., C. Y. Wang, and H. Y. M. Liao. 2020. Yolov4: Optimal speed and accuracy of object detection. *arXiv:2004.10934*.

Böhmer, M., J. Damarowsky, S. Kühnel, S. Parschat, and V. A. Mahn. 2022, July. "Preserve Autonomy–Developing and Implementing a Design Theory for Augmented Living Spaces." In *Pacific Asia Conference on Information Systems*, 6–9. Sydney, Taiwan.

Böhmer, M., J. Kendziorra, and S. Kuehnel. 2024. "A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Cognitive Impairments." In *Proceedings of ECIS 2024*. Paphos, Cyprus, Paper 2030.

Bozinovski, S., and A. Fulgosi. 1976. "The Influence of Pattern Similarity and Transfer of Learning upon Training of a Base Perceptron B2." In *Proceedings of Symposium Informatica*, vol. 121–126.

Chen, H., and S. E. Levkoff. 2015. "Delivering Telemonitoring Care to Digitally Disadvantaged Older Adults: Human-Computer Interaction (HCI) Design Recommendations." In *Human Aspects of IT for the Aged Population. Design for Everyday Life. ITAP 2015*, edited by J. Zhou, and G. Salvendy. Lecture Notes in Computer Science. vol. 9194. Cham: Springer. https://doi.org/10.1007/978-3-319-20913-5_5.

Chen, R. J., M. Y. Lu, T. Y. Chen, D. F. Williamson, and F. Mahmood. 2021. "Synthetic Data in Machine Learning for Medicine and Healthcare." *Nature Biomedical*

Engineering 5 (6): 493–497. https://doi.org/10.1038/s41551-021-00751-8.

Chhetri, C., and V. Genaro Motti. 2022. "User-Centric Privacy Controls for Smart Homes." *Proceedings of the ACM on Human-Computer Interaction* 6 (CSCW2): 1–36. https://doi.org/10.1145/3555769.

Chignell, M., L. Wang, A. Zare, and J. Li. 2023. "The Evolution of HCI and Human Factors: Integrating Human and Artificial Intelligence." *ACM Transactions on Computer-Human Interaction* 30 (2): 1–30. https://doi.org/10.1145/3557891.

Colantonio, S., G. Coppini, D. Giorgi, M. A. Morales, and M. A. Pascali. 2018. "Computer Vision for Ambient Assisted Living: Monitoring Systems for Personalized Healthcare and Wellness That are Robust in the Real World and Accepted by Users, Carers, and Society." In *Computer Vision for Assistive Healthcare*, edited by M. Leo and G. M. Farinella, 147–182. Academic Press.

Dhiman, H., C. Wächter, M. Fellmann, and Carsten Röcker. 2022. "Intelligent Assistants." *Business & Information Systems Engineering* 64 (5): 645–665. https://doi.org/10.1007/s12599-022-00743-1.

Dickinson, A., J. Arnott, and S. Prior. 2007. "Methods for Human–Computer Interaction Research with Older People." *Behaviour & Information Technology* 26 (4): 343–352. https://doi.org/10.1080/01449290601176948.

Duan, Z., O. Tezcan, H. Nakamura, P. Ishwar, and J. Konrad. 2020. "Rapid: Rotation-Aware People Detection in Overhead Fisheye Images." In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2020*, 636–637.

Flicker, C., S. H. Ferris, and B. Reisberg. 1991. "Mild Cognitive Impairment in the Elderly: Predictors of Dementia." *Neurology* 41 (7): 1006–1006. https://doi.org/10.1212/WNL.41.7.1006.

Fornell, C., and D. F. Larcker. 1981. "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error." *Journal of Marketing Research* 18 (1): 39–50. https://doi.org/10.1177/002224378101800104.

Friedman, B., P. H. Kahn, A. Borning, and A. Huldtgren. 2013. "Value Sensitive Design and Information Systems. Early Engagement and New Technologies." In *Early Engagement and New Technologies: Opening up the Laboratory. Philosophy of Engineering and Technology*, edited by N. Doorn, D. Schuurbiers, I. van de Poel, and M. Gorman, vol. 16, 55-95. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-7844-3_4.

Gao, Y. 2019. "Cognitive Guidance and Improvement of Alzheimer's Disease Patients Based on Human-Computer Interaction Design." *Cognitive Systems Research* 56:192–202. https://doi.org/10.1016/j.cogsys.2018.12.006.

Gauthier, S., Barry Reisberg, Michael Zaudig, Ronald C Petersen, Karen Ritchie, Karl Broich, Sylvie Belleville, et al. 2006. "Mild Cognitive Impairment." *The Lancet* 367 (9518): 1262–1270. https://doi.org/10.1016/S0140-6736(06)68542-5.

Gioia, D., K. Corley, and A. Hamilton. 2013. "Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology." *Organizational Research Methods* 16 (1): 15–31. https://doi.org/10.1177/1094428112452151.

Gonzales, A., G. Guruswamy, and S. R. Smith. 2023. "Synthetic Data in Health Care: A Narrative Review." *PLOS Digital Health* 2 (1): e0000082. https://doi.org/10.1371/journal.pdig.0000082.

Greenaway, M. C., S. M. Hanna, S. W. Lepore, and G. E. Smith. 2008. "A Behavioral Rehabilitation Intervention for Amnestic Mild Cognitive Impairment." *American Journal of Alzheimer's Disease & Other Dementias* 23 (5): 451–461. https://doi.org/10.1177/1533317508320352.

Griebel, M., A. Dürr, and N. Stein. 2019. "Applied Image Recognition: Guidelines for Using Deep Learning Models in Practice." In *Proceedings of Wirtschaftsinformatik 2019*. Universität Siegen.

Gu, J., D. Li, Z. Li, Y. Guo, F. Qian, Y. Wang, and L. Tang. 2022. "The Effect and Mechanism of Transcranial Direct Current Stimulation on Episodic Memory in Patients with Mild Cognitive Impairment." *Frontiers in Neuroscience* 16: 811403.

Herzog, N. J., and G. D. Magoulas. 2021. "Deep Learning of Brain Asymmetry Images and Transfer Learning for Early Diagnosis of Dementia." In *Proceedings of the 22nd Engineering Applications of Neural Networks Conference. EANN 2021. Proceedings of the International Neural Networks Society*, edited by L. Iliadis, J. Macintyre, C. Jayne, and E. Pimenidis, vol. 3, 57-70. Cham: Springer. https://doi.org/10.1007/978-3-030-80568-5_5.

Hinterstoisser, S., O. Pauly, H. Heibel, M. Martina, and M. Bokeloh. 2019. "An Annotation Saved is an Annotation Earned: Using Fully Synthetic Training for Object Detection." In *Proceedings of the IEEE/CVF 2019*.

Hulland, J. 1999. "Use of Partial Least Squares (PLS) in Strategic Management Research: A Review of Four Recent Studies." *Strategic Management Journal* 20 (2): 195–204. https://doi.org/10.1002/(SICI)1097-0266(199902)20:2<195::AID-SMJ13>3.0.CO;2-7.

Hwang, W., and G. Salvendy. 2010. "Number of People Required for Usability Evaluation: The 10±2 Rule." *Communications of the ACM* 53 (5): 130–133. https://doi.org/10.1145/1735223.1735255.

Ienca, M., C. Schneble, R. W. Kressig, and T. Wangmo. 2021. "Digital Health Interventions for Healthy Ageing: A Qualitative User Evaluation and Ethical Assessment." *BMC Geriatrics* 21 (1): 1–10. https://doi.org/10.1186/s12877-021-02338-z.

Iversen, T. R., and S. G. Joshi. 2015. "Exploring Spatial Interaction in Assistive Technology Through Prototyping." *Procedia Manufacturing* 3:158–165. https://doi.org/10.1016/j.promfg.2015.07.121.

Jamieson, S. 2004. "Likert Scales: How to (ab)use Them." *Medical Education* 38 (12): 1217–1218. https://doi.org/10.1111/j.1365-2929.2004.02012.x.

Jean, L., MÈ Bergeron, S. Thivierge, and M. Simard. 2010. "Cognitive Intervention Programs for Individuals with Mild Cognitive Impairment: Systematic Review of the Literature." *The American Journal of Geriatric Psychiatry* 18 (4): 281–296. https://doi.org/10.1097/JGP.0b013e3181c37ce9.

Jongsiriyanyong, S., and P. Limpawattana. 2018. "Mild Cognitive Impairment in Clinical Practice: A Review Article." *American Journal of Alzheimer's Disease & Other Dementias* 33 (8): 500–507. https://doi.org/10.1177/1533317518791401.

Julious, S. A. 2005. "Sample Size of 12 per Group Rule of Thumb for a Pilot Study." *Pharmaceutical Statistics: The*

Journal of Applied Statistics in the Pharmaceutical Industry 4 (4): 287–291.

Kim, O., Y. Pang, and J. H. Kim. 2019. "The Effectiveness of Virtual Reality for People with Mild Cognitive Impairment or Dementia: A Meta-Analysis." *BMC Psychiatry* 19 (1): 1–10. https://doi.org/10.1186/s12888-018-1996-0.

Kriglstein, S., M. Leitner, S. Kabicher-Fuchs, and S. Rinderle-Ma. 2016. "Evaluation Methods in Process-Aware Information Systems Research with a Perspective on Human Orientation." *Business & Information Systems Engineering* 58 (6): 397–414. https://doi.org/10.1007/s12599-016-0427-3.

Krump, M., M. Ruß, and P. Stütz. 2020. "Deep Learning Algorithms for Vehicle Detection on UAV Platforms: First Investigations on the Effects of Synthetic Training." In *Modelling and Simulation for Autonomous Systems. MESAS 2019*, edited by J. Mazal, A. Fagiolini, and P. Vasik, vol. 11995, 50–70. Lecture Notes in Computer Science. Cham: Springer. https://doi.org/10.1007/978-3-030-43890-6_5.

Kucharski, A., and A. Fabijańska. 2023. "Corneal Endothelial Image Segmentation Training Data Generation Using GANs. Do Experts Need to Annotate?" *Biomedical Signal Processing and Control* 85:104985. https://doi.org/10.1016/j.bspc.2023.104985.

Kuehnel, S., U. Neuhaus, J. Kaufmann, M. Schulz, and E. M. Alekozai. 2023. "Using the Data Science Process Model Version 1.1 (DASC-PM v1.1) for Executing Data Science Projects: Procedures, Competencies, and Roles." In *Apply Data Science*, edited by T. Barton, and C. Müller, 119–134. Wiesbaden: Springer Vieweg. https://doi.org/10.1007/978-3-658-38798-3_8.

Lahiri, A., A. Agarwalla, and P. K. Biswas. 2018. "Unsupervised Domain Adaptation for Learning eye Gaze from a Million Synthetic Images: An Adversarial Approach." In *Proceedings of the 11th Indian Conference on Computer Vision, Graphics and Image Processing*, 1–9.

Lee, C. H., C. Wang, X. Fan, F. Li, and C. H. Chen. 2023. "Artificial Intelligence-Enabled Digital Transformation in Elderly Healthcare Field: Scoping Review." *Advanced Engineering Informatics* 55:101874. https://doi.org/10.1016/j.aei.2023.101874.

Lin, T. Y., M. Maire, S. Belongie, J. Hays, P. Perona, D. Ramanan, P. Dollár, and C. L. Zitnick. 2014. "Microsoft Coco: Common Objects in Context." In *Computer Vision – ECCV 2014. ECCV 2014*, edited by D. Fleet, T. Pajdla, B. Schiele, and T. Tuytelaars, vol. 8693, 740–755. Lecture Notes in Computer Science. Cham: Springer. https://doi.org/10.1007/978-3-319-10602-1_48

Maedche, A., C. Legner, A. Benlian, Benedikt Berger, Henner Gimpel, Thomas Hess, Oliver Hinz, Stefan Morana, Matthias Söllner, et al. 2019. "AI-Based Digital Assistants." *Business Information Systems and Engineering* 61 (4): 535–544. https://doi.org/10.1007/s12599-019-00600-8.

Mallas, A., M. Xenos, and C. Katsanos. 2022. "A Descriptive Model of Passive and Natural Passive Human-Computer Interaction. Human-Computer Interaction: Theoretical Approaches and Design Methods." In *Human-Computer Interaction. Theoretical Approaches and Design Methods. HCII 2022.*, edited by M. Kurosu, vol. 13302, 104–116. *Lecture Notes in Computer Science*. Cham: Springer. https://doi.org/10.1007/978-3-031-05311-5_7.

Manenti, R., M. Sandrini, E. Gobbi, G. Binetti, and M. Cotelli. 2020. "Effects of Transcranial Direct Current Stimulation on Episodic Memory in Amnestic Mild Cognitive Impairment: A Pilot Study." *The Journals of Gerontology: Series B* 75 (7): 1403–1413. https://doi.org/10.1093/geronb/gby134.

Margrett, J. A., K. M. Ouverson, S. B. Gilbert, L. A. Phillips, and N. Charness. 2022. "Older Adults' use of Extended Reality: A Systematic Review." *Frontiers in Virtual Reality* 2:760064. https://doi.org/10.3389/frvir.2021.760064.

Mathews, S. C., M. J. McShea, C. L. Hanley, Alan Ravitz, Alain B. Labrique, and Adam B. Cohen. 2019. "Digital Health: A Path to Validation." *npj Digitial Medicine* 2 (38). https://doi.org/10.1038/s41746-019-0111-3.

Mavropoulos, T., S. Symeonidis, Athina Tsanousa, Panagiotis Giannakeris, Maria Rousi, Eleni Kamateri, Georgios Meditskos, Konstantinos Ioannidis, Stefanos Vrochidis, Ioannis Kompatsiaris, et al. 2021. "Smart Integration of Sensors, Computer Vision and Knowledge Representation for Intelligent Monitoring and Verbal Human-Computer Interaction." *Journal of Intelligent Information Systems* 57 (2): 321–345. https://doi.org/10.1007/s10844-021-00648-7.

Migo, E. M., O. O'daly, M. Mitterschiffthaler, E. Antonova, G. R. Dawson, C. T. Dourish, K. J. Craig, et al. 2016. "Investigating Virtual Reality Navigation in Amnestic Mild Cognitive Impairment Using FMRI." *Aging, Neuropsychology, and Cognition* 23 (2): 196–217. https://doi.org/10.1080/13825585.2015.1073218.

Mingers, J., and J. Brocklesby. 1997. "Multimethodology: Towards a Framework for Mixing Methodologies." *Omega* 25 (5): 489–509. https://doi.org/10.1016/S0305-0483(97)00018-2.

Mousavi Hondori, H., M. Khademi, L. Dodakian, S. C. Cramer, and C. V. Lopes. 2013. "A Spatial Augmented Reality Rehab System for Post-Stroke Hand Rehabilitation." In *Medicine Meets Virtual Reality 20*, 279-285. IOS Press.

Nastjuk, I., S. Trang, J. V. Grummeck-Braamt, M. T. Adam, and M. Tarafdar. 2023. "Integrating and Synthesising Technostress Research: A Meta-Analysis on Technostress Creators, Outcomes, and IS Usage Contexts." *European Journal of Information Systems* 33 (3): 361–382. https://doi.org/10.1080/0960085X.2022.2154712.

Nunnally, J. C. 1978. *Psychometric Theory*. 2nd edition. New York, NY, USA: McGraw-Hill.

Petersen, R. C. 2016. "Mild Cognitive Impairment." *CONTINUUM: Lifelong Learning in Neurology* 22 (2 Dementia): 404–418. https://doi.org/10.1212/CON.0000000000000313.

Petersen, R. C., O. Lopez, M. J. Armstrong, T. S. D. Gechius, M. Ganguli, D. Gloss, and A. Rae-Grant. 2018. "Practice Guideline Update Summary: Mild Cognitive Impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology." *Neurology* 90 (3): 126–135. https://doi.org/10.1212/WNL.0000000000004826.

Petersen, R. C., R. O. Roberts, D. S. Knopman, Bradley F. Boeve, Yonas E. Geda, Robert J. Ivnik, Glenn E. Smith, and Clifford R. Jack. 2009. "Mild Cognitive Impairment: Ten Years Later." *Archives of Neurology* 66 (12): 1447–1455. https://doi.org/10.1001/archneurol.2009.266.

Prakash, A. V., and S. Das. 2020. "Intelligent Conversational Agents in Mental Healthcare Services: A Thematic Analysis of User Perceptions." *Pacific Asia Journal of the Association for Information Systems* 12 (2): 1–34. https://doi.org/10.17705/1thci.12201.

Preum, S. M., S. Munir, Meiyi Ma, Mohammad Samin Yasar, David J. Stone, Ronald Williams, Homa Alemzadeh, and John A. Stankovic. 2021. "A Review of Cognitive Assistants for Healthcare: Trends, Prospects, and Future Directions." *ACM Computing Surveys* 53 (6): 1–37. https://doi.org/10.1145/3419368.

Raskar, R., G. Welch, and H. Fuchs. 1998. "Spatially Augmented Reality." In *First International Workshop on Augmented Reality*. San Francisco.

Schak, M., R. Blum, and B. Bomsdorf. 2022. "Smart Home for the Elderly – A Survey of Desires, Needs, and Problems." In *Human Aspects of IT for the Aged Population. Technology in Everyday Living. HCII 2022,* edited by Q. Gao and J. Zhou, vol. 13331. Lecture Notes in Computer Science. Cham: Springer. https://doi.org/10.1007/978-3-031-05654-3_7.

Scheck, T., R. Seidel, and G. Hirtz. 2020. "Learning from Theodore: A Synthetic Omnidirectional top-View Indoor Dataset for Deep Transfer Learning." In *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision*, 943–952.

Schmidt, J., M. R. Marques, S. Botti, and M. A. Marques. 2019. "Recent Advances and Applications of Machine Learning in Solid-State Materials Science." *npj Computational Materials* 5 (1): 83. https://doi.org/10.1038/s41524-019-0221-0.

Seib, V., B. Lange, and S. Wirtz. 2020. Mixing Real and Synthetic Data to Enhance Neural Network Training – A Review of Current Approaches. *arXiv:2007.08781*.

Seifert, A., and A. Schlomann. 2021. "The use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges." *Frontiers in Virtual Reality* 2:51. https://doi.org/10.3389/frvir.2021.639718.

Siepmann, C., and P. Kowalczuk. 2021. "Understanding Continued Smartwatch Usage: The Role of Emotional as Well as Health and Fitness Factors." *Electronic Markets* 31 (4): 795–809. https://doi.org/10.1007/s12525-021-00458-3.

Spiekermann, S., H. Krasnova, O. Hinz, Annika Baumann, Alexander Benlian, Henner Gimpel, Irina Heimbach, et al. 2022. "Values and Ethics in Information Systems." *Business Information Systems and Engineering* 64 (2): 247–264. https://doi.org/10.1007/s12599-021-00734-8.

Steinert, S., and M. J. Dennis. 2022. "Emotions and Digital Well-Being: On Social Media's Emotional Affordances." *Philosophy & Technology* 35 (2): 36. https://doi.org/10.1007/s13347-022-00530-6.

Takahashi, R., T. Matsubara, and K. Uehara. 2018. "Ricap: Random Image Cropping and Patching Data Augmentation for Deep Cnns." In *Proceedings of the Asian Conference on Machine Learning 2018*, 786–798.

Taleb, C., L. Likforman-Sulem, and C. Mokbel. 2020. "Improving Deep Learning Parkinson's Disease Detection Through Data Augmentation Training." In *Pattern Recognition and Artificial Intelligence. MedPRAI 2019*, edited by C. Djeddi, A. Jamil, and I. Siddiqi, vol. 1144, 79–93. Communications in Computer and Information Science. Cham: Springer. https://doi.org/10.1007/978-3-030-37548-5_7.

Tezcan, O., Z. Duan, M. Cokbas, P. Ishwar, and J. Konrad. 2022. "WEPDTOF: A Dataset and Benchmark Algorithms for In-the-Wild People Detection and Tracking from Overhead Fisheye Cameras." In *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision 2022*, 503–512.

Tobin, J., R. Fong, A. Ray, J. Schneider, W. Zaremba, and P. Abbeel. 2017. "Domain Randomization for Transferring Deep Neural Networks from Simulation to the Real World." In *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 23–30. Vancouver, BC, Canada. https://doi.org/10.1109/IROS.2017.8202133.

Tremblay, J., A. Prakash, D. Acuna, M. Brophy, V. Jampani, C. Anil, T. To, E. Cameracci, S. Boochoon, and S. Birchfield. 2018. "Training Deep Networks with Synthetic Data: Bridging the Reality gap by Domain Randomization." In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, 969–977.

Valtchev, S. Z., and J. Wu. 2021. "Domain Randomization for Neural Network Classification." *Journal of Big Data* 8 (1): 94. https://doi.org/10.1186/s40537-021-00455-5.

Van Den Haak, M., M. De Jong, and P. Jan Schellens. 2003. "Retrospective vs. Concurrent Think-Aloud Protocols: Testing the Usability of an Online Library Catalogue." *Behaviour & Information Technology* 22 (5): 339–351. https://doi.org/10.1080/0044929031000.

Venkatesh, V., S. A. Brown, and H. Bala. 2013. "Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems." *MIS Quarterly* 37 (1): 21–54. https://doi.org/10.25300/MISQ/2013/37.1.02.

Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS Quarterly* 27 (3): 425–478. https://doi.org/10.2307/30036540.

Venkateswara, H., S. Chakraborty, and S. Panchanathan. 2017. "Deep-learning Systems for Domain Adaptation in Computer Vision: Learning Transferable Feature Representations." *IEEE Signal Processing Magazine* 34 (6): 117–129. https://doi.org/10.1109/MSP.2017.2740460.

Vines, J., G. Pritchard, P. Wright, P. Olivier, and K. Brittain. 2015. "An age-old Problem: Examining the Discourses of Ageing in HCI and Strategies for Future Research." *ACM Transactions on Computer-Human Interacion* 22 (1): 1–27. https://doi.org/10.1145/2696867.

Williams, P. A., J. L. Jenkins, and J. S. Valacich. 2016. "Real-Time Hand Tremor Detection via Mouse Cursor Movements for Improved Human-Computer Interactions: An Exploratory Study." In *SIGHCI 2016 Proceedings*. 10, https://aisel.aisnet.org/sighci2016/10.

Wilson, G., and D. J. Cook. 2020. "A Survey of Unsupervised Deep Domain Adaptation." *ACM Transactions on Intelligent Systems and Technology* 11 (5): 1–46. https://doi.org/10.1145/3400066.

Wutich, A., M. Beresford, and H. R. Bernard. 2024. "Sample Sizes for 10 Types of Qualitative Data Analysis: An Integrative Review, Empirical Guidance, and Next Steps." *International Journal of Qualitative Methods* 23. https://doi.org/10.1177/16094069241296206.

Yang, L., G. Hu, Y. Song, G. Li, and L. Xie. 2020. "Intelligent Video Analysis: A Pedestrian Trajectory Extraction Method for the Whole Indoor Space Without Blind Areas." *Computer Vision and Image Understanding* 196:102968. https://doi.org/10.1016/j.cviu.2020.102968.

Yang, Y., Y. J. Park, H. Ro, S. Chae, and T. D. Han. 2018. CARe-bot: Portable Projection-based AR Robot for Elderly, *Companion of HRI 2018*.

Yu, J., C. L. Lam, and T. M. Lee. 2017. "White Matter Microstructural Abnormalities in Amnestic Mild Cognitive Impairment: A Meta-Analysis of Whole-Brain and ROI-Based Studies." *Neuroscience & Biobehavioral Reviews* 83:405–416. https://doi.org/10.1016/j.neubiorev.2017.10.026.

Yu, J., R. Seidel, and G. Hirtz. 2019. "Omnipd: One-Step Person Detection in top-View Omnidirectional Indoor Scenes." *Current Directions in Biomedical Engineering* 5 (1): 239–244. https://doi.org/10.1515/cdbme-2019-0061.

Zoccarato, F., M. Manzoni, D. Minotti, E. Lettieri, and A. Boaretto. 2024. "Unveiling the Interplay Between Rational, Psychological and Functional Factors in Continuous Glucose Monitoring Early Adoption: Novel Evidence from the Dexcom ONE Case in Italy." *BMC Health Services Research* 24 (1): 747. https://doi.org/10.1186/s12913-024-11195-6.

Zorin, D., and A. H. Barr. 1995. "Correction of Geometric Perceptual Distortions in Pictures." In *Proceedings of the 22nd Annual Conference on Computer Graphics and Interactive Techniques*, 257–264.

Appendix G

The following questionnaire was used to evaluate the ConZones interaction design summatively in the second design cycle (i.e., Chapter 4.4.1). This appendix also includes the detailed results of the conducted questionnaire.

Fragebogen ALiS

1. Aussagen zur Leistungserwartung und Aufwandserwartung der Interaktion in einem Augmented Living Space

Bitte bewerten Sie die Leistungserwartung und die Aufwandserwartung der Interaktion in einem Augmented Living Spaces, indem Sie auf den verbal-numerischen Skalen angeben, inwieweit Sie den Aussagen (INT 1 – INT 8) zustimmen oder nicht zustimmen können.

	Aussagen	Starke Ablehnung			Teilweise Zustimmung		Starke Zustimmung	Keine Angabe
INT 1	Ich würde das ALiS-System in meinem Alltag nützlich finden (bspw. bei bewältigen von Herausforderungen oder Gefahren).	☐	☐	☐	☐	☐	☐	☐
INT 2	Die Anwendung des ALiS-Systems ermöglicht es mir, Alltagsaufgaben schneller zu erledigen (bspw. beim Kochen).	☐	☐	☐	☐	☐	☐	☐
INT 3	Die Anwendung des ALiS-Systems könnte meine Produktivität im Alltag erhöhen (bspw. Aufgaben-bewältigung und Aktivitäten).	☐	☐	☐	☐	☐	☐	☐
INT 4	Wenn ich das ALiS-System nutze, erhöhe ich meine Chancen auf vergünstigte oder kostenlose Krankenkassenleistungen (bspw. Vorsorgeuntersuchungen, Prämien oder Massagen).	☐	☐	☐	☐	☐	☐	☐
INT 5	Meine Interaktion mit dem ALiS-System ist klar und verständlich (bspw. die Kommunikation und Nutzung des Systems).	☐	☐	☐	☐	☐	☐	☐
INT 6	Es wäre einfach für mich, das ALiS-System im Alltag gekonnt anzuwenden (bspw. in der Gefahrenerkennung).	☐	☐	☐	☐	☐	☐	☐
INT 7	Ich finde das ALiS-System einfach und intuitiv zu benutzen (bspw. für Alltagsaktivitäten).	☐	☐	☐	☐	☐	☐	☐
INT 8	Die Bedienung des ALiS-Systems fällt mir leicht (bspw. die Interaktion und indirekte Bedienbarkeit).	☐	☐	☐	☐	☐	☐	☐

2. Soziodemografische Daten

Für die Datenanalyse benötigen wir noch ein paar wenige soziodemografische Daten. Diese werden anonymisiert verarbeitet und lassen dementsprechend keine Rückschlüsse auf die Person zu.

SD 1) Welcher Altersgruppe können Sie zugeordnet werden?

- ☐ Jünger als 40 Jahre
- ☐ 40-50 Jahre
- ☐ 50-60 Jahre
- ☐ 60-70 Jahre
- ☐ 70-80 Jahre
- ☐ Älter als 80 Jahre

SD 2) Welches Geschlecht haben Sie?

- ☐ männlich
- ☐ weiblich
- ☐ divers
- ☐ Keine Angabe

SD 3) In welchem Beruf arbeiten Sie oder haben Sie gearbeitet?

_____

SD 4) Welcher Kategorie kann ihr monatliches Einkommen zugeordnet werden?

- ☐ < 1.000€
- ☐ 1.000€ – 1.500€
- ☐ 1.500€ - 2.500€
- ☐ > 2.500€

SD 5) Geben Sie hier bei Bedarf gern weitere Kommentare zum ALiS-System, Projekt o.ä.:

Vielen Dank für Ihre Teilnahme!

3. Ergebnisse Senioren

		ConZones Interaction Design										Socialdemographic Data		
	Person	INT 1 PE1	INT 2 PE2	INT 3 PE3	INT 4 PE4	INT 5 EE1	INT 6 EE2	INT 7 EE3	INT 8 EE4	SUM PE	SUM EE	SD1	SD2	SD3
Questionnaires	Subject 1	7	7	7	6	7	7	7	7	27	28	Senior	>80	m
	Subject 2	7	7	6	4	6	7	7	7	24	27	Senior	60-70	m
	Subject 3	4	4	4	5	4	4	4	4	17	16	Senior	60-70	w
	Subject 4	7	7	7	6	7	7	7	7	27	28	Senior	70-80	w
	Subject 5	6	5	6	3	5	5	5	7	20	22	Senior	70-80	w
	Subject 6	4	4	4	3	4	7	4	7	15	22	Senior	70-80	w
	Subject 7	4	6	4	4	7	2	6	6	18	21	Senior	>80	w
	Subject 8	7	6	7	7	6	7	6	6	27	25	Senior	60-70	m
	Subject 9	6	6	6	4	6	5	6	6	22	23	Senior	70-80	w
	Subject 10	4	6	7	4	7	7	7	7	21	28	Senior	60-70	w
	Subject 11	7	7	7	5	6	7	7	7	26	27	Senior	70-80	m
	Subject 12	3	4	3	5	6	7	7	7	15	27	Senior	70-80	m

4. Ergebnisse Expert*innen

		ConZones Interaction Design										Socialdemographic Data		
	Person	INT 1 PE1	INT 2 PE2	INT 3 PE3	INT 4 PE4	INT 5 EE1	INT 6 EE2	INT 7 EE3	INT 8 EE4	SUM PE	SUM EE	SD1	SD2	SD3
Questionnaires	Subject 1	7	7	7	6	7	7	6	7	27	27	Senior Researcher	12	m
	Subject 2	7	7	6	4	5	4	4	4	24	17	Professor	24	m
	Subject 3	6	7	7	5	7	7	6	6	25	26	HCI Professor	13	w
	Subject 4	7	7	7	4	5	5	6	4	25	20	HCI system engineer	6	w
	Subject 5	6	7	7	6	5	4	6	7	26	22	Researcher	4	w
	Subject 6	7	5	6	5	5	7	7	6	23	25	Software Developer	7	w
	Subject 7	7	6	6	4	7	6	6	7	23	26	AI engineer	5	w
	Subject 8	7	7	7	5	6	7	7	7	26	27	AI engineer	9	m
	Subject 9	6	7	6	4	5	6	6	7	23	24	IS Professor	16	w
	Subject 10	6	5	7	5	7	7	6	6	23	26	Project Lead Innovative Healthcare Solutions	6	w
	Subject 11	7	7	7	6	6	5	7	7	27	25	Project Lead Innovative Healthcare Solutions	7	m
	Subject 12	7	7	6	4	6	7	6	7	24	26	Researcher	2	w
	Subject 13	6	5	6	5	7	6	7	7	22	27	Researcher	7	m
	Subject 14	4	4	4	3	4	3	5	4	15	16	Project Lead Innovative Healthcare Solutions	5	m

Appendix H

Deep learning model evaluation results for model training and validation.

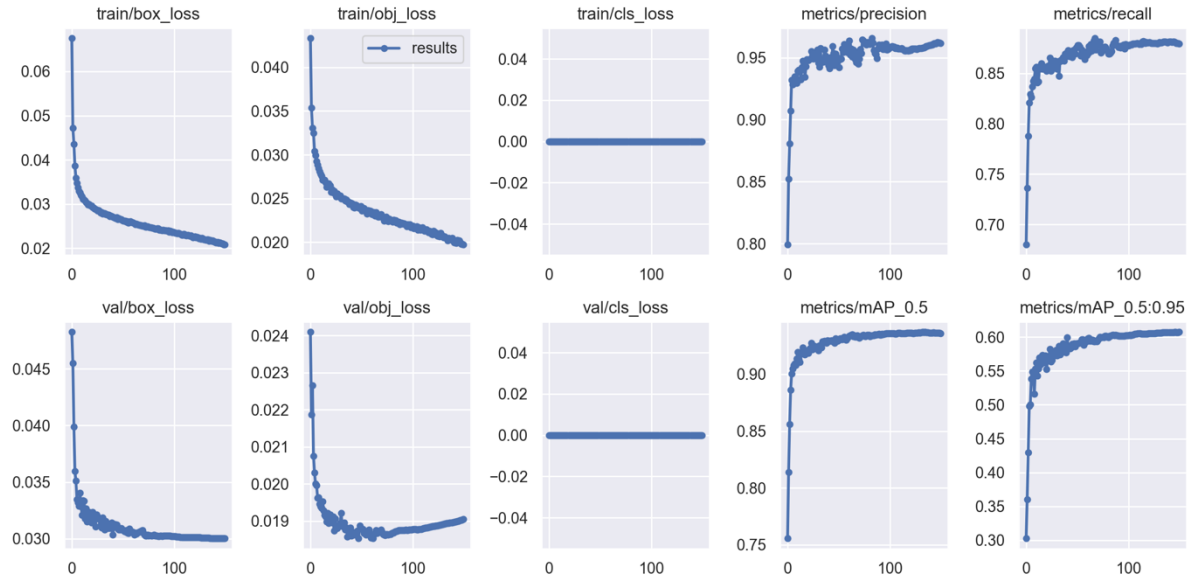
Note: Given the size of the dataset and a potentially unnecessary bloating of the appendix, the author can provide the synthetic image dataset and the code for the deep learning model upon request.

results

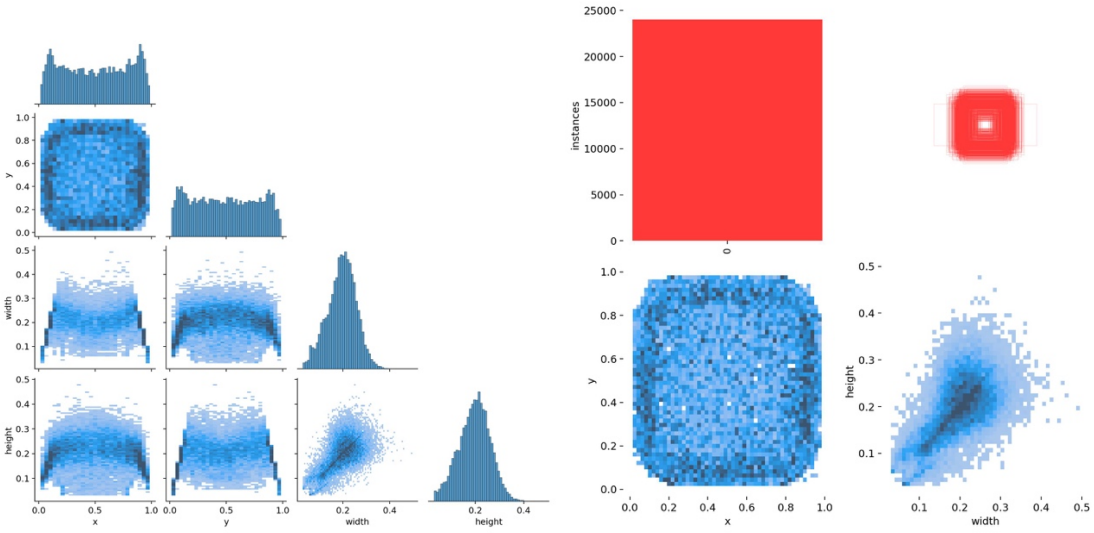
epoch	train/box_loss	train/obj_loss	train/cls_loss	metrics/precision	metrics/recall	metrics/mAP_0.5	metrics/mAP_0.5:0.95	val/box_loss	val/obj_loss	val/cls_loss	x/lr0	x/lr1	x/lr2
0	0.067483	0.043315	0	0.79917	0.67999	0.75566	0.30284	0.04826	0.024094	0	0.065602	0.0033227	0.0033227
1	0.047248	0.035367	0	0.85234	0.73615	0.81392	0.36043	0.045519	0.021868	0	0.037806	0.0066167	0.0066167
2	0.043582	0.033065	0	0.88072	0.78791	0.85619	0.42928	0.039865	0.022657	0	0.0099706	0.0098713	0.0098713
3	0.038629	0.032496	0	0.9072	0.82104	0.8864	0.4977	0.035946	0.020755	0	0.0098227	0.0098227	0.0098227
4	0.035934	0.03042	0	0.9319	0.82945	0.90056	0.5001	0.035096	0.020301	0	0.0098227	0.0098227	0.0098227
5	0.034715	0.029955	0	0.92817	0.82614	0.90504	0.53835	0.033456	0.019996	0	0.0097636	0.0097636	0.0097636
6	0.033724	0.029267	0	0.93007	0.83662	0.90793	0.54851	0.03318	0.01996	0	0.0097045	0.0097045	0.0097045
7	0.032917	0.028826	0	0.93482	0.84213	0.90916	0.54202	0.032875	0.019621	0	0.0096454	0.0096454	0.0096454
8	0.032568	0.028454	0	0.93341	0.84455	0.90786	0.51625	0.034035	0.019631	0	0.0095863	0.0095863	0.0095863
9	0.032001	0.028086	0	0.92953	0.85469	0.91389	0.55336	0.032828	0.019459	0	0.0095272	0.0095272	0.0095272
10	0.031635	0.027821	0	0.93916	0.8562	0.91944	0.56169	0.032075	0.019383	0	0.0094681	0.0094681	0.0094681
11	0.031174	0.027591	0	0.94018	0.84084	0.91349	0.54265	0.033372	0.019352	0	0.009409	0.009409	0.009409
12	0.030988	0.027106	0	0.93868	842	0.91053	0.55315	0.03331	0.01952	0	0.00935	0.00935	0.00935
13	0.030793	0.027092	0	0.93252	0.85441	0.91758	0.56959	0.031788	0.01928	0	0.0092909	0.0092909	0.0092909
14	0.030405	0.02711	0	0.94194	0.85758	0.91966	0.55872	0.032639	0.019154	0	0.0092318	0.0092318	0.0092318
15	0.030221	0.026812	0	0.94741	0.85992	0.92331	0.56926	0.031483	0.019111	0	0.0091727	0.0091727	0.0091727
16	0.029854	0.026309	0	0.9454	0.85459	0.92114	0.57295	0.031815	0.018981	0	0.0091136	0.0091136	0.0091136
17	0.029973	0.026521	0	0.93445	0.85697	0.91719	0.56177	0.032342	0.019211	0	0.0090545	0.0090545	0.0090545
18	0.029629	0.026734	0	0.94286	0.85543	0.9191	0.56886	0.031789	0.018937	0	0.0089954	0.0089954	0.0089954
19	0.029674	0.026474	0	0.94856	0.85385	0.92031	0.57244	0.031388	0.019172	0	0.0089363	0.0089363	0.0089363
20	0.029284	0.025712	0	0.94774	0.85247	0.9186	0.55254	0.032361	0.01902	0	0.0088772	0.0088772	0.0088772
21	0.029161	0.026022	0	0.94876	0.85716	0.92205	0.56925	0.031862	0.018953	0	0.0088181	0.0088181	0.0088181
22	0.028932	0.02567	0	0.94887	0.85523	0.92297	0.56495	0.031927	0.019117	0	0.008759	0.008759	0.008759
23	0.028888	0.025833	0	0.95494	0.86557	0.92732	0.58206	0.031072	0.018741	0	0.0086999	0.0086999	0.0086999
24	0.028704	0.025514	0	0.95079	0.85245	0.92181	0.56347	0.032134	0.019067	0	0.0086408	0.0086408	0.0086408
25	0.028508	0.025241	0	0.94904	0.86269	0.92448	0.56577	0.031966	0.01885	0	0.0085817	0.0085817	0.0085817
26	0.028607	0.025573	0	0.95212	0.86089	0.92474	0.57288	0.031787	0.01881	0	0.0085226	0.0085226	0.0085226
27	0.02838	0.025413	0	0.95092	0.85537	0.92285	0.57273	0.031696	0.01888	0	0.0084635	0.0084635	0.0084635
28	0.028065	0.025193	0	0.9519	0.86231	0.92354	0.57785	0.031169	0.018861	0	0.0084044	0.0084044	0.0084044
29	0.028111	0.025329	0	0.95619	0.86006	0.92427	0.58048	0.030979	0.018946	0	0.0083453	0.0083453	0.0083453
30	0.027844	0.024969	0	0.94568	0.85455	0.92095	0.57274	0.031865	0.019214	0	0.0082862	0.0082862	0.0082862
31	0.027897	0.024955	0	0.94256	0.86199	0.92543	0.57686	0.031257	0.018877	0	0.0082271	0.0082271	0.0082271
32	0.027919	0.02501	0	0.9576	0.8471	0.92526	0.58695	0.03079	0.018839	0	0.008168	0.008168	0.008168
33	0.027644	0.025011	0	0.94625	0.86174	0.92371	0.57391	0.031531	0.018948	0	0.0081089	0.0081089	0.0081089
34	0.027641	0.024775	0	0.94692	0.86325	0.92865	0.57619	0.031358	0.018756	0	0.0080499	0.0080499	0.0080499
35	0.027582	0.024879	0	0.94636	0.86392	0.92836	0.57882	0.031256	0.018815	0	0.0079908	0.0079908	0.0079908
36	0.027525	0.024664	0	0.95619	0.86571	0.92914	0.59051	0.030927	0.01857	0	0.0079317	0.0079317	0.0079317
37	0.027273	0.024618	0	0.95137	0.86226	0.92845	0.5837	0.031081	0.018779	0	0.0078726	0.0078726	0.0078726
38	0.027329	0.024327	0	0.94999	0.86951	0.9275	0.58566	0.030924	0.018698	0	0.0078135	0.0078135	0.0078135
39	0.027247	0.024515	0	0.94891	0.86695	0.9298	0.57718	0.031416	0.018818	0	0.0077544	0.0077544	0.0077544
40	0.027089	0.024459	0	0.94381	0.8707	0.92905	0.59918	0.030331	0.018606	0	0.0076953	0.0076953	0.0076953
41	0.026991	0.024434	0	0.94141	0.87274	0.92919	0.58537	0.031063	0.018667	0	0.0076362	0.0076362	0.0076362
42	0.026857	0.023987	0	0.95041	0.86667	0.92949	0.58461	0.031292	0.0187	0	0.0075771	0.0075771	0.0075771
43	0.0268	0.02396	0	0.94625	0.87109	0.92979	0.58318	0.031248	0.018626	0	0.007518	0.007518	0.007518
44	0.026966	0.024286	0	0.95898	0.86712	0.92943	0.58435	0.031217	0.01866	0	0.0074589	0.0074589	0.0074589
45	0.026539	0.024218	0	0.9534	0.86602	0.92818	0.58948	0.030854	0.018714	0	0.0073998	0.0073998	0.0073998
46	0.026785	0.024086	0	0.94361	0.87288	0.92732	0.58578	0.030797	0.018729	0	0.0073407	0.0073407	0.0073407
47	0.026601	0.023929	0	0.95292	0.87316	0.9313	0.59026	0.030791	0.018534	0	0.0072816	0.0072816	0.0072816
48	0.026521	0.023899	0	0.95059	0.86916	0.92994	0.58551	0.030911	0.018876	0	0.0072225	0.0072225	0.0072225
49	0.02632	0.024111	0	0.94852	0.87522	0.92927	0.59028	0.030797	0.018792	0	0.0071634	0.0071634	0.0071634
50	0.026208	0.023581	0	0.94196	0.87771	0.93026	0.5904	0.030721	0.018796	0	0.0071043	0.0071043	0.0071043
51	0.026213	0.023874	0	0.94846	0.87782	0.93155	591	0.030666	0.018773	0	0.0070452	0.0070452	0.0070452
52	0.026251	0.02386	0	0.94888	0.87633	0.93159	0.59086	0.030614	0.01867	0	0.0069861	0.0069861	0.0069861
53	0.025992	0.023701	0	0.95701	0.86723	0.93076	0.59294	0.030742	0.018705	0	0.006927	0.006927	0.006927
54	0.026069	0.023562	0	0.95444	0.87357	0.93174	0.59616	0.030514	0.018621	0	0.0068679	0.0068679	0.0068679
55	0.025799	0.02326	0	0.96098	0.86819	0.93267	0.59597	0.030489	0.018662	0	0.0068089	0.0068089	0.0068089
56	0.02602	0.023681	0	0.9569	0.8663	0.93048	0.58844	0.030866	0.018729	0	0.0067498	0.0067498	0.0067498
57	0.026052	0.0235	0	0.96037	0.86392	0.93014	0.59422	0.030622	0.01876	0	0.0066907	0.0066907	0.0066907
58	0.025868	0.023589	0	0.95439	0.87131	0.93147	0.59235	0.030592	0.01866	0	0.0066316	0.0066316	0.0066316
59	0.025824	0.023529	0	0.96033	0.86782	0.93286	0.59576	0.030603	0.018547	0	0.0065725	0.0065725	0.0065725
60	0.025783	0.023182	0	0.96358	0.86916	0.93379	0.59786	0.030454	0.018563	0	0.0065134	0.0065134	0.0065134
61	0.025692	0.0232	0	0.95216	0.87702	0.93432	0.59874	0.030331	0.018529	0	0.0064543	0.0064543	0.0064543
62	0.025442	0.023443	0	0.95722	0.8715	0.93481	0.59425	0.030511	0.018643	0	0.0063952	0.0063952	0.0063952
63	0.025523	0.023048	0	0.95073	0.87881	0.93496	0.59599	0.030428	0.018661	0	0.0063361	0.0063361	0.0063361
64	0.025366	0.023439	0	0.95619	0.87261	0.93341	0.59401	0.030532	0.018744	0	0.006277	0.006277	0.006277
65	0.025321	0.023152	0	0.95428	0.87477	0.93426	0.59568	0.030541	0.018667	0	0.0062179	0.0062179	0.0062179
66	0.025349	0.022933	0	0.94854	0.88253	0.93299	0.59353	0.030589	0.018691	0	0.0061588	0.0061588	0.0061588
67	0.025199	0.022908	0	0.94632	0.88476	0.93368	0.59351	0.030638	0.0187	0	0.0060997	0.0060997	0.0060997
68	0.025228	0.023053	0	0.95485	0.87316	0.93395	0.59428	0.030684	0.018734	0	0.0060406	0.0060406	0.0060406
69	0.025016	0.023223	0	0.94505	0.88211	0.93241	0.59314	0.030721	0.018758	0	0.0059815	0.0059815	0.0059815
70	0.02507	0.022895	0	0.94881	0.87901	0.93209	0.59527	0.030484	0.018694	0	0.0059224	0.0059224	0.0059224
71	0.025222	0.022811	0	0.95673	0.87826	0.93329	0.59754	0.03036	0.018644	0	0.0058633	0.0058633	0.0058633
72	0.024835	0.022462	0	0.95361	0.88134	0.9333	0.59978	0.030269	0.01863	0	0.0058042	0.0058042	0.0058042
73	0.02487	0.022685	0	0.96441	0.8704	0.93428	0.59927	0.030241	0.018609	0	0.0057451	0.0057451	0.0057451
74	0.024989	0.022922	0	0.96353	0.87205	0.93471	0.59912	0.030329	0.018636	0	0.005686	0.005686	0.005686
75	0.024862	0.022705	0	0.96179	0.87578	0.93384	0.59995	0.030252	0.018635	0	0.0056269	0.0056269	0.0056269
76	0.024742	0.022392	0	0.96238	0.87371	0.9334	0.59911	0.030316	0.018626	0	0.0055679	0.0055679	0.0055679
77	0.024707	0.022656	0	0.96035	0.87619	0.93416	0.60123	0.030244	0.018635	0	0.0055088	0.0055088	0.0055088
78	0.024624	0.022581	0	0.96238	0.87476	0.93479	0.60119	0.030252	0.018646	0	0.0054497	0.0054497	0.0054497
79	0.024651	0.022491	0	0.96139	0.87302	0.93479	0.60017	0.030289	0.018661	0	0.0053906	0.0053906	0.0053906
80	0.024548	0.022322	0	0.96084	0.86916	0.93307	0.59932	0.030322	0.018686	0	0.0053315	0.0053315	0.0053315
81	0.024385	0.022539	0	963	0.86943	0.9337	0.60114	0.030229	0.018678	0	0.0052724	0.0052724	0.0052724
82	0.024439	0.022452	0	0.96558	0.87019	0.93433	0.6013	0.030228	0.018702	0	0.0052133	0.0052133	0.0052133
83	0.02446	0.022477	0	0.96197	0.87184	0.93398	0.6021	0.030238	0.018719	0	0.0051542	0.0051542	0.0051542
84	0.024467	0.022198	0	0.95583	0.87719	0.93413	0.60281	0.03022	0.018725	0	0.0050951	0.0050951	0.0050951
85	0.024167	0.022248	0	0.95362	0.87991	0.93483	0.60265	0.030218	0.018737	0	0.005036	0.005036	0.005036
86	0.024173	0.022334	0	0.95253	0.88074	0.93466	0.60224	0.030252	0.018753	0	0.0049769	0.0049769	0.0049769
87	0.024133	0.022053	0	0.94929	0.88267	0.93482	0.60272	0.030229	0.018747	0	0.0049178	0.0049178	0.0049178
88	0.024064	0.022202	0	0.95717	0.87771	0.93511	0.60221	0.030215	0.018743	0	0.0048587	0.0048587	0.0048587

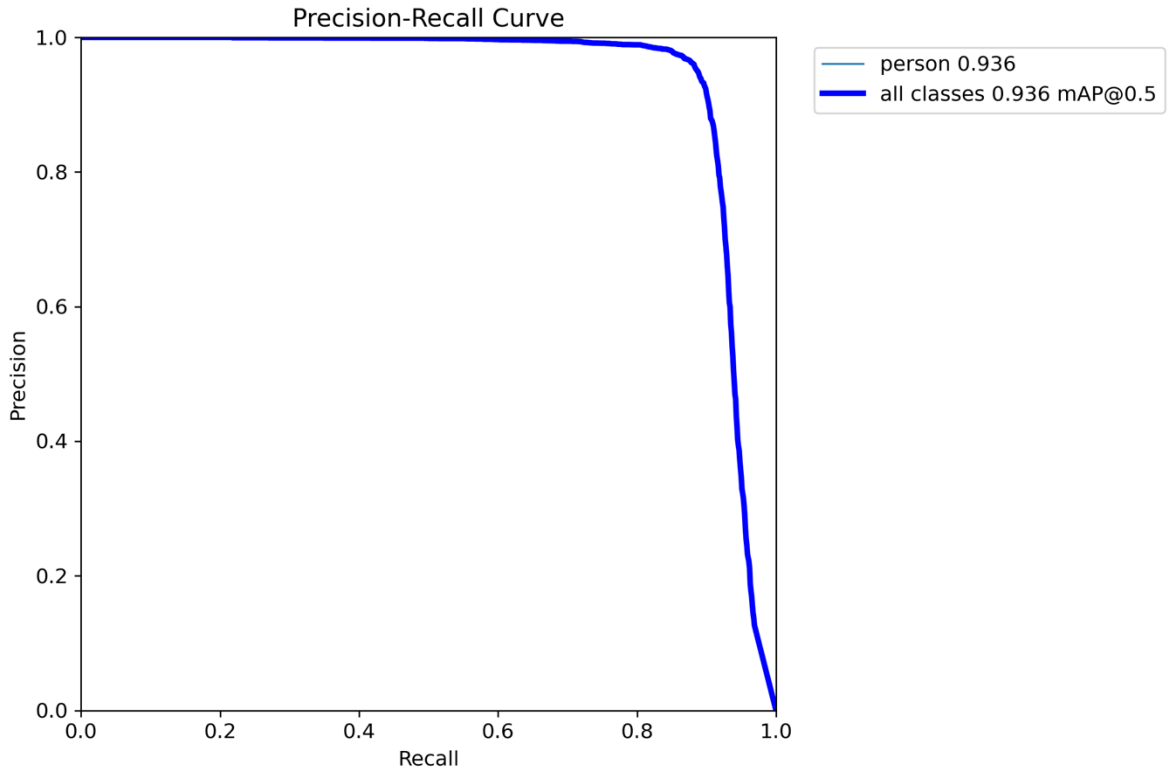
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90	0.024003	0.022081	0	0.95982	0.87605	0.93451	0.60178	0.030248	0.018747	0	0.0047405	0.0047405	0.0047405
91	0.024074	0.022144	0	0.95957	0.87688	0.9344	0.60162	0.030247	0.018743	0	0.0046814	0.0046814	0.0046814
92	0.02399	0.022084	0	0.96038	0.8756	0.93529	0.60157	0.03027	0.018748	0	0.0046223	0.0046223	0.0046223
93	0.023888	0.02199	0	0.95689	0.87729	0.93517	0.6017	0.030259	0.018757	0	0.0045632	0.0045632	0.0045632
94	0.024045	0.021789	0	0.95775	0.87757	0.93547	0.60159	0.030245	0.018753	0	0.0045041	0.0045041	0.0045041
95	0.023705	0.022024	0	0.95693	0.87826	0.93563	0.60165	0.030229	0.018755	0	0.004445	0.004445	0.004445
96	0.023898	0.021904	0	0.9612	0.8743	0.93599	0.60177	0.030232	0.018757	0	0.0043859	0.0043859	0.0043859
97	0.023812	0.022031	0	0.95633	0.87895	0.93606	0.6021	0.030211	0.018759	0	0.0043268	0.0043268	0.0043268
98	0.023588	0.021707	0	0.9569	0.87771	0.93577	0.60205	0.030213	0.018768	0	0.0042678	0.0042678	0.0042678
99	0.023681	0.021752	0	0.95764	0.87757	0.93576	0.60228	0.030208	0.018768	0	0.0042087	0.0042087	0.0042087
100	0.023554	0.021871	0	0.95843	0.87732	0.93581	0.60195	0.030199	0.018774	0	0.0041496	0.0041496	0.0041496
101	0.023491	0.021556	0	0.95842	0.8784	0.93601	0.60268	0.030195	0.018772	0	0.0040905	0.0040905	0.0040905
102	0.02349	0.021713	0	0.95914	0.8784	0.93593	0.60234	0.030173	0.018775	0	0.0040314	0.0040314	0.0040314
103	0.023339	0.021726	0	0.95877	0.87859	0.93594	0.60263	0.030167	0.018771	0	0.0039723	0.0039723	0.0039723
104	0.023482	0.021834	0	0.95858	0.8795	0.93583	0.60305	0.03016	0.018768	0	0.0039132	0.0039132	0.0039132
105	0.023337	0.021433	0	0.95765	0.87919	0.93562	0.60368	0.03014	0.018769	0	0.0038541	0.0038541	0.0038541
106	0.023221	0.021706	0	0.95774	0.87922	0.93561	0.6044	0.030133	0.018776	0	0.003795	0.003795	0.003795
107	0.023011	0.021432	0	0.95793	0.87922	0.93597	0.60458	0.030117	0.01878	0	0.0037359	0.0037359	0.0037359
108	0.023055	0.021508	0	0.95699	0.87977	0.93633	0.60483	0.030111	0.018783	0	0.0036768	0.0036768	0.0036768
109	0.023205	0.021696	0	0.95708	0.87977	0.93618	0.60503	0.030098	0.018784	0	0.0036177	0.0036177	0.0036177
110	0.023136	0.02148	0	0.9571	0.87881	0.93594	0.60528	0.030097	0.018797	0	0.0035586	0.0035586	0.0035586
111	0.022916	0.02127	0	0.95753	0.87936	0.93598	0.60505	0.030104	0.018803	0	0.0034995	0.0034995	0.0034995
112	0.022854	0.021333	0	0.95693	0.87906	0.93579	0.60465	0.030126	0.018812	0	0.0034404	0.0034404	0.0034404
113	0.023007	0.021436	0	0.95631	0.88122	0.93604	0.60447	0.030131	0.018816	0	0.0033813	0.0033813	0.0033813
114	0.022866	0.021248	0	0.95535	0.88198	0.93593	0.60439	0.030132	0.018819	0	0.0033222	0.0033222	0.0033222
115	0.022846	0.021129	0	0.95539	0.88157	0.93612	0.60466	0.030127	0.018826	0	0.0032631	0.0032631	0.0032631
116	0.02285	0.021286	0	0.95583	0.8801	0.93624	0.60473	0.030126	0.018834	0	0.003204	0.003204	0.003204
117	0.022709	0.021199	0	0.95553	0.88074	0.93619	0.60475	0.030121	0.018839	0	0.0031449	0.0031449	0.0031449
118	0.022488	0.020956	0	0.95569	0.88031	0.93631	0.60462	0.03012	0.018844	0	0.0030858	0.0030858	0.0030858
119	0.022614	0.020872	0	0.95627	0.88027	0.93637	0.60487	0.030119	0.018852	0	0.0030268	0.0030268	0.0030268
120	0.022686	0.02131	0	956	0.88072	0.93631	0.60514	0.030109	0.018857	0	0.0029677	0.0029677	0.0029677
121	0.022423	0.021029	0	0.95699	0.88046	0.93641	0.60504	0.030108	0.018862	0	0.0029086	0.0029086	0.0029086
122	0.022515	0.021119	0	0.95726	0.87991	0.93606	0.60521	0.030107	0.018868	0	0.0028495	0.0028495	0.0028495
123	0.022487	0.020833	0	0.95713	0.87977	0.93607	0.60506	0.030107	0.018874	0	0.0027904	0.0027904	0.0027904
124	0.022177	0.02071	0	0.95725	0.87993	0.93629	0.60532	0.030105	0.018878	0	0.0027313	0.0027313	0.0027313
125	0.022291	0.020824	0	0.95696	0.87976	0.93621	0.60555	0.030097	0.018885	0	0.0026722	0.0026722	0.0026722
126	0.022113	0.020666	0	0.95676	0.87964	0.93648	0.60545	0.030087	0.018888	0	0.0026131	0.0026131	0.0026131
127	0.022285	0.021032	0	0.95719	0.87991	0.9365	0.60595	0.030084	0.018895	0	0.002554	0.002554	0.002554
128	0.022052	0.020818	0	0.95747	0.8795	0.93665	0.60562	0.030078	0.018902	0	0.0024949	0.0024949	0.0024949
129	0.022033	0.020696	0	0.95752	0.87964	0.93659	0.60585	0.030074	0.01891	0	0.0024358	0.0024358	0.0024358
130	0.02204	0.020522	0	0.95762	0.88074	0.93697	0.60617	0.030064	0.018915	0	0.0023767	0.0023767	0.0023767
131	0.021906	0.020652	0	0.95771	0.88046	0.93686	0.60626	0.030064	0.018923	0	0.0023176	0.0023176	0.0023176
132	0.021945	0.020482	0	958	0.88056	0.93714	0.60621	0.030057	0.018928	0	0.0022585	0.0022585	0.0022585
133	0.022033	0.020494	0	0.95786	0.88088	0.93697	0.60677	0.030052	0.018933	0	0.0021994	0.0021994	0.0021994
134	0.021634	0.020191	0	0.95826	0.88115	0.93709	0.60661	0.030051	0.018937	0	0.0021403	0.0021403	0.0021403
135	0.021877	0.02048	0	0.95932	0.88122	0.93698	0.60685	0.030041	0.018942	0	0.0020812	0.0020812	0.0020812
136	0.021652	0.020295	0	0.95911	0.88115	0.93683	0.60669	0.030038	0.018947	0	0.0020221	0.0020221	0.0020221
137	0.02173	0.020302	0	0.95946	0.88107	0.93665	0.60676	0.030038	0.018952	0	0.001963	0.001963	0.001963
138	0.021551	0.020482	0	0.95992	0.8806	0.93635	0.60665	0.030031	0.018959	0	0.0019039	0.0019039	0.0019039
139	0.021478	0.020137	0	0.95986	0.88115	0.93624	0.60672	0.03003	0.018965	0	0.0018448	0.0018448	0.0018448
140	0.021261	0.019983	0	0.96034	0.88129	0.93659	0.60674	0.030031	0.01897	0	0.0017857	0.0017857	0.0017857
141	0.021296	0.019978	0	0.9606	0.88129	0.93654	0.6066	0.030028	0.018975	0	0.0017267	0.0017267	0.0017267
142	0.021441	0.019893	0	0.96123	0.88101	0.93661	0.6069	0.030023	0.018982	0	0.0016676	0.0016676	0.0016676
143	0.021238	0.020238	0	0.96149	0.88119	0.93651	0.60664	0.030022	0.018988	0	0.0016085	0.0016085	0.0016085
144	0.021309	0.020218	0	0.9612	0.88117	0.93619	0.60694	0.03002	0.018997	0	0.0015494	0.0015494	0.0015494
145	0.021153	0.020223	0	0.9617	0.88088	0.93639	0.6071	0.030023	0.019007	0	0.0014903	0.0014903	0.0014903
146	0.021094	0.019938	0	0.96245	0.88002	0.93637	0.6069	0.030019	0.019015	0	0.0014312	0.0014312	0.0014312
147	0.021094	0.0198	0	0.96187	0.87985	0.93636	0.60695	0.030024	0.019023	0	0.0013721	0.0013721	0.0013721
148	0.020831	0.019809	0	0.96186	0.87965	0.93615	0.60703	0.030029	0.019032	0	0.001313	0.001313	0.001313
149	0.020886	0.019724	0	0.96174	0.87922	0.93598	0.60726	0.030038	0.019043	0	0.0012539	0.0012539	0.0012539

Model Evaluation Metrics

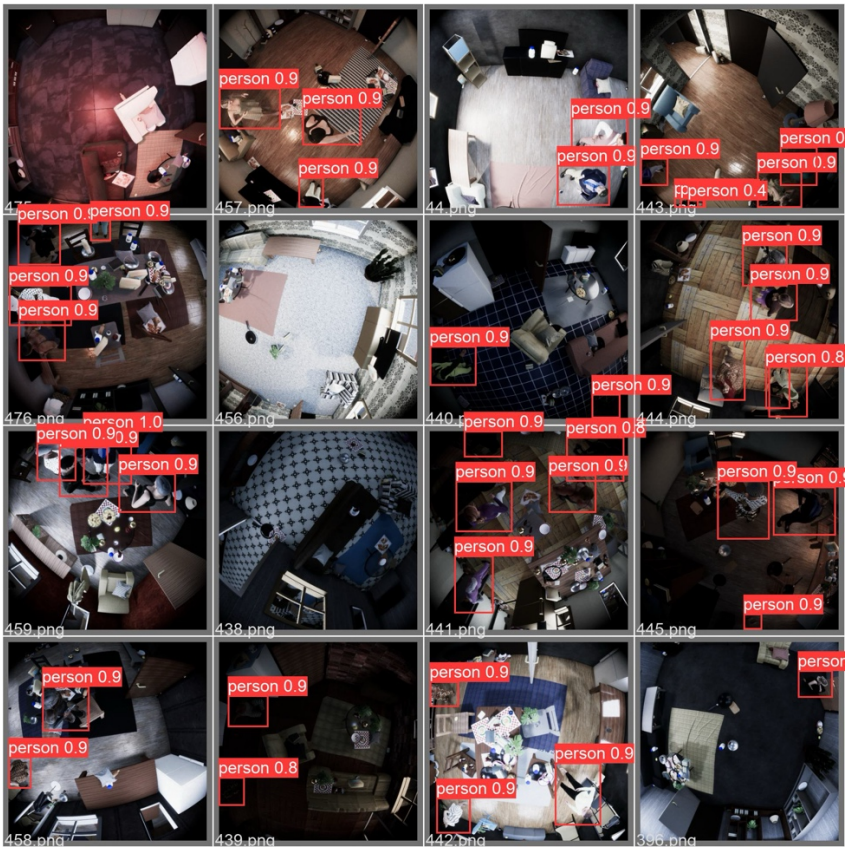


Label Correlogram





Validation Prediction Batch (Snippet)



Appendix I

Author's statement on the work shares in the Article: "SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning"

The article "*SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning*" was co-authored. The following table gives an overview of the authors' contributions to the article.

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Literature review	MB
Conceptualization of the topic	MB, SK, AB
Conducting and evaluating the qualitative analysis	MB
Definition & conceptualization of design theory	MB, SK, JD
Conducting and evaluating the evaluation session	MB
Revising the concepts and relationships of design theory	MB, SK, JD, AB
Qualitative and taxonomic classification of design theory	MB
Visualization of the research methodology	MB
Visualization of the theory	MB
Theoretical implications	MB
Practical implications	MB
Discussion of limitations and further research	MB
Conclusion	MB
Preparation of the manuscript	MB
Revision of the manuscript and the argumentation	MB, SK, AB, JD
Review and revision before submission	MB, SK, JD
Revision after review	MB, SK

Appendix J

Full text of the Article: "SynthEthics: Ensuring Digital Ethics and Performance with a Design Theory for Using Synthetic Image Data in Digital Health Deep Learning"

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Abstract

This paper addresses the need for ethical and effective use of synthetic image data in digital health computer vision. It explores the design requirements and design principles for both responsible use of artificial intelligence in digital health and model robustness, focusing on privacy, ethical compliance, and domain adaptation. Using the design science research paradigm along with value-sensitive design and sociotechnical systems theory, this study presents a design theory that provides actionable guidance for the generation, selection, and integration of synthetic data in digital health. Through heuristic theorizing over two design cycles, the work provides a robust theory artifact and conceptual model to ensure ethical use and improve model performance in digital health through appropriate domain adaptation, generalization, and accuracy. In addition to contributing to theoretical knowledge, this research offers practical implications for health authorities to promote ethical standards and performance in synthetically trained AI applications.

Keywords: Artificial Intelligence; Synthetic Data; Deep Learning; Design Theory; Digital Ethics.

Introduction

Deep learning models for computer vision, which typically contain millions to billions of parameters, rely on extensive datasets to achieve optimal performance and generalizability (Alzubaidi et al., 2021). Nevertheless, the process of collecting authentic training datasets for artificial intelligence (AI) systems is often expensive, prone to errors, and can result in limited or unbalanced datasets (Hinterstoisser et al., 2019; Seib et al., 2020; Zhang et al., 2018). Recently, synthetic image data (artificially generated images) has emerged as a promising alternative, offering scalability, feasibility, and fairly accurate deep learning models (Bird et al., 2020; Hinterstoisser et al., 2019; Krump et al., 2020). In particular, the digital health domain benefits from synthetic data in terms of tailored and innovative applications (Giuffrè & Shung, 2023; Gonzales et al., 2023; Murtaza et al., 2023), but it also raises various ethical and privacy concerns, as sensitive data in AI (e.g., how body parts or environments are modeled) has a high risk of misrepresentation, discrimination, intrusiveness, and bias (Kern et al., 2022; McBride, 2014; Obermeyer et al., 2019; Russel & Norvig, 2021). These concerns are compounded by the fact that while synthetic data is artificial, it is often rooted in real-world datasets through the real-world application settings for which the models are used, which may inadvertently retain identifiable or sensitive characteristics, posing significant privacy risks. While it may seem counterintuitive given the artificial nature of synthetic

data, the reliance on real-world references to create such data underscores the importance of proactively addressing these ethical and privacy concerns. However, even if it appears less risky due to its artificial nature, synthetic data does not entirely eliminate privacy risks or ethical challenges; patterns from the source or reference data can be reverse-engineered or misused, and its artificiality can lead to unanticipated harms, such as skewing demographic or clinical representations. In particular, the digital health domain inherently involves sensitive information and human interactions, making it critical to design technologies that are consistent with ethical standards and user values (Vayena et al., 2018; Rajkomar et al., 2018). Therefore, it is imperative that researchers and practitioners in deep learning and digital health carefully consider these ethical implications. Effective strategies must be developed to mitigate risks, including implementing rigorous standards for data anonymization, applying fairness metrics to ensure unbiased AI models, and establishing ethical guidelines for the use and distribution of synthetic image data (Obermeyer et al., 2019; Panch et al., 2019; Raji et al., 2020; Rajkomar et al., 2019; Zhang et al., 2018).

However, while there is considerable meta-level guiding knowledge on ethical research in IS and Design Science Research (DSR) (Myers & Venable, 2014; Herwix et al., 2022), we found that the ethical and effective use of synthetic image data in digital health computer vision in particular is underexplored, leaving both researchers and practitioners navigating a complex ethical AI landscape without a clear compass. We address this gap by responding to the call for value systems (Herwix et al., 2022) by focusing on the specific ethical challenges of synthetic image data in digital health beyond existing meta-level ethical frameworks in IS and DSR. Beyond meta-level ethical guidance, the lack of consensus on standards and guidance for the use of synthetic data in digital health further exacerbates the problem, making it difficult to ensure that the benefits of AI are harnessed without compromising patient privacy or reinforcing existing biases. This gap is significant because it hinders the ability to systematically address the challenges and realize the potential of synthetic data in ways that are both ethically responsible and technologically effective (Panch et al., 2018). Thus, this paper poses the following research question:

> **RQ:** *What are the design requirements and design principles to ethically and effectively utilize synthetic image data in digital health computer vision environments, considering potential tensions between ethical compliance and operational effectiveness?*

We answer this question by adopting a multi-method heuristic design theorizing approach (Gregory & Muntermann, 2014) that combines qualitative methods such as moderated focus groups and think-aloud sessions in the theorizing quadrant of the DSR focus matrix (Brendel et al., 2022) throughout two design iterations. Guided by value-sensitive design and sociotechnical systems theory as our kernel theories, we develop design requirements and principles as a constituted design theory that embodies a general design solution to the problem class (Baskerville & Pries-Heje, 2010) of lacking guidance in developing ethically and performant deep learning models trained on synthetic image data in IS research. Since recent literature explicitly calls for guidance on synthetic data utilization (Murtaza et al., 2023) and design decisions, in general, are not neutral (i.e., having moral and ethical implications) (Findeli, 1994), our design theory addresses key aspects such as ethical compliance, privacy protection, data governance, scene diversity, controlled composition, complexity management, data augmentation, and responsible AI, providing actionable and theory-grounded guidance for researchers and practitioners in the selection, generation, and integration of synthetic image data for digital health computer vision. By adopting the design theory and a derived conceptual model, researchers can ensure the ethical and responsible use of synthetic image data while enhancing model performance, privacy protection, and projectability.

This paper contributes to the theoretical discourse on AI healthcare computer vision systems by presenting a design theory grounded in sociotechnical systems theory and value-sensitive design. Our study addresses the ethical and technical challenges of using synthetic image data for computer vision model training, ensuring that ethical values are embedded in the design process. By integrating core theories, we offer a balanced approach that balances ethical and social imperatives with technical performance, thereby advancing the responsible use of AI in digital health. The following sections cover the theoretical foundations, research methodology, design theory description, evaluation, and discussion.

Theoretical Foundations

Kernel Theories and Theoretical Lens

To ensure scientific rigor and stringency, DSR endeavors can use kernel theories to derive design principles. Broadly speaking, kernel theory functions as a form of justificatory knowledge within the realm of design knowledge development, as indicated by the work of Gregor and Hevner (2013), such as in the form of design principles (Gregor et al., 2020). DSR efforts may employ kernel theories to derive foundational

design principles since the genesis of novel artifacts is grounded not merely in prototyping and user participation but fundamentally depends on a kernel theory (Walls et al., 1992; 2004). Thus, this study adopts the *analyze with lens*-mechanism proposed by Möller et al. (2022), drawing upon the theoretical foundations of employing kernel theories as a means of analysis and adhering to the conceptual boundaries of a theory. Using one or more kernel theories as a foundational framework can help clearly define normative prescriptions within design theories, directing the strategies and methods used to find specific solutions through design. Therefore, we argue that the use of a theoretical lens allows us to derive concepts indirectly, guiding the analysis or framing of data within the conceptual borders of a specific theory. This approach aligns with the perspective of Niederman and March (2019) on the theoretical lens, which emphasizes its role in aiding the theorization process, leading to the formulation of design principles or meta-requirements based on a data foundation. In the context of our study, we chose to use two kernel theories that not only informed our research methodology but were also used to inform our design requirements and principles. As shown in Figure 1, we used value-sensitive design theory (Friedman et al., 2002; 2013) specifically for our theory building and to frame our heuristic theorizing process, while sociotechnical systems theory (Trist & Bamforth, 1951; Emery & Trist, 1960) and its concepts were used for our theory grounding.

Value-sensitive design theory (Friedman et al., 2002; 2013) was chosen because it embodies a theoretically grounded approach that considers human values in a principled and comprehensive manner throughout the design process, which aligns with the research goal of developing technology that respects and incorporates user values while ensuring ethically responsible and user-centered design decisions. In general, value-sensitive design encompasses conceptual (Friedman et al., 2013), empirical (Deng et al., 2016), and technical investigations (Denning et al., 2010) of phenomena and their value conflicts and trade-offs (Mueller et al., 2018). Demonstrating its utility in addressing ethical issues in digital health (Dadgar & Joshi, 2018; Detweiler & Hindriks, 2012; Denning et al., 2014), value-sensitive design theory provides a structured approach to incorporating human and ethical values into technology design (Yetim. 2011). We also used value-sensitive design as a guiding framework to structure and evaluate the think-aloud sessions. Ethical considerations such as privacy, fairness, and inclusivity were explicitly embedded in the session design, allowing participants to reflect critically on these values while interacting with prototype artifacts. This approach ensured that the resulting design knowledge was aligned with the theoretical underpinnings of value-sensitive design. In the specific use-case of synthetic image data utilization for deep learning tasks in digital health, this especially connects to the synthetic depiction of humans (including separate or related characteristics, e.g. body parts or demographics), the use-case context in which the synthetically generated image data is used (often human-related, e.g. medicine or surveillance), and the potential ethical implications that arise from the creation and utilization of synthetic images. Given that synthetic imagery often closely mirrors real-image references, we aim to ensure that ethical implications, especially privacy concerns, are systematically addressed throughout the design process. This theoretical lens thus helps not only to derive design principles and requirements but also to establish a rigorous elicitation and evaluation (e.g., with think-aloud sessions) of these principles in the context of digital health. Using this kernel theory ensures that synthetic deep learning technology is not merely functional (i.e., precise, accurate, and reliable) but also ethically value-bound. By grounding the design process in a rigorous theoretical foundation, this approach not only facilitates the development of ethically responsible and user-centered digital health technologies but also contributes to the evolution and refinement of the theory itself, enhancing its applicability and relevance in the rapidly evolving landscape of digital health.

To complement the ethical framework established by value-sensitive design, this study integrates sociotechnical systems theory as an additional kernel theory to ensure a comprehensive approach to the design of synthetic image data in digital health computer vision. Originating from the seminal work of Trist and Bamforth (1951) and further developed by Emery and Trist (1960), sociotechnical systems theory emphasizes the intricate interplay between social subsystems (i.e., organizational structures, cultural practices, and human interactions) and technical subsystems (i.e., tools, processes, and technologies). In the context of using synthetic image data to train deep learning models in digital health, this interplay becomes particularly apparent. The sensitivity of health-related data and the potential for misrepresentation or bias necessitate a design approach that not only incorporates ethical considerations but also acknowledges the sociotechnical dynamics at play. Mumford's (2006) reflections on sociotechnical design underscore the need to align both social and technical elements to achieve sustainable and effective outcomes. This alignment is critical when generating synthetic imagery that must accurately represent diverse populations without perpetuating existing biases. Within the field of IS, Baxter and Sommerville (2011) highlight how sociotechnical systems theory can guide

the development of systems that are both technically robust and socially responsive, a principle that resonates with the challenges of ensuring data realism and utility in synthetic datasets. Similarly, Bostrom and Heinen's (1977) examination of MIS failures through a socio-technical lens highlights the importance of considering human factors alongside technical specifications to prevent system failures. By grounding our DSR process in sociotechnical systems theory alongside value-sensitive design, this study not only advocates for ethical and user-centered technology but also ensures that the complex interdependencies between healthcare professionals, patients, and technological systems are thoughtfully integrated. This dual theoretical foundation facilitates the derivation of design requirements and principles that address the multiple challenges of using synthetic image data in deep learning models - balancing technical performance with ethical imperatives and social considerations. Consequently, the integration of sociotechnical systems theory provides a robust framework for navigating the complexities inherent in digital health environments and promotes the development of AI solutions that are not only effective and accurate but also socially attuned and ethically sound.

Synthetic Images in Deep Learning

Given that state-of-the-art deep learning models for computer vision comprise millions, if not billions, of parameters, training such models requires large amounts of data, which is often costly, missing, or unbalanced (Alzubaidi et al., 2021). Synthetic image data (which is synonymous with artificial image data) in deep learning refers to artificially created imagery that is generated by algorithms (e.g., video game engines) to train deep learning models. Several studies have highlighted the effectiveness of synthetic data in various computer vision tasks. Lee et al. (2019) and Krump et al. (2020) utilized synthetic datasets for deep learning-based object detection, specifically in underwater sonar imaging and vehicle detection on unmanned aerial vehicle platforms, respectively, highlighting the effectiveness of synthetic data in various computer vision domains. Additionally, domain adaptation, which is a technique that involves adapting a model trained on one (synthetic) domain of data to perform well on a different but related (real) domain, and transfer learning have been extensively explored in the context of synthetic data. Lahiri et al. (2018), Venkateswara et al. (2017), and Kuhnke and Ostermann (2019) focused on unsupervised domain adaptation for synthetic data, learning transferable feature representations, and domain adaptation for pose estimation, respectively. Seib et al. (2020) conducted a comprehensive review of current approaches that combine real and synthetic data to enhance neural network training, supporting the argument for a combination of training data and data augmentation. Aranjuelo et al. (2021) discussed key strategies for synthetic data generation in people detection from omnidirectional cameras, emphasizing the effective use of both real and synthetic data. Valtchev and Wu (2021) demonstrated the utility of domain randomization for neural network classification, showcasing the effectiveness of synthetic data in training robust models.

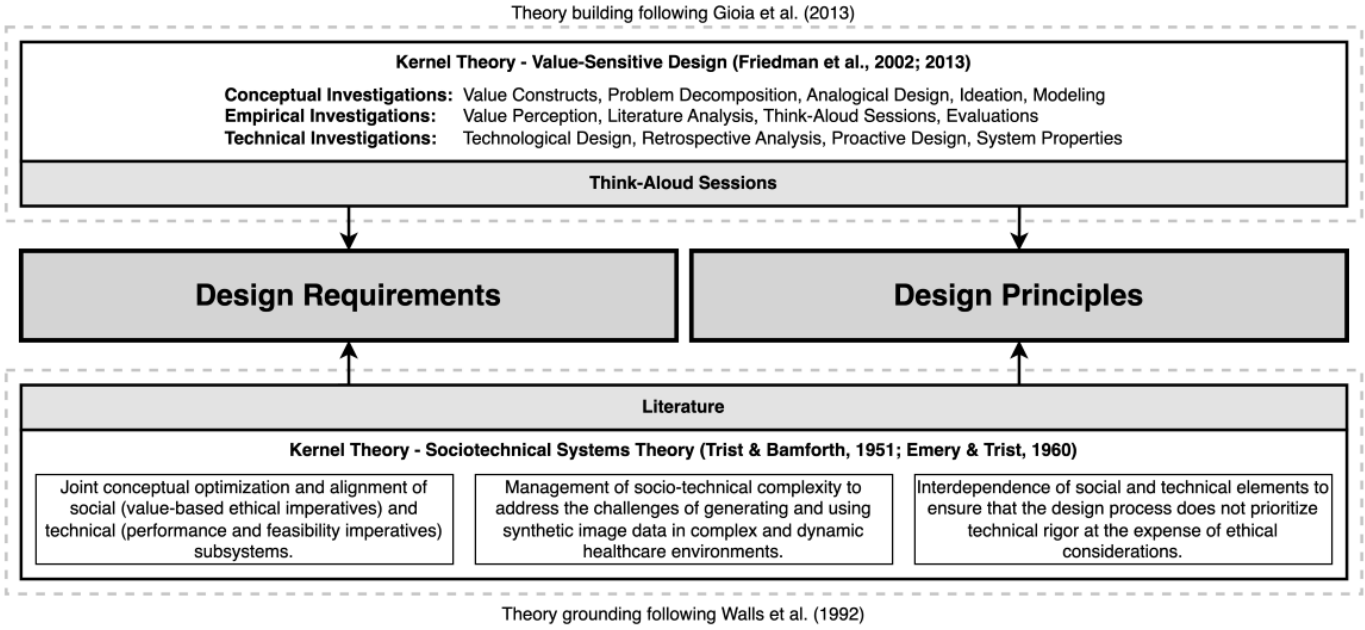


Figure 1. Our Kernel Theories and How They Inform the Design Science Approach of This Study

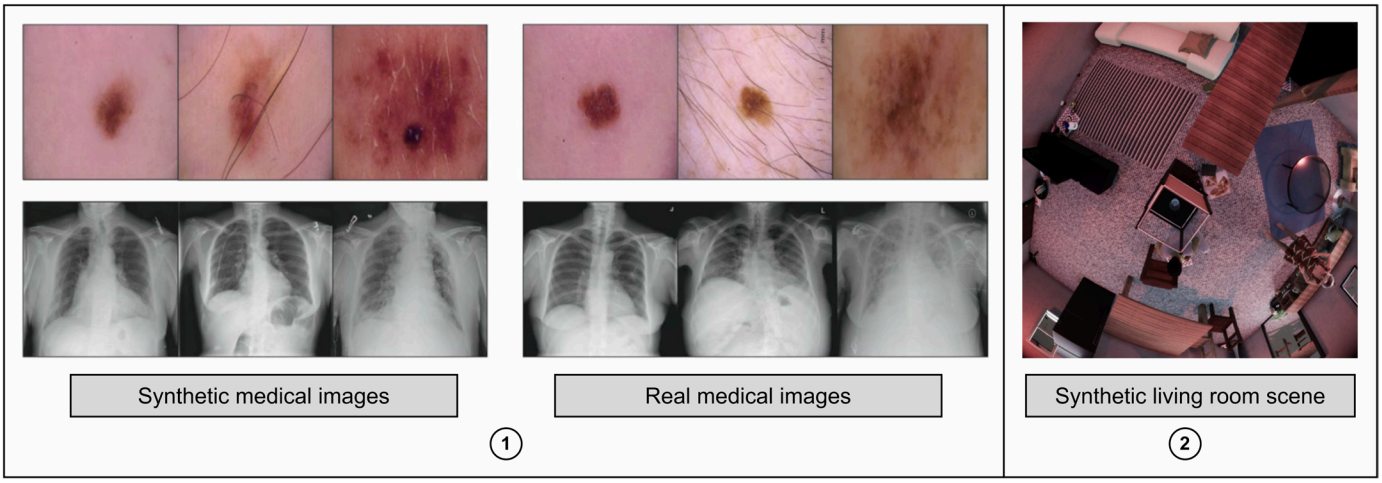


Figure 2. Exemplary Applications of Synthetic Data with 1) A Comparison of Synthetic and Real Image Data in Medicine (Chen et al., 2021) and 2) Synthetic Living Room Scenes in Digital Health (Own Study)

Moreover, the combination of synthetic and real training data has been investigated by several researchers. Wan et al. (2021) and Bird et al. (2020) utilized mixed datasets, comprising both synthetic and real data, for document layout analysis, scene classification, and object detection in augmented reality, respectively. Thereby, these studies highlight the benefits of leveraging both synthetic and real data for training computer vision models. Furthermore, the use of synthetic data generation techniques and simulators has been explored. Müller et al. (2018) introduced a photo-realistic simulator for generating synthetic data for computer vision applications, whereas Zhang et al. (2018) proposed a stacked multichannel autoencoder framework for efficient learning from synthetic data. In addition, Scheck et al. (2020) introduced a synthetic dataset that serves as a valuable resource for training and evaluating deep learning models in overhead object detection.

At the intersection of synthetic data (not limited to image data) and digital health, Giuffrè and Shung (2023) thoroughly examine the technical benefits and challenges of synthetic data in healthcare, focusing on its use in policy, privacy, and predictive analytics. They highlight how synthetic data can improve healthcare by enabling data-driven decision-making while addressing privacy concerns and data scarcity. However, they also identify significant risks, including data bias, the potential for re-identification, and regulatory gaps. As such, they point out that biases in training data can lead to inaccurate or discriminatory results in AI models, which is particularly problematic in healthcare, where decisions directly affect patient outcomes. The paper discusses the need for robust methods to verify the quality of synthetic data, calls for transparency in data generation processes, and proposes the establishment of a digital chain of custody to maintain data integrity and accountability. While these insights are essential, their work primarily addresses technical, privacy, and regulatory challenges, leaving a gap in ethical considerations, particularly as they relate to synthetic image data in digital health. Here, Murtaza et al. (2023) reviewed the generation of synthetic data in healthcare, while Gonzales et al. (2023) discussed the potential applications of synthetic data, focusing on datasets and innovative utility. As shown in Figure 2, synthetic image data can be applied across various medical and clinical healthcare applications such as skin lesion and cancer detection, x-ray diagnosis, or renal cell carcinoma treatment (Chen et al., 2021), providing insights into the generation and use of synthetic data for training deep learning models. At this point, we would like to note that the illustrative examples shown in Figure 2 are only one of many possible forms of synthetic image data applications in digital health, and that, for example, the correct classification rate for cancer detection needs to be significantly higher compared to preventive care use cases, as our instantiation will show later. We argue that a misdiagnosis in cancer detection with synthetic image data is much more fatal than an error in home care interaction with cognitively impaired individuals, for which Figure 2 is only an example of how photorealistic synthetic image data can be and what possible use cases are conceivable.

Despite the considerable research on utilizing synthetic image data for computer vision deep learning models, there remains a notable research gap in terms of a comprehensive framework or guidelines that provide design knowledge to effectively and systematically utilize synthetic data in this context. While individual studies have demonstrated the benefits and effectiveness of synthetic data in specific tasks, there is a lack of unified principles or guidelines that guide researchers and practitioners in the

selection, generation, and integration of synthetic image data for training deep learning models. Moreover, relying on synthetic data without a robust ethical framework risks exacerbating existing biases or introducing errors, particularly when synthetic datasets are generated without adequate consideration of demographic diversity or the potential for subtle patterns to be exploited, underscoring the critical need for proactive safeguards to prevent unintended harm in high-stakes scenarios such as cancer detection. Hereby, the absence of such design knowledge hinders the widespread adoption and consistent utilization of synthetic data, leading to potential inefficiencies, suboptimal performance, and challenges in real-world deployment (Giuffrè & Shung, 2023; Müller et al., 2018; Scheck et al., 2020; Zhang et al., 2018).

Ethics in IS and Digital Health

(Digital) Ethics has long been an afterthought in IS research but has gained some momentum in the last decade and is showing various manifestations with a growing number of studies (Kern et al., 2022). Ethics, broadly speaking, is a branch of philosophy that assesses the morality of human actions, offering a thorough examination of interconnected ethical dilemmas, concepts, principles, reasoning, and judgments through various ethical theories (Becker & Becker, 2001; O'Neil, 2004) that orbit around *teleological* (Aristotele et al., 2009), *deontological* (Habermas, 1987; Kant, 1998), and *weak normative/contextual* (Düwell et al., 2011) categories. Similarly, digital ethics focuses on the moral implications associated with the development and application of digital technologies, providing a comprehensive framework to address the ethical and moral challenges posed by digital innovation. Intending to formulate morally good solutions as defined by Floridi and Taddeo (2016), the field encapsulates varying viewpoints; for instance, Spiekermann et al. (2022) emphasize ethical virtues and values, while Schlagwein et al. (2019) advocate for discourse ethics as a foundation for analysis. While existing ethical research frameworks in IS and DSR, such as those proposed by Myers and Venable (2014), provide valuable meta-level guidance, these tend to focus on broad, generalizable principles that may not fully address the unique ethical challenges presented by synthetic image data in digital health computer vision. These unique challenges include the potential for synthetic data to replicate or amplify biases in source datasets, vulnerability to re-identification despite its artificial nature, and ethical ambiguities surrounding consent for its creation and use (i.e., in terms of accountability, fairness, transparency, or compliance). In addition, the perceived infallibility of synthetic data risks fostering complacency, while its increasing accessibility increases the potential for misuse in sensitive digital health contexts. Addressing these issues requires rigorous, domain-specific ethical frameworks that consider the high stakes and sociotechnical complexities of healthcare applications. Similarly, while Herwix et al. (2022) emphasize the importance of value systems design in IS research, there remains a critical need for domain-specific ethical guidelines that not only build upon these existing frameworks but also provide actionable insights tailored to the sociotechnical demands of digital health applications, where the ethical stakes are particularly high. Subsequently, digital health is considered a branch in the interdisciplinary field of digital ethics, which overlaps with, for example, computer science (Mahieu et al., 2018) or the paradigm of computer ethics (Floridi, 2010). More specifically, the IS concept of technology adoption in terms of privacy and e-health records has been reviewed by Hansen and Baroody (2020), while Turja et al. (2020) studied the acceptance of robotic caretakers that pay attention to ethical values and Al-Dhaen et al. (2021) explored the ethical considerations in the internet-of-medical-things use intentions.

On a more conceptual theory level and as shown in Figure 3, digital health ethics can be allocated to *AI ethics* and the design and development of positive/beneficial artificial intelligence (Floridi & Cowls, 2019); *value ethics* and the indication that a person strives for higher intrinsic values (Becker & Becker, 2001); and *IS ethics* that specifically applies to information systems research (McBride, 2014). From this perspective, the developed concepts (Kern et al., 2022) of *artificial intelligence* to act effectively and safely in AI environments (Russell & Norvig, 2021) and *privacy* to determine the extent of personal information exposure (Hung & Cheng, 2009) hereby inform our study of synthetic image data in digital health computer vision in terms of the guiding theoretical orientation. In addition, Rajkomar et al. (2019) delve into the application of AI in healthcare, discussing both its potential benefits and associated challenges. Their comprehensive analysis covers a range of issues, from improving patient care to ethical considerations and data privacy. Focusing on the critical issue of bias in healthcare AI, Obermeyer et al. (2019) provide an in-depth examination of how AI algorithms can inadvertently perpetuate bias and offer methods for identifying and reducing these biases, contributing to the development of fairer and more equitable AI tools in healthcare. In this context, Raji et al. (2020) explored the ethical dimensions of auditing facial recognition technologies, focusing on the methodological challenges and moral implications associated with auditing these AI systems and situating their study within the broader conversation about AI, ethics, and societal impact, with a particular

focus on facial recognition technology. Building on this, Vayena et al. (2019) present an ethical framework tailored for AI applications in healthcare. They argue for a multi-stakeholder approach, involving collaboration between technologists, ethicists, and legal experts, highlighting the importance of balancing innovation with ethical responsibility and ensuring that AI advancements enhance healthcare while safeguarding patient privacy and data security. In the larger context of AI research in healthcare, Panch et al. (2019) critically examine the application of AI in healthcare, addressing what they refer to as the 'inconvenient truth' of AI in this domain and highlighting its contributions to the ongoing discussion about the realistic and ethical application of AI technologies in medical settings. Their work serves as a critical reminder of the need to balance enthusiasm for AI with a clear-eyed assessment of its challenges and limitations. Since digital health environments and especially image-based computer vision approaches are exposed to sensitive data, the incorporation of digital ethics is necessary.

However, as digital ethics has gained momentum in recent years, there is a significant lack of research in the area of computer vision healthcare, particularly in the use of synthetically generated image data – both theoretically and practically. The notion of generating synthetic medical images, for instance, creates a potential ethical grey area around consent, data privacy, and the authenticity of information. The stakes are high, as missteps can lead to misinformation, misdiagnosis, or the exploitation of sensitive personal data, such as potential demographic biases or misrepresentations (Giuffrè & Shung, 2023; Gonzales et al., 2023, Murtaza et al., 2023; Obermeyer et al., 2019; Panch et al., 2019). Interestingly, while it could be argued that synthetic data is artificial data and therefore easier to protect privacy, synthetic data often mirrors real-world data, meaning that identifiable patterns or sensitive information from real-world reference datasets may be unintentionally replicated in the synthetic output (Giuffrè & Shung, 2023, Gonzales et al., 2023). This link between synthetic and real data underscores the need for robust ethical frameworks and privacy protections, particularly in the sensitive context of digital health, where the potential for re-identification and misuse remains significant. Moreover, the intersection of AI ethics, value ethics, and IS ethics with the realm of synthetic image data in digital health computer vision needs a thorough exploration to ensure the responsible development and deployment of these technologies. Therefore, design knowledge and guidance are needed to ensure the ethical and performant use of synthetically trained deep learning models in digital health, and to generate compliant image data that is both realistic and value-sensitive (Becker & Becker, 2001; Giuffrè & Shung, 2023; Murtaza et al., 2023).

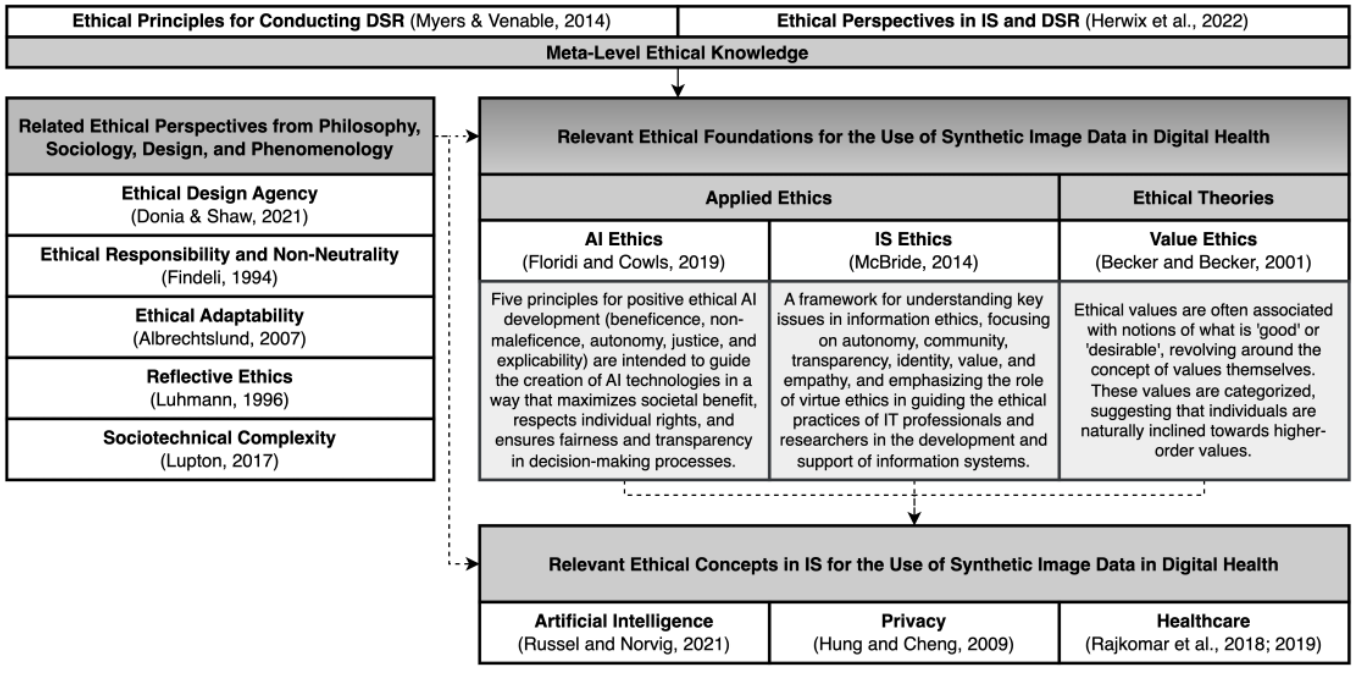


Figure 3. Relevant Ethical Foundations and Concepts for the Use of Synthetic Image Data in Digital Health

From a more philosophical, sociological, and phenomenological perspective, our study is further informed by theoretical foundations and (design) knowledge from related fields to IS and digital ethics. In general, ethical design decisions are not neutral but have inherent moral implications, as highlighted by Donia and Shaw (2021), who argue that the degree of designer agency - constrained by external factors such as corporate/performance pressures - significantly influences the integration of values into design processes. Moreover, the concept of *normative strength* within design emphasizes how strongly ethical principles are embedded in these processes, challenging us to consider how the constraints on designers' agency affect the ethical quality of the resulting artifacts. This aligns with Albrechtslund's (2007) critique of positivist assumptions in value-sensitive design, which argues for a flexible approach that recognizes the multistability of technologies and the unpredictable ways in which they can be used or misused once deployed. This phenomenological approach shifts the focus from predicting ethical use to preparing for ethical adaptability and flexibility in design. In addition, Findeli's (1994) exploration of the intertwined relationship between ethics and aesthetics in design emphasizes that design decisions should take into account both ethical and aesthetic judgments, reinforcing the notion that design in socio-technical systems carries moral responsibility, especially when designing artifacts that mediate between the human and technological realms (biocosm, sociocosm, and technocosm). The term *technoethics* is introduced to discuss the ethical issues arising from technological developments and their impact on professions, including design. Findeli (1994) emphasizes that designers have a professional responsibility for the moral implications of their creations that goes beyond mere functionalism. Designers must consider how their designs affect users, society, and the environment at large, which is consistent with the key assumptions of sociotechnical systems theory. Integrating this with Luhmann's (1996) reflections on ethical systems as adaptive and reflective processes within social contexts underscores the need for continuous ethical deliberation in complex environments such as computer vision and digital health. Finally, Lupton (2017) critiques mainstream design thinking for neglecting sociocultural complexity and advocates for speculative design approaches that address technological systems' broader social and ethical implications. Together, these perspectives deepen our engagement with ethical and sociotechnical frameworks and ground our study in a comprehensive theoretical foundation that not only addresses the challenges of synthetic data but also ensures that ethical considerations are central to the design of health technologies.

Literature Review

As shown in the previous sections, research on deep learning models, especially concerning synthetic training data, and digital ethics in IS has become increasingly sophisticated. While real image models in computer vision depend on the availability and quality of training data, this particular challenge can be addressed by synthetic data, which is scalable, cheap, and less error-prone, but also raises questions of ethical use, especially in digital health. Research has consistently highlighted the complexity and data-intensive nature of deep learning models in computer vision, underscored by the challenges of acquiring the diverse and extensive datasets required for these models (Alzubaidi et al., 2021). This gap in effective and efficient data acquisition, which is particularly relevant in digital health, affects model accuracy and generalizability, which directly impacts human health outcomes. Looking at Research Stream 1, which focuses on synthetic image data in deep learning, it can be conceptually divided into the effectiveness and application of synthetic data (EA-SD) as well as the challenges and strategies in synthetic data utilization (CS-SDU), as shown in Table 1. Studies listed in the former category, such as those by Lee et al. (2019), Krump et al. (2020), and Aranjuelo et al. (2021), focus specifically on the applications and effectiveness of synthetic data in different deep learning and computer vision contexts. On the other hand, CS-SDU includes papers such as those by Lahiri et al. (2018) and Seib et al. (2020), which address domain adaptation, challenges in using synthetic data, and strategies for combining real and synthetic data. Research Stream 2 can then be conceptually divided into the theoretical and philosophical foundations of digital ethics (TPF-DE) and the practical applications and implications in digital health (PAI-DH). Here, studies from the former category, such as those by Becker and Becker (2001) and Floridi and Taddeo (2016), focus on the ethical theories and philosophical foundations relevant to digital ethics, which is different from the practical applications of these theories. On the other hand, the studies listed in PAI-DH, such as those by Hansen and Baroody (2020) and Turja et al. (2020), are specifically focused on the application of ethical considerations in digital health, which is distinct from the theoretical underpinnings of digital ethics. At the intersection of these conceptually divided research streams, general synthetic data has been addressed in terms of application, privacy, and policy (Giuffrè & Shung, 2023; Gonzales et al., 2023) while also covering healthcare settings (Murtaza et al., 2023). By further grounding our theory-driven approach (Schoormann et al., 2024) in philosophical, sociological, and

phenomenological perspectives from related fields (Donia & Shaw, 2021; Albrechtslund, 2007; Findeli, 1994; Luhmann, 1996; Lupton, 2017), we ground our study in this prior (design) knowledge.

Table 1. Literature and Research Streams are Categorized Based on Their Conceptual Orientation

Literature	**Research Stream 1:** Synthetic Image Data in Deep Learning		**Research Stream 2:** Digital Ethics in IS	
	EA-SD	*CS-SDU*	*TPF-DE*	*PAI-DH*
Lee et al. (2019)	X			
Krump et al. (2020)	X			
Aranjuelo et al. (2021)	X	X		
Valtchev and Wu (2021)	X			
Wan et al. (2021)	X			
Bird et al. (2020)				
Lahiri et al. (2018)		X		
Venkateswara et al. (2017)		X		
Kuhnke and Ostermann (2019)		X		
Seib et al. (2020)		X		
Müller et al. (2018)		X		
Zhang et al. (2018)		X		
Scheck et al. (2020)		X		
Giuffrè and Shung (2023)		X		X
Murtaza et al. (2023)	X			X
Gonzales et al. (2023)	X			X
Becker and Becker (2001)			X	
O'Neill (2004)			X	
Floridi and Taddeo (2016)			X	
Spiekermann et al. (2022)			X	
Schlagwein et al. (2019)			X	
Vayena et al. (2019)			X	
Donia and Shaw (2021)			X	
Luhmann (1996)			X	
Lupton (2017)			X	
Albrechtslund (2007)			X	X
Findeli (1994)			X	X
Obermeyer et al. (2019)			X	X
Panch et al. (2019)			X	X
Hansen and Baroody (2020)				X
Turja et al. (2020)				X
Al-Dhaen et al. (2021)				X
Floridi and Cowls (2019)				X
Russel and Norvig (2021)				X
Raji et al. (2020)				X
Rajkomar et al. (2019)				X
Hung and Cheng (2009)				X
Our study approach	X	X	X	X
Note	• EA-SD = Effectiveness and Application of Synthetic Data • CS-SDU = Challenges and Strategies in Synthetic Data Utilization • TPF-DE = Theoretical and Philosophical Foundations of (Digital) Ethics • PAI-DH = Practical Applications and Implications in Digital Health.			

Despite the considerable work that has been done in these categories, there remains a significant gap in synthesizing these diverse streams into cohesive design knowledge that can inform the development of digital health technologies using synthetic image data. This gap is significant because it hinders the ability to systematically address the challenges and realize the potential of synthetic data in ways that are both ethically responsible and technologically effective (Rajkomar et al., 2018; Panch et al., 2018). This is particularly relevant given the rapid evolution of digital health technologies and their increasing reliance on complex deep learning models. The need for unified design knowledge becomes even more apparent when considering the diverse applications and implications of synthetic image data in digital health. Unlike meta-level approaches to ethical guidance in IS and DSR (Myers & Venable, 2014; Herwix et al., 2022), the need for knowledge about the ethical use of synthetic data stems from its growing use in healthcare, where it presents unique ethical challenges and, despite being artificially generated, often reflects real-world data that may inadvertently carry sensitive or identifiable characteristics. For example, using synthetic data to train algorithms for diagnostic purposes requires a socio-technical perspective with technical precision and a deep understanding of ethical considerations such as patient privacy and data security. Similarly, when synthetic data is used to train models for predictive healthcare analytics or in digital health applications aimed at assisting vulnerable populations, it is critical to ensure that the models are not only accurate but also unbiased and fair. Thus, the need for a design theory to address the research gap in the ethical and effective use of synthetic image data in digital health computer vision is multifaceted. First, it has the potential to integrate technical and ethical aspects of healthcare, providing a comprehensive framework for practitioners and researchers (Chandra et al., 2015; Meth et al., 2015). Furthermore, it aims to emphasize ethical compliance and social responsibility, focusing on values such as privacy and fairness in the use of synthetic data (Gregor & Jones, 2007). The design theory could, therefore, improve AI-driven medical diagnosis and treatment, promote innovation in medical imaging, and address risks such as AI bias and legal issues. It could, therefore, also foster interdisciplinary collaboration and reduce indeterminacy in design theory (Burton-Jones et al., 2021; Lukyanenko & Parsons, 2020), ensuring that digital health technologies remain adaptable and responsible.

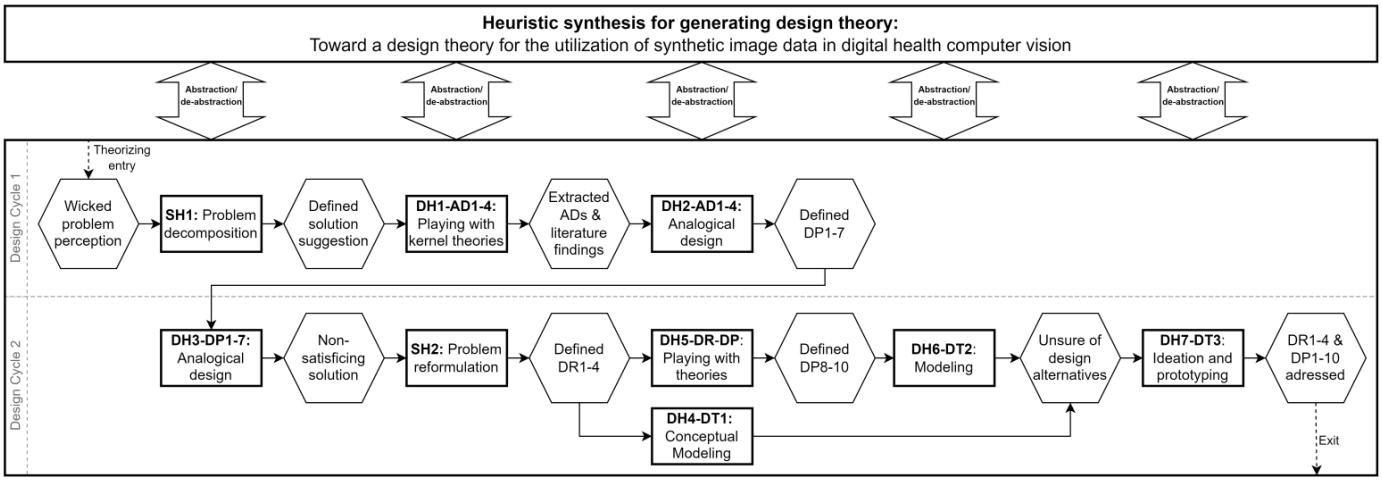
Research Methodology

We drew on the DSR paradigm (Hevner et al., 2004), as our study seeks to provide prescriptive insights for research on synthetic image data, rather than merely descriptive knowledge, as outlined by Gregor and Hevner (2013). Given that the DSR paradigm can be instantiated through a variety of methodological processes (Venable et al., 2017), and that design theories, in general, embody a form of theorizing in IS research (Brendel et al., 2022; Burton-Jones et al., 2021; Dehling & Sunyaev, 2023; Gregory & Muntermann, 2014; Kane et al., 2021; Lee et al., 2011; Mandviwalla, 2015; Young et al., 2021), our study can be placed in the *theorizing* domain of the DSR focus matrix (Brendel et al., 2022), which implies a higher focus on rigor and derivation of theoretical artifacts. This matrix domain generally involves using higher-level kernel theories (i.e., in our case, value-sensitive design theory and sociotechnical systems theory) to form new design theories for a given problem space (i.e., in our case, the use of synthetic image data in digital health). In this domain, the development of design principles and propositions, similar (but not equal) to hypothesis formulation, plays a central role, emphasizing the importance of grounding new theories in prior knowledge (Brendel et al., 2022; Schoormann et al., 2024). Thus, we followed the grounding and conceptualization step for theory-driven DSR configurations as suggested by Schoormann et al. (2024) to ground our design requirements and principles in prior work and theory based on our theoretical foundations.

As such, we meticulously followed the heuristic design theorizing framework proposed by Gregory and Muntermann (2014) over two design cycles to ensure both transparency and stringency (Figure 4) for design theory replication as discussed by Brendel and Muntermann (2022). In our case, heuristic theorizing is defined as the process of proactively creating design theory from problem-solving experiences and prior theories. This is achieved by continuously iterating between seeking a satisficing (adequate) problem solution (heuristic search) and synthesizing new information generated during the heuristic search through, e.g., literature, theory, or practical findings (Gregory & Muntermann, 2014). Thus, our theorizing approach contained multiple rounds of analogical design (e.g., transferring design knowledge about one design situation to another), reformulating the problem (e.g., for specific domains), playing with kernel theories (i.e., value-sensitive design and sociotechnical systems theory), and modeling (cf. Figures 6 and 7). Here, our design theorizing approach is located in the abstract theoretical domain, seeking an abstract solution that solves an abstract problem, and using abductive reasoning because there is an objective to guide learning and problem-solving (Lee et al., 2011). From a more metatheoretical perspective of our theorizing approach, and in line with the general design theory development directions mentioned

above, we followed the *envision*-strategy proposed by Burton-Jones et al. (2021) for next-generation theorizing. In doing so, our proposed design theory helps to study a new phenomenon (i.e., synthetically generated image data in computer vision) emerging in a changing world (i.e., dynamic digital health domain and increased ethical awareness), which effectively leads to a new IS theory.

Therefore, a multi-method research approach (Mingers & Brocklesby, 1997) consisting of a focus group session for data collection and two think-aloud sessions for evaluating the theorized artifacts was chosen to address the shortcomings of single methods and ensure validity. While the heuristic design theorizing process does not require formal evaluation (Gregory & Muntermann, 2014), we incorporated these evaluation episodes to align our design theory with the broader principles of DSR, ensuring both theoretical rigor and practical applicability. As such, our iterative, heuristic process of data collection and analysis ensured that the findings from these sessions were continually refined. We acknowledge that sample size is often questioned in qualitative research (Marshall et al., 2013; Hwang & Salvendy, 2010; Noushad et al., 2024), especially when dealing with smaller numbers of participants (see Figure 8 for our study sample), who in our case were selected for their specialized expertise in synthetic (image) data, digital ethics, and AI in digital health. However, theoretical saturation was reached when no new insights emerged to further inform our design theory (Glaser & Strauss, 2017; Charmaz, 2006), while data saturation occurred when additional data collection did not yield new second-order themes or aggregate dimensions (Saunders et al., 2018), signaling that further data would not contribute new insights. Code/thematic saturation (Bowen, 2008; Guest et al., 2020; Hennink et al., 2022) confirmed that the identified themes fully captured the essence of our study focus, even after adding or subtracting experts from the sample. Finally, we reached meaning saturation, where our interpretive understanding of the themes was fully developed, and no new meaning could emerge from additional data or sessions (Hennink et al., 2017; Yang et al., 2022). The depth of engagement with our expert participants allowed us to make meaningful design decisions without the need for a larger participant pool, focusing on the premise that qualitative rigor comes from the richness of the data rather than the number of participants (Bryant & Charmaz, 2007; Sandelowski, 1995). The rather small sample size was used to ensure the participation of a practical and realistically recruitable subset of the target community, allowing for a focused yet meaningful evaluation of the proposed design requirements and principles by relevant practitioners outside the DSR project (Iivari et al., 2021).



Note: SH=structuring heuristics; DH=artifact design heuristics; DR=design requirement; DP=design principle; AD=aggregate dimension; DT=design theory.

Figure 4. Heuristic Design Theorizing Approach, adapted from Gregory and Muntermann (2014)

Table 2. Value-Sensitive Design as a Companion to the Heuristic Design Theorizing Process

Kernel Theory Steps of Value-Sensitive Design	Application in our Health and Ethics Context	Application in the Heuristic Design Theorizing Process
1) *Start with a Value, Technology, or Context of Use*	Synthetic image data in the context of digital health deep learning, focusing on ethical implications, privacy concerns, and the need for unbiased AI models.	Corresponds to the initial entry into the theorizing process where the "wicked problem perception" is identified. Transitions into problem decomposition (SH1).
2) *Identify Direct and Indirect Stakeholders*	Researchers, designers, developers and regulatory bodies as direct stakeholders. Patients and healthcare providers as indirect stakeholders.	Corresponds to the problem decomposition where stakeholders' roles and impacts are considered.
3) *Identify Harms and Benefits for Each Stakeholder Group*	Identified privacy breaches, bias, misrepresentation as potential harms. Identified model performance, accuracy, scalability, and applicability as potential benefits.	Occurred during the problem decomposition and continued through the analogical design and playing with kernel theory stages where potential design solutions were discussed and evaluated.
4) *Map Harms and Benefits onto Corresponding Values*	Aligned identified harms and benefits with the ethical values of privacy and consent, fairness and non-discrimination, accountability and transparency, and beneficence and non-maleficence.	Achieved through analogical design stages where harms and benefits are aligned with the defined ethical values. Subsequently, these were incorporated into design requirements and principles.
5) *Conduct a Conceptual Investigation of Key Values*	Analyzed values and enriched them by theoretical and practical underpinnings to ensure they are embedded in the design requirements and principles.	Conducted in-depth theoretical analysis and aligned these insights with the theory-building dimensions of the think-aloud content analysis.
6) *Identify Potential Value Conflicts*	Addressed conflicts such as performance vs. transparency or anonymity vs. accountability, and balancing these in the design theory.	Addressed through problem reformulation (SH2) and iterative design cycles to balance conflicting values and find adequate design solutions.
7) *Integrate Value Considerations into the Design Process*	Ensured that the design and implementation processes are aligned with the ethical values/standards of the design theory.	Corresponds to the final design and the exit of the heuristic theorizing process.

As shown in Table 2, and according to our analyze-with-lens kernel theory mechanism (Möller et al., 2022), we used value-sensitive design to inform our heuristic theorizing process in terms of the methods used and aspects of the design requirements and principles. By incorporating value-sensitive design theory as a theoretical lens into the heuristic theorizing process, we ensure that ethical values are systematically integrated into both our research methodology and the design artifact. Thus, we based the structured heuristics (SH1, SH2) on problem decomposition and reformulation and their understanding of ethical and technical challenges. Subsequently, our artifact design heuristics (DH1-DH7) ensured that our design artifact embodied the identified values and addressed the key ethical and technical concerns. Thus, the iterative process of value-sensitive design accompanied the equally iterative nature of our DSR methodology.

As shown in Figure 4, our multi-cyclical research approach contains two sequentially completed design cycles, with each of them containing theorized artifacts, whereas the second completed cycle drew on the conclusion of the first one. The design knowledge encompasses the collective design intuitions, design decisions, principles of form and function, and the descriptive insights employed to comprehend the problems and formulate the respective solutions in each cycle. Therefore, the approach and results within this paper are presented for both design cycles.

The first design cycle was dedicated to gathering initial and foundational design knowledge about the use of synthetic image data in digital health computer vision environments, focusing on information security and model performance. In this first cycle, the main artifact proposed was a set of nascent design principles based on the literature and a qualitatively analyzed focus group session with AI experts (n = 11). For the qualitative content analysis, we followed the methodological approach proposed by Gioia et al. (2013) and developed first-order concepts, second-

order themes, and aggregate dimensions (AD). This particular content analysis methodology is used to build theory within IS (Magnani & Gioia, 2023) and provides our foundation for design requirement development. This approach to concept development allowed us to balance the often-conflicting goals of developing new concepts inductively and maintaining high standards of rigor in IS research. We used first-order coding (inductive) to capture informant-centered concepts, which were then interpreted into second-order themes through constant comparison and theoretical reflection (abductive), as shown in Böhmer et al. (2023). These themes were then aggregated into four dimensions representing core design constructs: *privacy and ethical compliance* (AD1), *data governance* (AD2), *synthetic scene generation* (AD3), and *robust learning and generalization* (AD4). These ADs, together with the literature, formed the basis of the design principles, which are prescriptive and universal in this context, specifying how an instantiation should be designed to meet the proposed requirements (Fu et al., 2016). In this context, the design principles were derived from a supporting approach (Möller et al., 2020) that complements the conceptual scheme of Gregor et al. (2020) (see Appendix A for the detailed scheme), whose a priori specification suggests a prescriptive formulation (Fu et al., 2016). Moreover, the use of the framework allowed us to formulate accessible, precise, and expressive design knowledge (Gregor et al., 2020). By evaluating the reusability of the design principles in the context of digital health (Iivari et al., 2021), we derived several areas for improvement and revision, which were crucial for initiating the second design cycle. Evaluation feedback from the first cycle included suggestions for strengthening the responsible AI paradigm due to ethical and social concerns, revising ambiguous design principle descriptions, addressing control mechanisms in data generation, and reevaluating the strategy for increasing complexity in synthetic scenes. Concerns were also raised about the specific applicability of these principles in the digital health domain, especially in the context of digital ethics, through potentially missing design knowledge, as their applicability may vary in different support, treatment, or diagnostic contexts, which ultimately triggered the need for a second cycle. Based on the evaluation feedback from the first cycle and its results (Böhmer et al., 2023), we decided to revise the artifact and conduct a second cycle, focusing on a more holistic theoretical approach, incorporating the revision suggestions, and operationalizing our design theory artifact.

Design Theory

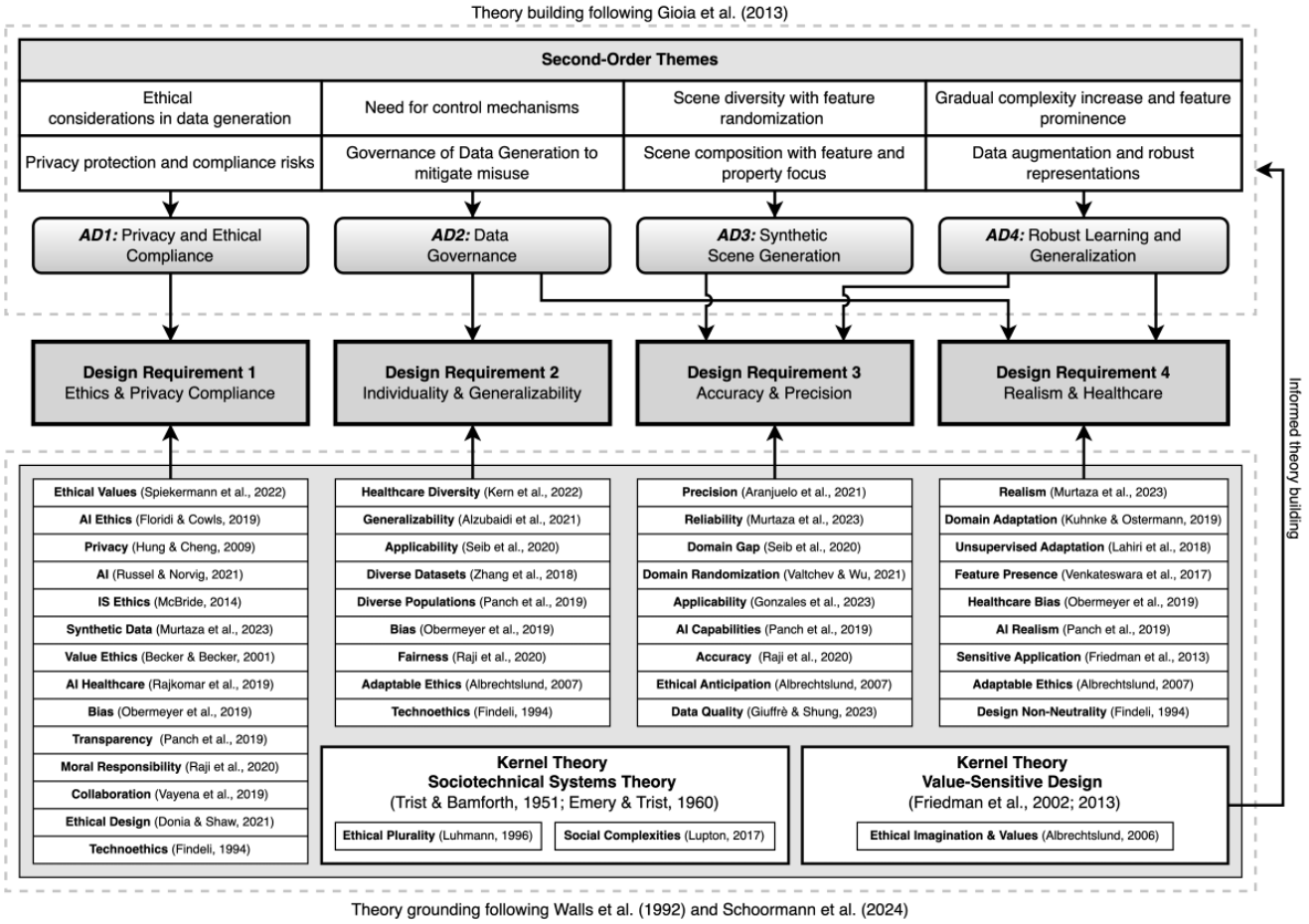
Design Requirements

The design requirements outlined by our design theory serve as the main objectives for the theoretical and conceptual artifact. In a way, these requirements can be seen as meta-requirements, as they guide the development of the subsequent reference architecture (Baskerville & Pries-Heje, 2010; Walls et al., 1992; Schoormann et al., 2024). Following evaluation feedback on missing design requirements from cycle 1 (cf. Table 2), we derived the requirements of *ethics & privacy compliance* (**DR1**), *individuality & generalizability* (**DR2**), *accuracy & precision* (**DR3**), and *realism & healthcare relevance* (**DR4**). Figure 5 shows both the theory building (Gioia et al., 2013) and theory grounding (Walls et al., 1992; Schoormann et al., 2024) of those DRs, while Figure 6 shows a simplified depiction of our design theory and its core components.

When working with synthetic image data in digital health, it is crucial to ensure that all processes related to the generation and use of synthetic imagery are ethical and privacy-compliant (**DR1**), protecting individual privacy rights and ethical norms (Dadgar & Joshi, 2018; Mueller et al., 2018). Drawing from *AD1*, it highlights the need for ethical responsibility in the development and deployment of technologies that handle sensitive data in digital health environments as depicted by value-sensitive design theory (Friedman et al., 2002; 2013), the use of ethical values in IS (Spiekermann et al., 2022), and the general necessity for ethical AI and IS considerations (Floridi & Cowls, 2019; Hung & Cheng, 2009; McBride, 2014; Murtaza et al., 2023; Russell & Norvig, 2021). While it builds on general meta-level guidance on ethical research in IS (Myers & Venable, 2014; Herwix et al., 20222), it embodies the core ethical values, which include adherence to the aspects of privacy and consent, fairness and non-discrimination, accountability and transparency, and beneficence and non-maleficence. Grounded in philosophical, sociological, and phenomenological ethics, Donia and Shaw (2021) emphasize the role of designer agency in embedding ethical values, while Findeli's (1994) concept of "technoethics" emphasizes the moral responsibility of designers to consider the ethical implications of technological decisions and to ensure privacy. Deng et al. (2016) and Yetim (2011) emphasize the need for fairness, inclusiveness, and transparency, reinforcing the importance of ethical guidelines and privacy protection in the generation of synthetic data, especially in understanding stakeholder values (Denning et al., 2014). These tenets ensure compliance with privacy standards such as GDPR, promote equitable treatment, require transparent methodologies, and focus on maximizing benefits

while minimizing harms, thereby aligning synthetic data use with societal values and ethical standards (Becker & Becker, 2001; Hung & Cheng, 2009; Floridi, 2010; Russel & Norvig, 2021). In this context, it is important to recognize that while synthetic data is artificially generated, it can still pose risks of re-identification and privacy breaches if not properly managed. This is particularly relevant when the synthetic data is modeled on sensitive real-world datasets, as it may inadvertently retain identifiable features or patterns (Giuffrè & Shung, 2023; Gonzales et al., 2023). For example, synthetic images generated from a dataset of patient scans may still contain patterns or features that, when combined with other data, could potentially be traced back to the original patient. Therefore, DR1 emphasizes the critical need for rigorous data governance and transparency in the synthetic data generation process to avoid a false sense of security (i.e., the misconception that it is just "artificial data"). This ensures that synthetic data does not circumvent ethical and legal obligations, especially when it reflects the sensitive real-world scenarios for which models are trained. As originally proposed by sociotechnical systems theory (Trist & Bamforth, 1951; Emery & Trist, 1960), the need for joint optimization of social and technical subsystems emphasizes preventing the technical subsystem (i.e., data generation) from undermining the social subsystem (i.e., ethical values and practices) by balancing technical capabilities with social imperatives. This approach is based on Mumford's (2006) reflections on the need to align social and technical elements to achieve sustainable outcomes. Hence, Rajkomar et al.'s (2019) insights into the diverse applications of AI in healthcare, including improving patient care and addressing ethical challenges, set the stage for a more informed and balanced adoption of these technologies. The imperative to uphold ethical standards and protect privacy in digital health is further highlighted by Obermeyer et al. (2019) and the importance of addressing bias in healthcare AI to avoid ethical pitfalls, while Panch et al. (2019) inform DR1 in the context of the ethical and practical challenges of implementing AI in healthcare, emphasizing the need for transparency and protection of patient privacy. Therein, the work of Raji et al. (2020) serves as a guiding frame for the moral responsibilities that accompany the deployment of AI technologies, especially those with profound societal impacts. Building up on this, DR1 is further grounded in the framework proposed by Vayena et al. (2019) as their advocacy for a multi-stakeholder approach resonates with the need for collaborative efforts in developing AI solutions that are not only innovative but also ethically sound and respectful of privacy and data security.

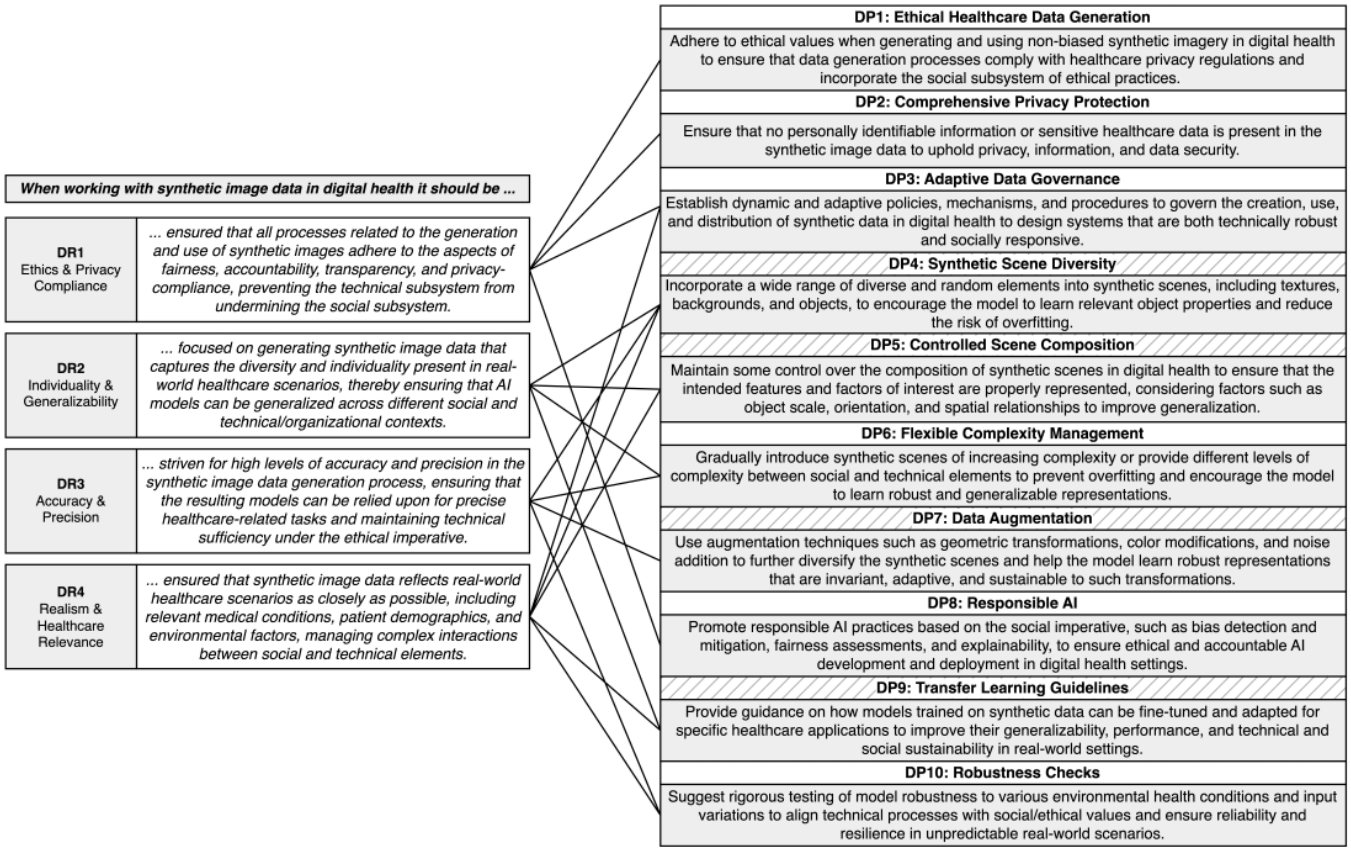
Drawing from *AD2*, **DR2** highlights the importance of capturing the diversity and individuality present in real-world healthcare scenarios (Kern et al., 2022), ensuring that models trained on synthetic data are highly generalizable and applicable to a wide range of situations (Alzubaidi et al., 2021; Seib et al., 2020). These diverse applications can cover areas such as predictive healthcare (Gonzales et al., 2023), evaluation and testing (Murtaza et al., 2023), or classifying diseases (Giuffrè & Shung, 2023), and set the objective of high generalizability in various healthcare settings. The call for comprehensive and diverse datasets (Zhang et al., 2018) further supports DR2, highlighting the need for AI in healthcare to encompass a wide range of patient data to ensure applicability across different patient demographics and conditions, which is consistent with advocacy for AI systems in healthcare that are not only accurate but also versatile in their application to address the nuanced needs of diverse patient populations (Mueller et al., 2018; Panch et al., 2019). Drawing on phenomenological and socio-technical perspectives, Albrechtslund (2007) emphasizes the need for adaptable designs to manage the multistability of technology, while, again, Findeli's (1994) principle of "technoethics" reinforces the ethical obligation to avoid bias in the representation of patient demographics and medical conditions. This further aligns with value-sensitive design's emphasis on autonomy and diversity, which highlights the need for synthetic data models to be generalizable and adaptable to different healthcare scenarios (Deng et al., 2016), as well as the importance of addressing diverse patient values and needs (Dadgar & Joshi, 2018). In addition, the ethical dimension of AI model development, particularly in terms of bias and fairness, as discussed by Raji et al. (2020) and Obermeyer et al. (2019), is integral to DR2. From a sociotechnical systems theory perspective, this means designing data and systems that are responsive to the needs and concerns of patients, healthcare providers, and regulators. This follows Baxter and Sommerville's (2011) emphasis on designing technically robust and socially responsive systems, ensuring that governance frameworks consider the diverse requirements of all stakeholders, thus maintaining the integrity and applicability of synthetic data across different healthcare settings (Rajkomar et al., 2018). In general, the mentioned studies shed light on the need to develop AI tools that are not only high-performing but also fair and unbiased in different healthcare settings. Thus, DR2 embodies the aspect of developing synthetically trained AI models that are ethically sound, highly generalizable, and adaptable to the diverse nature of digital health.



Note: AD = aggregate dimension

Figure 5. Theory Building and Theory Grounding of the Design Requirements

Drawing from both *AD3* and *AD4*, **DR3** addresses the need for high levels of accuracy and precision in the synthetic image data generation process. This is crucial in ensuring that the resulting models can be reliably employed for precise healthcare-related tasks (Aranjuelo et al., 2021; Murtaza et al., 2023; Seib et al., 2020; Valtchev & Wu, 2021, Giuffrè & Shung, 2023), ultimately benefitting patient outcomes in a variety of potential applications (Gonzales et al., 2023). Thus, the importance of high accuracy in healthcare AI applications is driven by the importance of realistic assessments of AI capabilities to prevent potential misdiagnoses or treatment errors (Panch et al., 2019). DR3 further addresses the need to maintain accuracy in AI algorithms, especially in sensitive applications such as facial recognition (Raji et al., 2020), drawing a parallel to the criticality of accuracy in healthcare AI. The issue of competence marginalization in repetitive tasks supports the need for synthetic images to be accurate and capable of handling complex healthcare tasks (Deng et al., 2016). Therefore, it raises awareness regarding potential risks or inaccuracies in AI models, especially in terms of perpetuating biases, which can have serious consequences in healthcare decision-making (Obermeyer et al., 2019). This is further rooted in the potential value trade-off between performance and ethics, and the discourse on pragmatic, ethical, and moral issues (Yetim, 2011; Albrechtslund, 2007) that encompass the appropriate use and impact of security designs (Denning et al., 2014). Given this potential value trade-off, a nuanced understanding and management of both the technical and social subsystems is required, maintaining technical sufficiency in terms of accuracy and precision while focusing on the ethical value imperative as per sociotechnical systems theory (Trist & Bamforth, 1951; Emery & Trist, 1960; Mumford, 2006). Therefore, DR3 captures the essence of producing synthetically trained deep learning models that are not only technically proficient but also reliable and safe in their application in healthcare.



Note: AD = aggregate dimension; DR = design requirement; DP = design principle; Hatched DPs = generally applicable across domains.

Figure 6. The Core Constructs and Simplified Representation of our Design Theory

Lastly, **DR4** draws from *AD2* and *AD4* and emphasizes the importance of ensuring that synthetic image data is reflective of real-world healthcare scenarios (Murtaza et al., 2023), accurately representing relevant medical conditions, patient demographics, and environmental factors through adequate domain adaptation (Kuhnke & Ostermann, 2019; Lahiri et al., 2018; Venkateswara et al., 2017). It stresses the importance of addressing biases in healthcare AI, which resonates with DR4's focus on accurately representing diverse patient populations and conditions (Obermeyer et al., 2019). Herein, the critical examination by Panch et al. (2019) of the realistic application of AI in healthcare underscores the necessity for DR4 to ensure that synthetic image data is not only functional but also aligns with the realistic and ethical considerations crucial in the medical and digital health domain. This further ensures that the technology is not only functional but also ethically sound and user-centric, aligning with value-sensitive design theory (Mueller et al., 2018; Friedman et al., 2002; 2013) and maintaining ethical adaptability (Albrechtslund, 2007; Findeli, 1994). Particularly, the value placed on making a meaningful impact drives the need for synthetic data that accurately reflects real-world healthcare contexts (Dadgar & Joshi, 2018; Deng et al., 2016). Further grounded in sociotechnical systems theory, DR4 addresses the need to manage complex interactions between social and technical elements. Bostrom and Heinen's (1977) analysis of MIS failures through a sociotechnical systems lens reinforces the need to consider both human factors and technical specifications to ensure that synthetic image data accurately represents the complexity of real-world healthcare scenarios and can be effectively used to train deep learning models.

Design Principles

Based on evaluation feedback from the first design cycle, we have revised DP1, DP2, DP3, and DP6 to make them more accessible, easier to understand (in regards to general AI domains), and more nuanced in their connection to digital health. As shown in Figure 4, we added DP8, DP9, and DP10 throughout our heuristic theorizing process to ensure a strong ethical and model performance focus. The addressed connections between the design requirements and principles can be seen in Figure 6. **DP1** draws from *AD1* and states that ethical guidelines and principles should be followed when generating and utilizing synthetic image data. Incorporating value-sensitive design theory (Friedman et al., 2002; 2013) with value embedding (Donia & Shaw, 2021) and meta-ethical

guidance (Myers & Venable, 2014; Herwix et al., 2022), it is important to align data generation processes with privacy regulations and to show respect for individual privacy rights (Floridi & Cowls, 2019; Hung & Cheng, 2009; McBride, 2014; Murtaza et al., 2023; Russell & Norvig, 2021; Spiekermann et al., 2022). Following Donia and Shaw's (2021) emphasis on designer agency and Findeli's (1994) concept of "technoethics," ethical guidelines should ensure the constraint that every technological act (i.e., using synthetic image data in digital health AI) has an ethical dimension where design decisions are not neutral. DP1 underscores the imperative to recognize that while synthetic data is artificial, it is not inherently private; rigorous oversight is required to prevent the accidental inclusion of sensitive or identifiable information that could compromise privacy based on real-world reference data. Therefore, care should be taken to employ suitable data generation techniques (e.g., via Unity3D) and to refrain from incorporating sensitive information or biases that could potentially compromise the privacy or security of individuals. Informed by the ethical values of DR1, the critical role of transparency in reducing marginalization supports the need for ethical, transparent synthetic image generation processes (Deng et al., 2016; Mueller et al., 2018; Panch et al., 2018). In addition, DP1 addresses Yetim's (2011) advocacy for discourse ethics, supporting transparency and ethical integrity throughout the synthetic data generation process. This means documenting and explaining the decisions made in generating synthetic imagery, such as the selection of source data, the algorithms used, and the rationale behind those decisions (Obermeyer et al., 2019; Panch et al., 2019). Such transparency is critical to building trust among users and stakeholders, and to ensuring accountability in the use of synthetic data (Panch et al., 2018; Raji et al., 2020; Vayena et al., 2018). It further ensures the generation of synthetic data upholds the ethical values as stated in DR1, aligning with Mumford's (2006) emphasis on balancing social and technical elements to prevent the technical subsystem from undermining these values.

DP2 also builds on *AD1* and addresses the need for the synthetic image data to contain no personally identifiable information (PII) or sensitive data, which often depends on how the data is generated and processed. As such, it addresses the ethical principles of public interest, informed consent, and privacy (Myers & Venable, 2014). DP2 is based on Albrechtslund's (2007) call for flexible ethical designs and Luhmann's (1996) reflections on societal norms and requires that synthetic data be thoroughly anonymized to prevent re-identification while also adapting to unforeseen or anticipated ethical challenges. In general, the idea of synthetic data is to create a dataset that mimics real-world data without actually containing sensitive information. However, there are scenarios where PII or sensitive data may still be present when closely derived from real patient data that may risk re-identification or contain sensitive metadata, raising privacy and bias concerns. DP2 emphasizes the critical need to recognize that synthetic data, while artificial, is not automatically free of privacy risks; it is essential to apply robust anonymization techniques to ensure that even subtle, potentially identifiable characteristics of the real image reference are not replicated, thereby protecting against re-identification and privacy breaches. As such, concerns about security and exploitation align with the importance of excluding identifiable information from synthetic data (Deng et al., 2016). Techniques such as imperfect anonymization (e.g., altering key features in scans) or model inversion attacks (i.e., reconstructing patient data) can inadvertently reveal PII. Hence, it is necessary to anonymize or obfuscate any elements that could potentially reveal an individual's identity (Giuffrè & Shung, 2023; Hansen & Baroody, 2020; Hung & Cheng, 2009; Kern et al., 2022). To achieve this, DP2 recommends the implementation of advanced anonymization techniques that go beyond the removal of obvious identifiers such as names or faces (Raji et al., 2020). They extend to subtle features that, in combination, could lead to the identification of an individual (Panch et al., 2019; Vayena et al., 2018). This could include background details, specific patterns, or even color schemes that may be unique to a person's environment or possessions. It is recommended that comprehensive privacy mechanisms be incorporated into the generation and use of synthetic image data, where controlled noise or perturbations are introduced during data generation to prevent individual data points from being distinguished with a high degree of certainty (Seib et al., 2020; Zhang et al., 2018). This approach can protect the privacy of individuals even in the presence of external information.

Based on *AD2*, **DP3** states that mechanisms should be implemented to control and regulate the generation of synthetic image data, such as process frameworks, toolkits, virtual environments, or guidelines (Gonzales et al., 2023; Murtaza et al., 2023). Following DP1 and DP2, DP3 emphasizes that even though synthetic data is artificially generated, it requires strong governance frameworks to ensure that its creation and use are conducted ethically and responsibly, recognizing that artificial data is not inherently free from risks related to privacy, security, and ethical concerns. Advocating the establishment of clear and comprehensive governance structures, these structures should not only enforce regulations but also foster an environment of responsible and ethical use of synthetic imagery (Panch et al., 2019; Vayena et al.,

2018). This includes the development of robust process frameworks to guide each stage of data generation, from initial design to final output (Rajkomar et al., 2018), which should be based on common meta-ethical guidance (Myers & Venable, 2014; Herwix et al., 2022). These frameworks should be flexible enough to adapt to different contexts and use cases while maintaining a core set of ethical and privacy standards (Panch et al., 2019; Rajkomar et al., 2019). For example, it makes sense to use automated compliance checks, data anonymization templates, and simulation environments to safely test data generation methods without risking data breaches. Hence, policies and procedures need to be established to govern the creation, usage, and distribution of synthetic data to prevent unauthorized access or misuse, ensuring value-sensitive compliance (Becker & Becker, 2001; Friedman et al., 2002; 2013). In that context, the suggestion of structured deliberation and boundary critique reinforces the need for comprehensive governance frameworks to guide ethical synthetic data generation (Yetim, 2011). As such, the need for ICTs that support patient autonomy and accountability suggests the importance of establishing governance structures that ensure ethical and responsible generation and use of synthetic image data (Dadgar & Joshi, 2018). This design principle underscores the need for socio-technical governance that can flexibly adapt to changes in both the technological landscape and the organizational culture of healthcare institutions (Mumford, 2006; Baxter & Sommerville, 2011).

DP4 stems from *AD3* and specifies that a wide range of diverse and random elements should be incorporated into synthetic scenes, including textures, backgrounds, and objects, to address a variety of security concerns and contexts (Denning et al., 2014). Following Lupton (2017) and Donia and Shaw (2021), such scene diversity must incorporate sociocultural variability to ensure the representation of diverse patient populations and settings without reinforcing biases. By introducing a wide range of diverse elements into synthetic scenes that challenge conventional assumptions and biases (Obermeyer et al., 2019; Raji et al., 2020), models can be trained to recognize and understand objects in a variety of contexts, reducing the likelihood of bias toward specific environments or scenarios and model overfitting. This approach is particularly beneficial for models used in dynamic and unpredictable real-world environments. For example, in digital health, a model trained on a variety of scene elements is better able to recognize medical devices or conditions in a variety of settings, from well-equipped urban hospitals to resource-limited rural clinics (Rajkomar et al., 2019). By varying these factors, the model will be encouraged to learn relevant object characteristics instead of relying on color or other irrelevant cues (Scheck et al., 2020; Seib et al., 2020). To further improve generalization, cross-domain scene randomization should be used, which involves incorporating scene elements from different domains or contexts (e.g., non-healthcare elements in healthcare settings). Introducing unconventional backgrounds, objects, or textures that are not typically associated with the objects of interest can push the model to learn their intrinsic properties, thereby promoting adaptability to real-world scenarios (Seib et al., 2020; Valtchev & Wu, 2021).

DP5 closely connects to DP4 and further relates to *AD3*, stating that while aiming to promote scene diversity (and randomness), it is important to maintain a level of control over the composition of synthetic scenes. Albrechtslund's (2007) and Findeli's (1994) integration of ethical and aesthetic values suggests that synthetic scenes should be carefully composed to balance diversity, adaptability, and realism while respecting ethical dimensions. While it is crucial to introduce variety and randomness, it is equally important to ensure that these elements do not overshadow or distort the primary objects of interest in the scene. This balance is achieved by carefully controlling aspects such as scale, orientation, and spatial relationships of objects within the scene (e.g., the scale and proportions of disease characteristics or living environments). This ensures that the intended features and factors of interest are properly represented, where factors such as object scale, orientation, and spatial relationships should be considered to enhance generalization (Krump et al., 2020; Scheck et al., 2020). Rather than relying solely on changing the appearance of synthetic objects, the focus should be on varying their key features, and changing attributes such as shape, size, material properties, and structural characteristics will challenge the model to learn object representations. By doing so, models are trained to recognize and understand the essence of objects, making them more robust to changes in appearance that might occur in real-world settings. In addition, DP5 recognizes the importance of contextual relevance in synthetic scene composition. Objects should be placed in contexts that are representative of real-world scenarios, even when introducing elements of randomness. This approach ensures that while the model is exposed to a wide range of scenarios, it still learns to associate objects with their typical environments and situations.

DP6 draws from *AD4* and addresses the introduction of synthetic scenes with varying complexity. It emphasizes the strategic introduction and flexible management of complexity in synthetic scenes to optimize the learning process of deep learning models, addressing the value trade-off between security needs

and usability (Denning et al., 2014). The approach can start with simpler scenes or a variety of complexity levels, allowing the model to first understand and identify the core characteristics of the objects and factors of interest. As the model becomes more proficient, more complex elements and scenarios can be gradually introduced. This incremental approach helps build a solid foundation before exposing the model to more challenging environments (Alzubaidi et al., 2021; Bird et al., 2020; Seib et al., 2020; Wan et al., 2021). On the other hand, the varied complexity aspect prevents the model from becoming overly specialized in recognizing only simple scenes and instead promotes the development of a more adaptive and versatile learning capability. As such, this design principle emphasizes the importance of managing complexity in a way that is consistent with the socio-technical challenges of digital health and promotes models that are both socially sound and technically feasible (Mumford, 2006; Bostrom & Heinen, 1977). By encountering a wide range of complexity early on, the model is trained to generalize better across different scenarios, increasing its effectiveness in real-world applications. In addition, DP6 emphasizes the importance of monitoring and adjusting model performance as complexity increases. Regular evaluation is necessary to ensure that synthetically trained models are not only able to cope with the increased complexity but also learn effectively from it to be used in the highly precise digital health environment (Panch et al., 2019; Rajkomar et al., 2019). If the model shows signs of struggle or overfitting, the complexity can be adjusted accordingly to find the right balance that promotes learning without overwhelming the model. Finally, DP6 recognizes the need for diversity in the types of complexity introduced. This includes not only quantitative changes (such as more objects) but also qualitative changes (such as different types of interactions or more nuanced object properties). This comprehensive approach to complexity ensures that the model is well-rounded and prepared for a wide range of situations.

DP7 also stems from *AD4* and states that augmentation techniques, such as geometric transformations, color modifications, and noise addition, should be utilized to enhance the diversity of synthetic scenes (Müller et al., 2018; Seib et al., 2020; Zhang et al., 2018). By applying geometric transformations such as scaling, rotating, and mirroring, models can learn to recognize objects regardless of their orientation or position within the scene. This helps build a more versatile model capable of recognizing objects in different spatial arrangements. Color modifications also play a critical role in enhancing synthetic scene diversity. Adjusting brightness, contrast, saturation, and hue can help the model become resilient to changes in lighting conditions and color variations that occur in real-world environments (Seib et al., 2020). This aspect of augmentation ensures that the model's performance is consistent across different visual presentations. By introducing noise through random variations at the pixel level, models are trained to focus on the essential features of an object rather than being misled by minor imperfections or variations in image quality, which correlates with DP4. This type of augmentation is particularly useful in scenarios where the model must perform reliably despite the presence of visual noise, such as in low-resolution images or when dealing with sensor imperfections. DP7 further advocates for the use of more advanced augmentation techniques, such as perspective warping and synthetic occlusion. These methods introduce additional levels of complexity, teaching the model to understand objects even when they are partially obscured or viewed from unusual angles (Seib et al., 2020; Zhang et al., 2018). These techniques simulate real-world variations and assist the model in learning robust representations that remain invariant to such transformations, which further mitigates the risk of model overfitting (Alzubaidi et al., 2021). This design principle reflects the general socio-technical imperative to create synthetic data that can be generalized across different healthcare settings and patient populations, ensuring that AI models are adaptable and sustainable (Emery & Trist, 1960). Nonetheless, DP7 emphasizes the importance of balancing the augmentation process. Over-augmentation can lead to unrealistic synthetic scenes that do not represent real-world conditions, potentially hindering the model's ability to generalize effectively. Therefore, it is critical to find the right mix of augmentation techniques that enhance scene diversity while maintaining realism.

Drawing from *AD1*, **DP8** emphasizes the importance of promoting responsible AI practices, including bias detection and mitigation, fairness assessments, and explainability, to guarantee ethical and accountable AI development and deployment in digital health settings (Alzubaidi et al., 2021; Floridi & Cowls, 2019; Hung & Cheng, 2009; McBride, 2014; Murtaza et al., 2023; Obermeyer et al., 2019; Russell & Norvig, 2021; Vayena et al., 2018). DP8 emphasizes that although synthetic data is used in AI development, it does not inherently eliminate bias or ensure fairness, so it is critical to implement robust bias detection, fairness assessment, and accountability practices. This is critical to maintaining trust and transparency in healthcare AI applications, especially in value-sensitive environments (Friedmann et al., 2002; 2013; Herwix et al., 2022), where the responsibility of AI developers is balanced between technical and social/ethical imperatives (Mumford, 2006, Donia & Shaw, 2021; Luhmann, 1996). As such, the duality of empowerment and marginalization suggests the need

for continuous bias detection and mitigation in AI models (Deng et al., 2016; Panch et al., 2018; Rajkomar et al., 2018). Hereby, bias detection and mitigation are key components of DP8, including the use of diverse synthetic datasets for training to ensure that AI models do not inherently favor or disfavor any particular group of patients (Obermeyer et al., 2019; Vayena et al., 2018). In addition, continuous monitoring for bias in AI decisions is recommended, along with the implementation of corrective measures when bias is detected. On the other hand, fairness assessments involve evaluating AI models to ensure that they make equitable decisions across different patient demographics (Obermeyer et al., 2019). The goal is to ensure that all patients receive fair and unbiased medical advice, assistance, or diagnoses, regardless of their background. In addition, explainability in AI models is also emphasized by DP8. In healthcare, medical professionals and patients must understand how AI models arrive at their conclusions. This transparency is critical to building trust in AI systems based on synthetic image data, as it allows users to validate the reasoning behind AI decisions and ensures that AI augments, rather than replaces, human judgment (Vayena et al., 2018). From a more indirect perspective, DP8 also calls for ethical training and awareness among those developing and using AI in healthcare. This includes educating AI professionals about the ethical implications of their work and the importance of considering the diverse needs and values of patients.

DP9 stems from AD4 and highlights the need for clear guidelines on how models trained on synthetic data can be fine-tuned and adapted for specific healthcare applications to enhance their generalizability and performance in real-world environments (Murtaza et al., 2023). Its adaptability is based on sociotechnical imperatives (Emery & Trist, 1960), which emphasize the need for systems to evolve and remain effective in dynamic environments. A major focus of DP9 is to establish protocols for domain adaptation. These are techniques that help the model adapt from the synthetic data environment to the nuances and characteristics of real-world healthcare data, tailoring systems to specific patient needs (Dadgar & Joshi, 2018). Such adaptation is critical for models to maintain high levels of accuracy and reliability when confronted with real patient data, which may differ considerably from the controlled conditions of synthetic datasets and artificial environments. In addition to domain adaptation, DP9 highlights the potential of fine-tuning models on real image data. This process involves adjusting the model parameters based on real digital health data to improve its performance and generalizability in clinical, assistive, or predictive settings. Fine-tuning ensures that the model is not only theoretically sound but also practically effective in diagnosing and treating real patients. This further ensures a working domain adaptation toward real-image model deployments and fine-tuning tasks on real-image data (Kuhnke & Ostermann, 2019; Lahiri et al., 2018; Venkateswara et al., 2017).

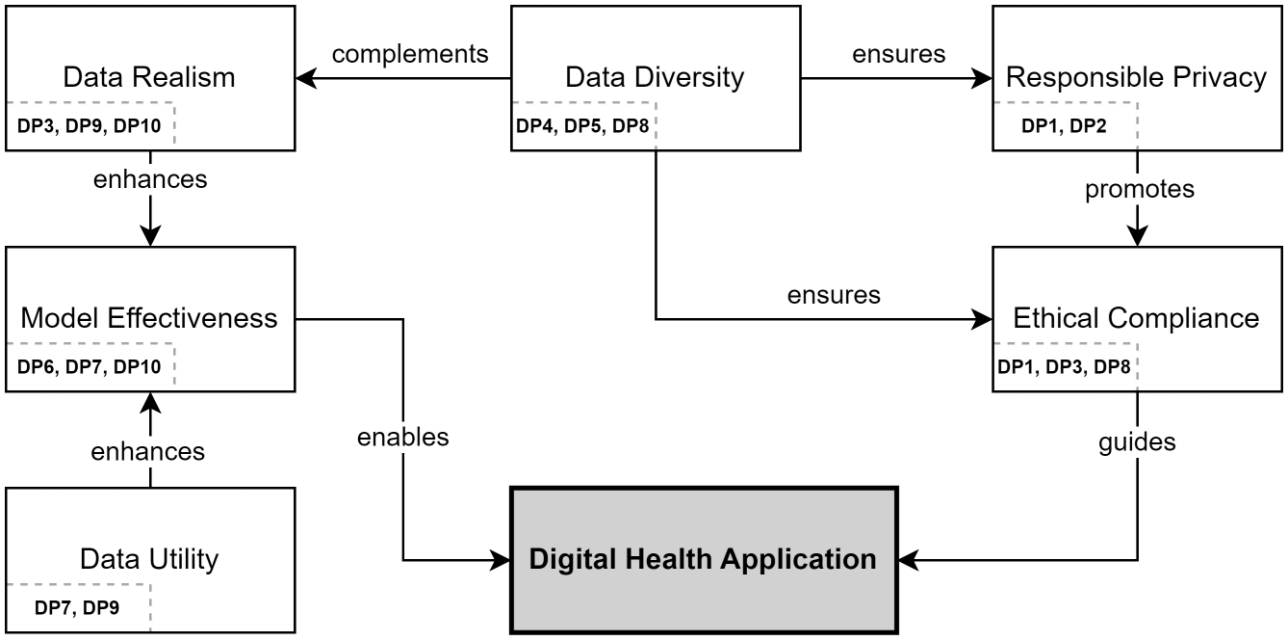
Lastly, **DP10** draws from *AD1* and *AD4*, underscoring the importance of conducting rigorous testing for model robustness against various environmental healthcare conditions and input variations. Emphasized by technological marginalization concerns (Deng et al., 2016), this robustness checking is essential to ensure the reliability and resilience of AI models in unpredictable real-world scenarios, safeguarding against potential errors or malfunctions that could have serious implications for patient care (Floridi & Cowls, 2019; Giuffrè & Shung, 2023; Gonzales et al., 2023; Rajkomar et al., 2019; Russel & Norvig, 2021; Valtchev & Wu, 2021). Hence, a key aspect of DP10 is the simulation of a wide range of environmental conditions during the testing phase. This includes variations in lighting, background noise, and other factors that could affect the performance of AI models in digital health settings. For example, a diagnostic AI tool should be tested for accuracy on different types of medical imaging equipment and under different imaging conditions to ensure consistent performance of the synthetically trained deep learning model. Following on from this, DP10 also emphasizes the importance of testing AI models on a variety of patient data. This includes data from patients of different ages, genders, ethnicities, and health conditions to ensure that the model will perform reliably across the diverse patient population it will serve (Obermeyer et al., 2019; Rajkomar et al., 2019; Vayena et al., 2018). This type of testing is critical to identify and mitigate any biases the model may have and to ensure equitable healthcare outcomes based on the synthetic image data fed to the model. In these scenarios, particularly in the digital health domain, and in light of a common utilitarian view that often overlooks social complexity (Lupton, 2017), it seems reasonable to stress test AI models to assess their resilience to extreme or rare scenarios. This could involve simulating emergencies or rare medical conditions to ensure that the AI model can handle such cases effectively without compromising accuracy or reliability. Finally, models should be continuously monitored and updated after deployment. As real-world conditions and healthcare practices evolve, AI models must be periodically reassessed and updated to maintain their robustness and reliability. As such, not only should their technical performance be assessed, but also their ethical and social implications (Mumford, 2006; Bostrom & Heinen, 1977), to ensure that any emerging issues or changes in health care standards are addressed promptly.

Following general design theory communication, justification, and cumulation, we adopted the outlined process for design theory "anatomy" proposed by Gregor and Jones (2007). Table 3 provides a summary of this process and shows how we have theorized along it.

Table 3. Components of a Design Theory (Gregor & Jones, 2007)

Component	Description
Purpose and Scope	The current trajectory of synthetic image data utilization in digital health computer vision settings is unguided and inconsistent due to its sudden occurrence in the rapidly evolving deep learning field. As such, this inconsistency may hinder the ethical deployment of such models and their performance in IS digital health applications. We aim to develop a design theory that will not only alter this trajectory but also path the way for ethical, effective, and compliant synthetic image use in such settings. Therefore, the theorized artifact's goals are: ensuring ethical and privacy compliance (**DR1**); focusing on individuality of image data and model generalizability (**DR2**); fostering model accuracy and precision through scene diversity (**DR3**); and ensuring data realism and healthcare feasibility (**DR4**).
Constructs	We conceptualize guiding and framing requirements and principles for the utilization of synthetic image data in digital health computer vision. As such, our proposed design requirements and design principles build the foundation for our conceptual model (Fig. 7), encompassing the constructs of data realism, model effectiveness, data utility, data diversity, responsible privacy, and ethical compliance that are representations of the entities of interest in our design theory.
Design Principles of form and function	Features of current synthetically trained computer vision deep learning models in digital health are fundamentally epitomized by uncontrolled data generation (i.e., potential misrepresentations, privacy data breaches, or ethnical biases), insufficient data and model preparation, overfitting problems, and faulty domain adaptation. The dynamic and rapidly evolving nature of digital health deep learning hence requires novel and contemporary guidance in the form of design knowledge on how to utilize such data in these sensitive environments. Through theorizing, ten relevant design principles were developed to address this goal (Figure 5): ethical healthcare data generation (**DP1**); comprehensive privacy protection (**DP2**); adaptive data governance (**DP3**); synthetic scene diversity (**DP4**); controlled scene composition (**DP5**); flexible complexity management (**DP6**); data augmentation (**DP7**); responsible AI (**DP8**); transfer learning guidelines (**DP9**); robustness checks (**DP10**).
Testable propositions	The design theory offers guidance on how to use synthetic image data in digital health both ethically and effectively. Therefore, the design principles and requirements as the core components of our design knowledge, offer high accessibility, importance, novelty and insightfulness, actability and guidance, and effectiveness. Users can design (synthetically trained) computer vision deep learning solutions in digital health by altering conventional approaches and adhering to our design theory. We view the testable propositions as varying in their degree of generality and as truth statements about our design theory, meaning that these general statements describe expected outcomes (i.e., addressing the DRs) based on the application of the DPs. Thus, we hypothesize that in the context of synthetic image data in digital health computer vision, if System A uses our design theory, it will work or be more ethical and efficient than a System B that does not. On a more granular level, the testable propositions here refer to the relationships between DRs and DPs, as shown in Figure 5, emphasizing that if someone has similar DRs in a different context, the corresponding DPs from our design theory can be applied and their effective relationship can be tested. To give a specific example, if DP4 (Synthetic Scene Diversity) is applied during synthetic image generation, the resulting data will (partially - since multiple DPs address DR3) satisfy DR3 (Accuracy & Precision), leading to improved model performance in diverse healthcare tasks, which can be tested by comparing the accuracy and precision metrics of models trained on diverse versus homogeneous datasets. Thus, the following testable propositions arise: **DR1** → *DP1/DP2/DP3/DP8*; **DR2** → *DP4/DP5/DP6/DP9*; **DR3** → *DP4/DP6/DP7/DP10*; **DR4** → *DP3/DP4/DP5/DP9/DP10*
Artifact mutability	We theorize the framing constructs for the utilization of synthetic image data in digital health as a type of guidance to change the current trajectory in digital health computer vision that works in a complementary relationship to real image-based approaches. Our theorized artifact can be used in various digital health computer vision domains, such as medical imaging, diagnosis, human computer interaction, monitoring, detection, or predictive analytics. In addition, it provides general design principles that can be applied across domains of synthetic image processing, and its applicability is deep learning-model independent.
Justificatory Knowledge	Universal themes of synthetic image data use and value sensitive design theory (Friedman et al., 2002, 2013) together with an initial think aloud session and first cycle evaluation feedback serve as the theoretical and practical foundations of our design theory. The chosen kernel theory and qualitative analysis findings remain consistent across various domains, justifying the derivation of DRs and DPs.

Component	Description
Principles of implementation	The universally design knowledge suggests various implementation criteria to the conventional use of synthetic image data in digital health that will yield ethical and performance outcomes. Thus, the design theory can be used in computer vision project processes as a form of feasible and applicable guiding knowledge. Therefore, we present 20 design features (Figure 8) that illustrate how we operationalized the design theory.
Expository instantiation	We developed a series of DRs and DPs that, alongside a conceptual model for synthetic image use in digital health, show how researchers can apply the proposed constructs to develop ethical and performant computer vision models. Furthermore, we show how the design theory can be used to derive theoretical models or concepts in digital health.



Note: DP = design principles.

Figure 7. Conceptual Model as Abstract Instantiation and Theorizing Step

Conceptual Model

As a result of our heuristic theorizing approach, we conducted various steps of modeling (i.e., Figures 6 and 7) to visually develop different types of representations of the problem solution (Gregory & Muntermann, 2014). Following one of many approaches to graphically depict a conceptual solution schema for design theories (Müller-Wienbergen et al., 2011), we developed a conceptual model based on our design theory for the ethical use of synthetic image data in digital health (Figure 7). Within the theorizing process, such a conceptual model enables a more accurate expression of the underlying assumptions, thoughts, constructs, and implications, and can be seen as an abstract instantiation of the design theory (Bittmann & Thomas, 2013; Schermann et al., 2009). As such, our conceptual model represents the abstract constructs as entities of interest in our design theory (Gregor & Jones, 2007; Kane et al., 2021).

Based on our design theory, and in particular the design principles, the conceptual model graphically depicts how the theorized constructs ultimately affect the application of synthetically trained computer vision models in digital health. Based on DP4, DP5, and DP8, *data diversity* complements *data realism* (DP3, DP9, and DP10) and ensures both *responsible privacy* (DP1, DP2) and *ethical compliance* (DP1, DP3, DP8). Thus, the conceptual model underscores the importance of a holistic design approach that integrates technical data and model robustness with rigorous ethical standards to promote trust and reliability in digital health settings. In addition, *data realism* and *data utility* (DP7, DP9) both enhance *model effectiveness* (DP6, DP7, DP10) while addressing potential biases to ensure that the use of these models leads to equitable and accurate health outcomes for diverse populations. Finally, *model effectiveness* enables ethical compliance to guide digital health applications, creating a balanced

framework where AI-driven solutions not only meet healthcare expectations but also align with ethical values and privacy concerns, paving the way for sustainable innovation in digital health.

Evaluation

To ensure rigor in evaluating our design cycles, the well-established FEDS framework proposed by Venable et al. (2016) was used. The evaluation phase is highly relevant in DSR (Hevner et al., 2004; Venable et al., 2016), as it is necessary to select an appropriate strategic process and determine the constructs to be evaluated. This complementary evaluation approach, while not integral or necessary to the heuristic theorizing process (Gregory & Muntermann, 2014), served to validate the reusability, practicality, and relevance of the design theory, ensuring that it "works" in real-world applications and resonated with stakeholder needs. Given the complexity of human factors in digital health, ethical considerations, and the practical application of technology in healthcare settings, the *Human Risk & Effectiveness* evaluation strategy (Venable et al., 2016) was chosen to address the socio-technical and value-based imperatives of our research (Figure 8).

While our problem-centered research approach was theory-driven (Schoormann et al., 2024; Iivari, 2015), we sought to balance both rigor and relevance in our evaluation strategy. Thus, the goal was to conduct an evaluation episode to complete both design cycles and to move quickly to a summative evaluation result. Despite the relatively small sample sizes of our evaluation episodes, we achieved theoretical, data, code, thematic, and meaning saturation, confirming that further data collection was unlikely to yield new insights. This saturation across multiple dimensions ensured the rigor and robustness of our findings and validated our evaluation approach as both thorough and efficient.

Design Requirement and Design Principle Reusability

To ensure the objectives of feasibility, accessibility, completeness, and applicability, we applied the framework of design principle reusability proposed by Iivari et al. (2021). This framework provides a systematic approach to evaluating the design principles generated during the design cycles, and by assessing the reusability of these principles, researchers can determine their potential for wider application and adoption in similar contexts (Iivari et al., 2021). Since we introduced additional design requirements for our design theory, and the framework was designed for the reusability of design principles, we adapted it to evaluate design requirements as well. Iivari et al. (2021) actively call for adaptations of their framework, for which we have applied it to a different level of design abstraction. Thus, we identified 3 levels of reusability for design requirements (RDR) based on the items in the framework: 1) direct application (items for design principles can be directly mapped to design requirements), 2) item adoption (individual items of a construct can be mapped), and 3) non-applicability (items cannot be mapped to design requirements). Because design requirements embody the objective that design principles address, their evaluation differs to some extent. To ensure content validity based on the framework and questionnaire (Iivari et al., 2021), the constructs of *accessibility* (i.e., understandability, comprehensibility, intelligibility) and *importance* (i.e., real and important problem addressing) were allocated to level 1 RDR and could be asked without tweaking them. The constructs of *actability and guidance*, and *effectiveness* were assigned a level 2 RDR with necessary adjustments. Therefore, we decided to use "sufficient guidance," "sufficient direction," and "sufficient freedom" for *actionability and guidance*, and "usefulness," "design help," and "artifact quality" for *effectiveness*, ensuring content validity by not evaluating items that are explicitly tied to design principles and their empirical validation on these items. Finally, the construct of *novelty and insightfulness* was assigned level 3 RDR and therefore deemed inapplicable due to the goal-oriented formulation of the design requirements. Consistent with our kernel theory of value-sensitive design and beyond the first cycle evaluation, a reconvened qualitative think-aloud session was conducted to address the reusability of the proposed design theory constructs. Therefore, the method of concurrent think-aloud (Van Den Haak et al., 2003) was employed with n=12 AI experts, where the sample size was decided based on the "10±2 rule" for think-aloud sessions (Hwang and Salvendy, 2010). The participants were asked to verbalize their thoughts about the design principles and requirements (to the aforementioned extent) in terms of the reusability categories proposed by Iivari et al. (2021). Table 4 presents the qualitative think-aloud results, including the categories of the reusability framework and the manually aggregated verbalized thoughts of the participants.

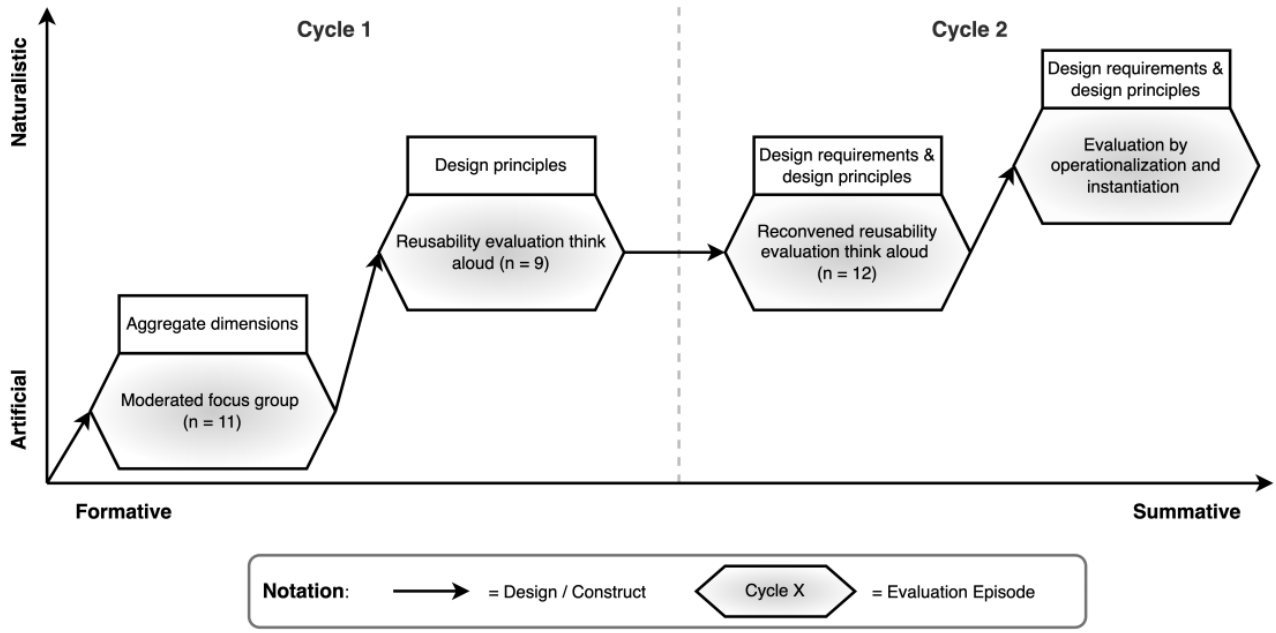


Figure 8. Evaluation Strategy Following the FEDS Framework (Venable et al., 2016)

Table 4. Reusability Framework According to Iivari et al. (2021)

Reusability Category	Design Theory Component	Verbalized Think Aloud Results
Accessibility	**Design Requirements**	The subjects stated the design requirements to be highly accessible in terms of their understandability, comprehensibility, and intelligibility. They particularly highlighted their detailed description and formulation, emphasizing the importance of ethical responsibility in the development and deployment of technologies that handle sensitive data in digital health.
	Design Principles	The subjects appreciated the prescriptive formulation of the design principles, especially the causality of cause and effect, which helped them understand. For some, a shorter description would have been sufficient, but for others, the comprehensive nature of the principles was crucial in ensuring a thorough grasp of the concepts and their application.
Importance	**Design Requirements**	The subjects emphasized that the design requirements address a real and particularly important problem, and highlighted **DR1** and **DR3** as their key requirements. Privacy and accuracy are paramount, and adherence to the DRs would enhance trust and responsible use of synthetic image data, ensuring not only the safeguarding of sensitive information but also the reliability and validity of the data generated for research and development purposes.
	Design Principles	The subjects highlighted the significant importance of DPs related to privacy and responsible AI (**DP1**, **DP2**, **DP3**, **DP8**) and positively assessed their importance. Especially these would address critical foreseeable problems in their professional practice. They acknowledged that incorporating these principles into their workflows would not only mitigate risks but also foster a culture of responsibility and integrity in the handling of such advanced technologies.
Novelty and Insightfulness	**Design Principles**	The subjects appreciated design principles related to synthetic scene diversity, complexity, and composition (**DP4**, **DP5**, **DP6**) as they not only conveyed new ideas to them but also found them insightful. They expressed that these are particularly innovative in regards to synthetic image data generation and its scalability, flexibility, and versatility, emphasizing the potential these principles have in safeguarding the way synthetic image data is utilized across various industries. By incorporating these principles, they foresee a significant enhancement in the quality and applicability of synthetic imagery, paving the way for more advanced, ethical, and diverse applications.

Reusability Category	Design Theory Component	Verbalized Think Aloud Results
Actability and Guidance	**Design Requirements**	The subjects indicated that the DRs would provide sufficient guidance, direction, and freedom for designing and working with synthetic image data in digital health. This would increase standardization across different implementations and lead to reasonably consistent interpretations, thus facilitating a uniform approach to handling data while allowing for innovative uses. The flexibility within the DRs was seen as a key factor in promoting creativity and adaptability in digital health solutions, ensuring that evolving needs and challenges in the field can be met effectively.
	Design Principles	The subjects found design principles related to data generation and domain adaptation (**DP7**, **DP9**, **DP10**) most useful in terms of guidance for designing. They expressed that the majority could easily and realistically be carried out in practice. However, some concerns were raised about restricted design freedom due to the number of DPs, suggesting that a more streamlined set of principles might enhance creativity and experimentation. Some of the subjects indicated a need for a balance between structured guidance and creative flexibility to foster innovative approaches in synthetic image data generation and domain adaptation.
Effectiveness	**Design Requirements**	The subjects expressed a high degree of usefulness and design assistance in terms of artifact (i.e., the design requirements) quality. They mentioned that using the DRs could potentially lead to more effective design and development when working with synthetic image data. They appreciated the comprehensive nature of the DRs, which they believed would not only enhance the quality of design outcomes but also contribute to a deeper understanding and better implementation practices in the field of synthetic image data and digital health.
	Design Principles	The subjects positively emphasized the prevention of ethical/privacy risks (**DP1**, **DP2**) and ensuring exemplary performance (**DP4**, **DP5**, **DP9**, **DP10**), thereby increasing their performance, productivity, effectiveness, and quality at a given task. They noted that the DPs act as a form of guiding knowledge when they need to design such digital health applications efficiently and effectively. However, they expressed concerns about whether DPs would improve the reputation and morale of the organization/company.

Overall, the think-aloud subjects rated the design requirements and principles positively in terms of their theoretical and practical reusability, especially regarding accessibility, importance, novelty & insightfulness, actability & guidance, and effectiveness. Emphasizing digital ethics and precision, these evaluation results indicate a well-founded acceptance and potential for integration of the proposed design theory artifact into existing and future practices within synthetic image data and digital health. The consistent acknowledgment of the detailed and actionable nature of the design requirements and principles by our think-aloud subjects indicates a promising trajectory for the successful application of this theory, particularly in terms of construct understanding and meaning. The articulated concerns regarding the balance between guidance and design freedom, as well as a more nuanced construct description, point to an area for further refinement to ensure that the principles facilitate innovation while maintaining a clear ethical and performance-oriented framework and guiding language.

Evaluation by Operationalization and Instantiation

In addition, the evaluation schema employed in this study takes into account the roles of key stakeholders involved in the formulation of design principles, allowing design science researchers to assess the usability of generated design principles for different user groups. Two critical questions arise from this perspective: first, whether the design principles are theoretically and practically useful, and second, whether they effectively serve the goals of users who implement the resulting instantiations (Gregor et al., 2020). Therefore, *evaluation activity 3* (Sonneberg & vom Brocke, 2012) was used, which describes a validated artifact instance as proof of the applicability of the design theory. To ensure the feasibility and operationality of our design artifact, the evaluation method of *demonstration with a prototype* was chosen (Sonneberg & vom Brocke, 2012).

DP1 Ethical Healthcare Data Generation	**Design Feature 1:** Used data privacy laws and value-sensitive design to guide data generation.
	Design Feature 2: Used non-genuine characters and a variety of ethnicities, cultures, etc. for data generation.
DP2 Comprehensive Privacy Protection	**Design Feature 3:** Used positional reasoning via bounding box coordinates rather than visual representation.
	Design Feature 4: Anonymized subtle features such as background details, specific patterns, and colour schemes.
DP3 Adaptive Data Governance	**Design Feature 5:** Automatically reviewed all generated synthetic images against a set of predefined standards.
	Design Feature 6: Developed a policy document that outlines the ethical creation and usage of that image data.
DP4 Synthetic Scene Diversity	**Design Feature 7:** Used a script for Unity3D to automatically generate random and compliant scenes.
	Design Feature 8: Used a script for Unity3D to randomly add or modify objects, backgrounds, and textures.
DP5 Controlled Scene Composition	**Design Feature 9:** Used scene balancing in Unity3D to maintain the correct scale and orientation of structures.
	Design Feature 10: Used an algorithm that maintains appropriate spatial relationships between objects in a scene.
DP6 Flexible Complexity Management	**Design Feature 11:** Used a script that introduces both quantitative and qualitative complexity changes.
	Design Feature 12: Used an algorithm to ensure that models don't become overly specialized in simpler scences.
DP7 Data Augmentation	**Design Feature 13:** Used a tool that applies geometric transformations such as scaling, rotating, and mirroring.
	Design Feature 14: Used a script that adds controlled noise at pixel level and perspective warping.
DP8 Responsible AI	**Design Feature 15:** Implemented an AI bias monitoring algorithm to ensure that it does not favor or disfavor groups.
	Design Feature 16: Used an AI model evaluation tool to ensure equitable decisions across patient demographics.
DP9 Transfer Learning Guidelines	**Design Feature 17:** Developed a protocol to guide the adaptation of synthetic models to real-world data nuances.
	Design Feature 18: Implemented a process to fine-tune models on real-image data and assessing performance.
DP10 Robustness Checks	**Design Feature 19:** Developed a testing protocol that simulates a wide range of environmental conditions.
	Design Feature 20: Conducted stress tests to evaluate model resilience against unusual or rare conditions.

Figure 9. Operationalized Design Principles as Design Features for Our Prototypical Instantiation

As shown in Figure 9, we operationalized the design principles as design features to validate their feasibility in a real-world application scenario. This iterative process ensured that the design features were not only consistent with the theoretical underpinnings of the design theory but also met the practical needs of users in a dynamic healthcare environment. As a result, the prototype demonstrated the practicality of the design principles and bridged the gap between theory and practice. The design features shown in Figure 9 serve as a transparent description of how we implemented the design theory for a specific digital health scenario, where we used the synthetic image data as a means to locate people with amnestic mild cognitive impairment, monitor their health status, and project appropriate information at the right place and time (see Figure 10). It is meant to be an illustrative example that shows how the design principles can be operationalized by specific actions we took to instantiate the design theory. These design features can be seen as possible characteristics and actions when using the design theory, but they are not meant to be mandatory.

In addition, Figure 10 shows the aforementioned exemplary instantiation of the design principles, operationalized by the design features, in a computer vision deep learning setting for person detection and reasoning, which is therefore concerned with ethical data generation. This example detects people and objects to introduce a seamless, indirect, and intuitive approach to human-computer interaction, where the display of information is triggered when the person moves into a certain area of the living environment. In comparison to the examples of synthetic image data in digital health (Figure 2), i.e., cancer detection and skin conditions, our illustrative example shows a very attenuated form of application, where model errors are certainly not as drastic as in disease diagnosis. Hence, the design principles for such critical applications are even more relevant and decisive.

By following value-sensitive design theory, abstract and non-genuine characters were generated for the scenes, ensuring ethical data generation (DP1) and privacy preservation (DP2). In addition, data gathering and processing for zone alignment only refers to the coordinates of the person's bounding box, not their actual appearance (see Figure 10 and the white rectangle), further ensuring that no sensitive data is displayed or actively used for processing. Using a video game engine and various mechanisms to generate the synthetic image data (DP3), a wide variety of scenes (DP4) and compositions (DP5) were achieved, significantly and intentionally varying the key features. Figure 10 shows the aforementioned domain gap and its adaptation, where our model trained on synthetic image data is applied to real scenes. In addition, several scenes contain varying complexity (DP6) to achieve better generalization and scalability, while data augmentation techniques (DP7) in the form of geometric transformations (i.e., lens distortion) were used to reduce the risk of overfitting. Prior bias detection, e.g., ethnicity or gender, was performed for data generation (DP8), and transfer learning (DP8) and robustness checking (DP10) strategies were employed. By incorporating these design principles that were operationalized by our design features, our instantiation ensures ethical data generation practices in person and activity detection,

promoting accurate and reliable results while considering privacy, diversity, generalization, and controlled complexity. Exaggerated by our blatantly privacy-invasive example for positional reasoning in home care settings, the use of ethically generated and applied synthetic image data, properly operationalized by the design features, has the potential to mitigate these privacy-related concerns while still meeting the ethical requirements associated with digital health applications.

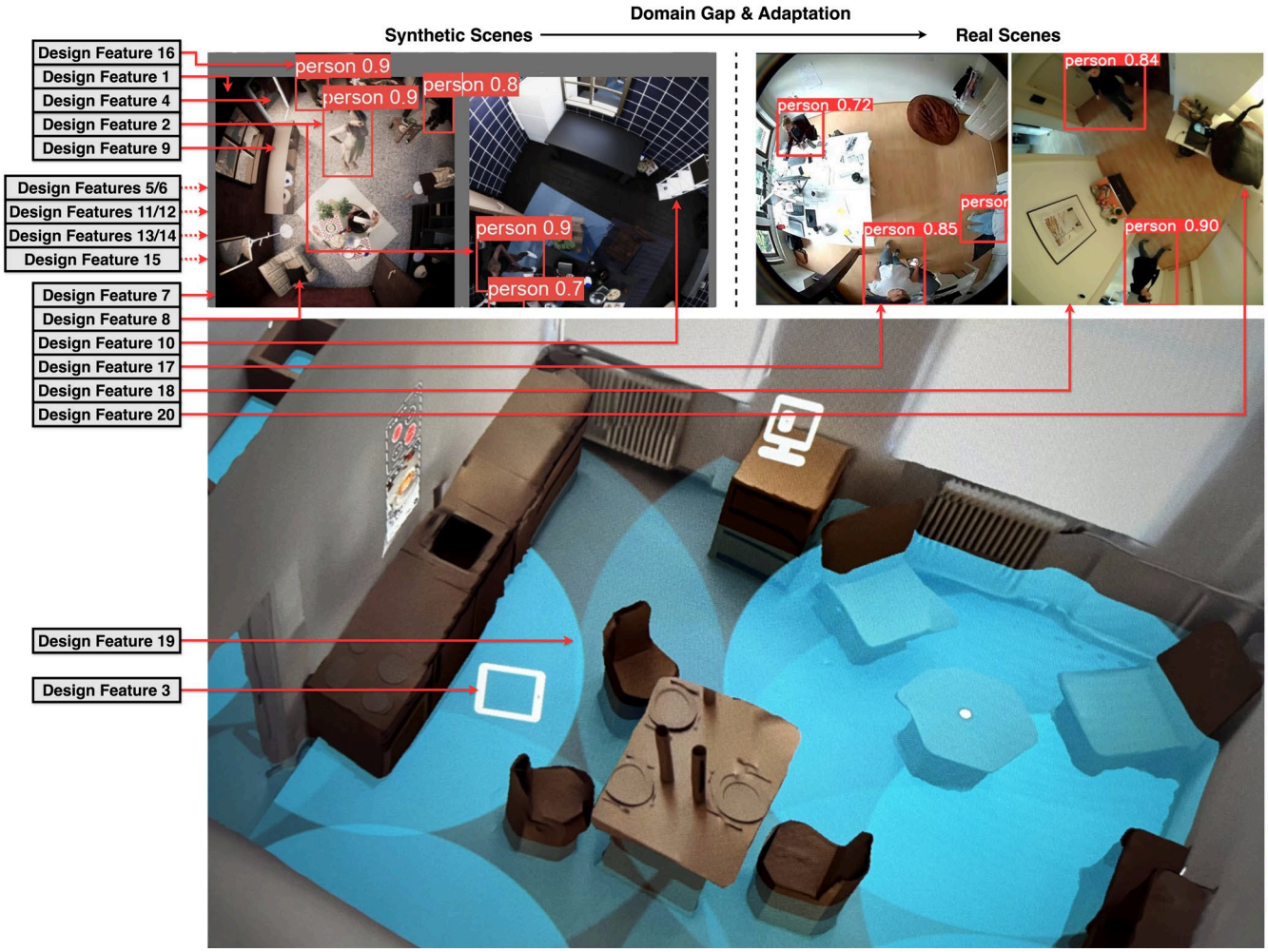


Figure 10. Example of Ethically Generated Synthetic Image Data for Digital Health and Corresponding Design Features From the Instantiation

Note: Dashed lines indicate design features that are not directly visible from this illustration.

Discussion

In this paper, we articulate a design theory that addresses the ethical and technical challenges of using synthetic image data in digital health, particularly for training deep learning models in computer vision. Our core argument is straightforward: if the social and ethical dimensions of health care are not integrated into the technical design of synthetic data systems, the resulting AI models may inadvertently perpetuate biases, compromise patient privacy, and ultimately undermine the very goals they are intended to serve. We are not suggesting that the developers of these systems are acting with malicious intent. Rather, we argue that without a concerted effort to align technical capabilities with ethical imperatives, the deployment of such systems could lead to significant and unintended ethical consequences. This dialog is not only about guiding academic research but also about influencing the policies and frameworks that will determine how these technologies are deployed in real-world settings. The ethical and technical challenges, especially inherent in this sensitive domain, are significant, and our design theory addresses them by proposing a framework that balances ethical integrity with technical performance, particularly in domain adaptation. The overall positive evaluation of our design theory, as evidenced by high levels of agreement across various reusability categories, suggests that our artifact is both feasible and relevant. We argue that the design requirements and principles we developed not only add to the body of IS knowledge but also have the potential to change the way we approach the design and implementation of synthetic image data systems in healthcare. By synthesizing these requirements and principles into an inter-field design theory, as suggested by Darden and Maull (1977), we contribute to the prescriptive knowledge base within the IS community, consistent with the frameworks proposed by Gregor and Hevner (2013) and Woo et al. (2014).

Further locating the theorized artifact within the DSR knowledge framework of Gregor and Hevner (2013), it can be described as a level 3 well-developed design theory about the embedded phenomenon of ethically sound use of synthetic image data in digital health computer vision. While this design theory is presented as a comprehensive theorized artifact, it can also be interpreted as a nascent design theory (Gregor & Hevner, 2013), depending on the lens or context through which it is viewed. We argue that positioning the design theory as a comprehensive framework is more consistent with its multi-cyclical approach to addressing the ethical and technical challenges of synthetic data in digital health, which transcends the characteristics of a nascent design theory. Since our study is located within the *theorizing* area of the DSR focus matrix (Brendel et al., 2022), and according to the classification of DSR artifacts by Gregor and Hevner (2013), the DT can be seen as *Design Theory*, whereas its instantiation as conceptual model is epitomized as *Model*. From a more meta-theoretical perspective, our design theory artifact embodies a *midrange design science theory* (Kuechler & Vaishnavi, 2012) and general midrange theory in IS research (Young et al., 2021).

By adopting the heuristic theorizing approach, we sought to reduce replication errors while maximizing transparency, reproducibility, and traceability. Following the design theory replication framework proposed by Brendel and Muntermann (2022), we effectively addressed various critical aspects of replication in the context of our design theory for digital health computer vision using synthetic image data (Table 5). Encompassing design theory replication aspects of problem class and solution space, robust and generalizable constructs, explicit methods and processes, the rationale for design choices, variability and adaptation, and iterative testing and feedback, our design theory is positioned for effective application and future development in the rapidly changing landscape of digital health and synthetic data use, while providing a theoretical contribution to the field.

Theory Building in DSR

Our study contributes to the accumulation of knowledge in DSR by focusing on midrange theories (Offermann et al., 2011), specifically within the IS design theory genre (Peffers et al., 2018), while aligning with the broader concept of midrange theory in both general theorizing (Young et al., 2021) and DSR (Kuechler & Vaishnavi, 2012). The design theory developed in this study is testable across different populations and settings, although it is not universally applicable. It clarifies the design process and its outcomes by following Gregor and Jones' (2007) design theory framework (Table 3), which includes the essential components of a design theory, addressing user needs (meta-requirements) and the design's response to these (meta-design). This approach bridges theory and practice and emphasizes the importance of design principles in communicating actionable design knowledge (Meth et al., 2015; Chandra et al., 2015). We further address the challenge of design theory indeterminacy by balancing abstraction with actionable principles, following the concerns of Lukyanenko and Parsons (2020). Using the schema of Gregor et al. (2020), along with supportive and prescriptive methods (Möller et al., 2020; Fu et al., 2016), as well as the presentation of application-oriented design features, we mitigate such indeterminacy in the development of design theory.

Table 5. Design Theory Replication Aspects According to Brendel and Muntermann (2022)

Design Theory Replication Aspects	
Replication Aspect	**Our Implementation**
Problem Class & Solution Space	The design theory addresses the problem of ethical and effective utilization of synthetic image data in digital health, focusing on privacy, ethical compliance, bias mitigation, domain adaptation, generalization, and accuracy. The solution space includes design requirements and respective design principles for responsible AI use in digital health computer vision and enhancing model robustness for synthetic image data.
Robust & Generalizable Constructs	To ensure robust constructs, the design theory is based on value-sensitive design and sociotechnical systems theory, incorporating a multi-method (i.e., focus group, think-aloud sessions, qualitative theory building) approach and heuristic theorizing across two design cycles, presenting design requirements and principles as the main artifact and theorized constructs. These primarily apply to the use of synthetic image data in digital health computer vision but can be utilized and adapted across various deep learning domains. Moreover, the design theory contains generally applicable design principles that should be applied regardless of the specific application domain.
Explicit Methodologies & Processes	The development of the design theory followed a structured approach using a heuristic design theorizing methodology (Gregory & Muntermann, 2014) over two completed design science research cycles. In addition, the theory-driven approach of learning from abstract theoretical knowledge (i.e., our kernel theories and the literature) and translating it to solve a problem (Schoormann et al., 2024) and formulating rigorous design principles (Gregor et al., 2020) for conceptualizing fewer abstract artifacts was applied.
Rationale for Design Choices	The multi-faceted study approach ensures that the design requirements and principles are not arbitrary but are grounded in conceptual and theoretical work (Schoormann et al., 2024). The rationale for design choices emphasizes that ethics and privacy are consistent with value-sensitive design and sociotechnical imperatives, preventing the technical subsystem from undermining the social subsystem in digital health AI. We argue that design decisions are never neutral, prioritizing individuality and generalizability to ensure our models' adaptability across diverse healthcare contexts. A focus on accuracy and precision in data generation underpins the reliability and effectiveness of healthcare applications. Finally, our emphasis on realism and healthcare relevance in synthetic data underscores our commitment to creating technically and ethically sound, user-centered solutions.
Variability & Adaptation	Proactively anticipating the need for variability and adaptation in the rapidly evolving nature of both digital health and synthetic image data, we provide guidelines for adapting our theory to evolving technologies and ethical values, ensuring ongoing relevance. Our approach accounts for future advances and changes in the field, both technically and ethically, and maintains the applicability of the theory in diverse and changing scenarios by not only proposing design principles that are generally applicable (e.g., DP4) regardless of the target domain, but also by choosing a wording that is invariant to future developments and maintains clarity (e.g., DP1 - ethical guidelines and laws may change, but adherence to them should not). This foresight underscores our commitment to a flexible, responsive design that can adapt to new ethical imperatives and technological developments, reinforcing the theory's robustness and longevity.
Iterative Testing & Feedback	Given the nature of DSR, we emphasized the importance of iterative testing and feedback, advocating a continuous refinement process beyond the two cycles presented. This iterative approach allows for the consistent incorporation of new insights and technological advancements, ensuring the design theory remains relevant and effective. By incorporating reconvened think-aloud sessions addressing the design theory's constructs, we categorize their reusability in terms of accessibility, importance, novelty & insightfulness, actability & guidance, and effectiveness (Iivari et al., 2021). Hence, we specifically targeted design theory indeterminacy (Lukyanenko & Parsons, 2020), enabling the theory to be applied in various contexts with minimal modifications, extended to cover broader scenarios, and scaled to accommodate different levels of use.
Result Documentation & Sharing	In our design theory, we underscore the significance of meticulously documenting and sharing comprehensive data and results by grounding the design theory's constructs with their theory-grounding and theory-building foundations. Therefore, we chose to unfold our qualitative content analysis following Gioia et al. (2013) to ensure traceability and comprehensibility throughout the design process. This commitment to transparency allows other researchers and practitioners to replicate, validate, and extend our findings, guided by our work. We ensure that every aspect of our research process, from initial theory-grounding, theory-building, and formulation of design requirements and principles to iterative reusability evaluation results, is thoroughly recorded and accessible. By sharing detailed data and results, we foster a deeper understanding of the development and application of our theory and encourage collaborative improvement.

Our approach emphasizes that the projectability of design theories - their applicability in different contexts - determines their relevance and utility in DSR. We argue that while generalizability often emphasizes broad applicability, projectability shifts the focus to ensuring that design principles can be effectively applied in specific but diverse scenarios. As the empirical justification of design principles or theories in DSR is based on their prescriptive projectability rather than descriptive generalizability, this concept is especially critical in the rapidly evolving fields of AI and digital health, where the ability to adapt theories to new technologies and ethical considerations is paramount. By framing projectability as a prescriptive alternative to traditional generalizability (Baskerville & Pries-Heje, 2019), we emphasize its importance in the broader DSR landscape. In this context, high projectability suggests that our design theory is not only applicable within the initial domain of synthetic imagery but is also adaptable to future advances and other domains (vom Brocke et al., 2020). On the other hand, the replication aspect of our design theory (Table 5), in line with the framework proposed by Brendel and Muntermann (2022), further ensures the robustness of the design theory. Nonetheless, the traditional aspects of generalizability and transferability of our design theory are ensured by its emphasis on fundamental design principles that are broadly applicable across domains. Specifically, DP4, DP5, DP7, and DP9 are constructed to be adaptable and effective beyond the initial domain of digital health. These principles are grounded in AI literature (e.g., Alzubaidi et al., 2021; Giuffrè & Shung, 2023; Gonzales et al., 2023; Murtaza et al., 2023; Scheck et al., 2020) and ensure that the synthetic image data generation process captures diverse and varied scenarios, supporting the applicability of the theory across contexts (e.g., fall detection, autonomous driving, or robotics). Interestingly, this could also have implications for the use of generative AI and the feeding of computer vision models with AI-generated (synthetic) images (which would mean that AI applications feed AI applications, the vicious cycle of AI collaboration). As AI models increasingly rely on synthetic data generated by other AI systems/models, we could see the emergence of self-sustaining AI ecosystems that operate independently of human input, which could raise concerns about the oversight and control of such systems – and, as such, require ethical safeguards.

Furthermore, our study contributes to next-generation theorizing in IS research (Burton-Jones et al., 2021; Young et al., 2021) by envisioning a new (design) theory that studies a new phenomenon (i.e., synthetic image data) emerging in a changing world (i.e., the digital health and ethics domain), especially from a DSR focus (Brendel et al., 2022) to adapt to concurrent and emerging research conversations. We extend the application of Iivari et al.'s (2021) design principle reusability framework by proposing three levels of reusability to evaluate design requirements, thereby advancing theoretical evaluation approaches within the DSR domain. We argue that this may lead to more nuanced and multifaceted evaluations of design theories in the future, in line with next-generation theorizing (Burton-Jones et al., 2021). In this context, we advocate for a transparent and replicable approach to design theorizing, emphasizing the importance of heuristic theorizing across *multiple* design cycles alternating between (re)structuring the problem and generating new design constructs (Gregory & Muntermann, 2014; Brendel & Muntermann, 2022). Finally, with our design features and instantiation, we actively worked to mitigate the phenomenon of *theory fetishism* in IS (Ivari, 2020) by promoting a judicious use of theory that bridges the gap between abstract theoretical concepts and practical design applications.

The Value-Sensitive Design Perspective

In the context of our theoretical lens and two kernel theories, our design theory can enrich the theoretical discourse around the kernel theory of value-sensitive design as conceptualized by Friedman et al. (2002, 2013), particularly in the context of the use of synthetic image data in digital health. By addressing the ethical and practical challenges associated with deep learning models, this research not only aligns with the foundational constructs of value-sensitive design but also extends them in meaningful ways. Central to value-sensitive design is the integration of human values such as privacy, fairness, and accountability into the design process. Here, we extend Stilgoe et al.'s (2020) concept of *responsible innovation* by integrating these ethical values into the core design process in the context of IS and DSR, thereby offering a practical application that takes responsible innovation beyond theoretical discourse and aligns with its *anticipatory dimension*, which emphasizes the importance of anticipating the potential impacts of emerging technologies such as AI and synthetic data. Our design theory builds on this by embedding these ethical considerations into the design of synthetic image data systems to ensure that privacy is protected, bias is mitigated, and fairness is promoted, resonating with the principles emphasized by Owen et al. (2013), who advocate for anticipatory, reflective, and inclusive practices in innovation. In addition, our design theory extends the theoretical discourse around value-sensitive design by addressing the need to capture the diversity and individuality inherent in real-world healthcare scenarios, ensuring that AI models apply to diverse populations. This commitment to generalizability and inclusivity is informed by value-sensitive design's emphasis on respecting

stakeholder diversity and autonomy, as highlighted in the work of Yetim (2011) and Dadgar and Joshi (2018). Furthermore, our design theory advances value-sensitive design by providing concrete operational steps for implementing ethical principles, particularly in managing complexity and ensuring data realism in synthetic image generation. This practical focus is in line with Denning et al. (2010) and Mueller et al. (2018), who emphasize the importance of balancing technical accuracy with ethical considerations in AI. By introducing structured heuristics for resolving value conflicts - such as those between precision and transparency, or privacy and accountability - our artifact provides a more nuanced approach to integrating ethical values into technology design, thereby expanding the applicability of value-sensitive design in complex ethical landscapes. In addition, the generalizability of the design theory across different AI and computer vision contexts extends the reach of value-sensitive design theory, providing a framework that can adapt to different industries while maintaining its relevance in the evolving landscape of AI and healthcare.

The Sociotechnical Systems Perspective

From a sociotechnical systems theory perspective, our design theory may contribute to the specific demands of digital (health) environments, particularly in how we understand the dynamic interplay between social and technical systems in applying synthetic image data and its ethical imperatives. We drew on the concept of joint optimization (Trist & Bamforth, 1951), emphasizing that ethical considerations (the social subsystem) and the technical requirements of deep learning models (the technical subsystem) must be addressed simultaneously to ensure robust yet ethical AI applications. Our design theory, further informed by Mumford's (2006) perspective on sociotechnical systems, ensures that ethical values (as defined per DR1), privacy protections, and responsible AI practices are not afterthoughts but are embedded at the heart of the design process. For instance, while synthetic image data offers the promise of scalable and diverse datasets necessary for robust AI models, it is the careful calibration of these datasets - through mechanisms such as synthetic scene diversity (DP4) and controlled scene composition (DP5) - that prevents the oversimplification or distortion of real-world healthcare scenarios. Our study thus extends the discourse of sociotechnical systems theory by applying its constructs to the dynamic and evolving field of (synthetically trained) AI in digital health. As such, our design theory not only accommodates but also anticipates the ethical challenges that arise as digital health and AI technologies evolve. This approach is consistent with Bostrom and Heinen's (1977) emphasis on integrating behavioral and organizational considerations into system design, ensuring that the social implications of synthetic data use are addressed as rigorously as the technical ones. Moreover, our design theory goes beyond simply applying the principles of sociotechnical systems theory and actively extends them. For example, Baxter and Sommerville's (2011) concepts of affordances and constraints are used to refine the interaction between users and synthetic data systems, ensuring that these systems are not only technically sound but also socially responsive. This nuanced approach allows us to address the tensions between ethical imperatives and technical requirements, and to propose a framework in which both can be optimized simultaneously, thereby avoiding the pitfalls of ethical negligence. We argue that ethical integration is not simply a matter of adding ethical safeguards; it requires a fundamental rethinking of how we approach the design of digital health systems, especially when the generation of synthetic data is just a click away. This will ensure that such systems are as focused on the social and ethical complexities of healthcare as they are on the technical demands of AI.

Implications for Synthetic Image Data and AI Ethics

Besides methodological and kernel theory perspectives, our design theory adds new perspectives and specific domain applications to synthetic image data in computer vision (Alzubaidi et al., 2021; Aranjuelo et al., 2021; Kuhnke & Ostermann, 2019; Scheck et al., 2020; Seib et al, 2020; Valtchev & Wu, 2021), and introduces and extends such phenomena in digital health (Giuffrè & Shung, 2023; Gonzales et al., 2023; Murtaza et al., 2023) with an explicit focus on digital ethics (Kern et al., 2022; McBride, 2014; Russel & Norvig, 2021). Our study responds to the call for more measures to protect patient well-being and maintain ethical standards while working with synthetic data in healthcare (Giuffrè & Shung, 2023). While Giuffrè and Shung (2023) laid a strong general technical and regulatory foundation for synthetic data in healthcare, our study extends this work by building design knowledge that addresses the socio-technical and critical ethical dimensions, providing a theoretical framework to guide the responsible and equitable use of synthetic data in digital health applications. We argue that while synthetic data is often perceived as inherently private due to its artificial nature, it still has significant ethical implications that must be addressed through rigorous theoretical and practical frameworks. Thus, our design theory challenges the assumption that synthetic data is free from privacy and bias risks and highlights the need for robust mechanisms to prevent re-identification, mitigate bias, and ensure fairness in AI applications.

Moreover, as synthetic data generation becomes more accessible and automated, the potential for its misuse increases, particularly when assumptions of inherent privacy lead to a lack of critical oversight. We argue that without robust safeguards, synthetic datasets may propagate systemic biases or be exploited in ways that compromise the very ethical standards they are intended to uphold, underscoring the urgency of a proactive and multifaceted governance approach. By operationalizing the ethical values into actionable design principles, our research provides a structured approach to navigating the complex ethical landscape of AI in digital health, ensuring that synthetic image data is used responsibly and ethically. Specifically, it contributes to the discourse on *ethical AI* in healthcare. While existing literature (Mittelstadt et al., 2016; Spiekermann et al., 2020) primarily focuses on the ethical implications of AI, our design theory goes a step further by operationalizing these ethical considerations. As such, our design theory makes a distinctive contribution by addressing the specific ethical risks associated with synthetic image data in digital health through actionable design principles, complementing the broader meta-level frameworks of Myers and Venable (2014) and Herwix et al. (2022), which provide valuable general guidance but do not fully encompass the specific socio-technical challenges in this particular domain, and shifting the conversation from what should be done to how it can be done. Thus, narrowing the scope can enhance value, particularly in sciences that prioritize practical applicability, but if the IS community typically favors a broader scope, we risk lacking the detailed information needed to fully understand IS phenomena (Siponen et al., 2023).

Furthermore, our study draws on Floridi and Cowls' (2019) framework of AI ethics, which emphasizes the importance of AI being beneficial rather than detrimental to humanity. This aligns with our focus on developing AI systems that improve health care while mitigating risks such as bias, privacy violations, and ethical dilemmas. We also integrate insights from Topol (2019) and therefore address the discourse on *deep medicine*, exploring how AI can transform healthcare by personalizing medicine, increasing diagnostic accuracy, improving patient care, and ensuring that our AI designs contribute positively to these aspects. Finally, our design theory advances AI in healthcare by providing a structured, ethical framework for using synthetic image data, addressing key concerns like privacy, bias mitigation, and ethical compliance (Obermeyer et al., 2019; Panch et al., 2019; Rajkomar et al., 2019). It builds on Panch et al.'s (2019) discussion by offering actionable principles, responds to Obermeyer et al.'s (2019) findings on racial bias, and aligns with Raji et al.'s (2020) and Vayena et al.'s (2018) emphasis on ethical challenges and fairness in medical deep learning. Thus, our research addresses the concerns raised in AI and digital health systems about the potential risks of AI exacerbating existing inequities if not properly managed (Panch et al., 2018). In response to calls for transparency in the design, deployment, and evaluation of deep learning models to build trust and accountability (Rajkomar et al., 2018), we advocate for clear documentation and explanation of data generation processes, model design decisions, and ethical considerations to ensure that models do not perpetuate disparities.

Integrating related theoretical perspectives from philosophical, sociotechnical, and phenomenological design ethics deepened our understanding of the moral and ethical responsibilities inherent in using synthetic data for digital health. Donia and Shaw (2021) highlight that design decisions are shaped by the agency of designers, who must navigate external pressures (often commercial and technical) while embedding ethical values in their work. Thus, our study may reinforce the idea that design is never neutral, as moral implications are inherent in every decision, especially in sensitive areas such as healthcare. Findeli's (1994) concept of "technoethics" further emphasizes that this responsibility for ethical implications in system design goes beyond mere functionalism. We argue that adopting a more speculative and adaptive approach to design - one that anticipates and responds to the broader societal impacts of technology - is critical to addressing the evolving challenges posed by synthetic data (Lupton, 2017; Burton-Jones et al., 2021). Through the lens of our sociotechnical systems theory, and as emphasized by Albrechtslund (2006), we contend that the multistability of technology demands ethical adaptability. The unpredictable ways in which innovative technologies, such as synthetic data, will be used once they are deployed underscore the need for flexible design frameworks that can accommodate unforeseen ethical challenges. Finally, in line with Luhmann's (1996) reflections on ethical systems as adaptive and reflective processes, we contend that ongoing ethical deliberation is essential to ensure that synthetic data systems remain ethically sound as they evolve in the dynamic landscape of health care.

Practical Implications

By immersing ourselves in the practical world of healthcare, we have developed a design theory that is not only grounded in the realities of synthetic data use but also anticipates future challenges. It provides practitioners with a robust framework for the ethical use of synthetic data, not just in terms of theoretical considerations but with actionable insights and guidelines that can be directly implemented in real-

world scenarios to reduce design theory indeterminacy (Lukyanenko & Parsons, 2020). We argue that the practical implications of our work go beyond immediate applications and serve as a blueprint for how design theories in digital health can be systematically developed and implemented to address complex ethical challenges, thereby setting a precedent for future innovations in health technology. Importantly, recognizing that synthetic image data is not inherently free of privacy risks is the crucial first step - one that, if widely understood and accepted by practitioners, would constitute a significant part of the effort in safeguarding against potential ethical violations. We advocate a sensible and cautious approach to synthetic data that does not consider it inherently risk-free. However, it is certainly less risky than previous approaches using real image data (because privacy is less of an issue), but the problem remains, and we argue that prevention is better than hindsight, especially when working with sensitive healthcare data.

Subsequently, model inversion and adversarial attacks, while likely rare, remain a critical concern, as advanced AI models trained on synthetic data may still be vulnerable to malicious actors who could reverse engineer the synthetic data to extract sensitive information. Although synthetic data is artificial, models may retain traces of the underlying real data, particularly in the case of unexplained AI models, exposing private details. Therefore, we argue that for synthetic data to be trusted, transparency about its origins and associated risks is essential, as stakeholders may overestimate privacy protections if they are unaware of the close link between synthetic and real data. As the field of digital health continues to evolve at a rapid pace, the implications of our design theory extend beyond academic discourse, fostering a culture of ethical mindfulness that is crucial for sustaining the integrity and trustworthiness of health-related AI applications.

At the organizational level, health authorities face several significant challenges when trying to introduce or implement innovative changes or systems (Thakur et al. 2012). Therefore, the implications of our research reach beyond academic theorizing, holding significant promise for real-world healthcare and management applications, as these authorities can develop and implement ethical, effective, and precise computer vision models based on synthetic image data in digital health. Our study highlights the dynamic nature of DSR in line with the principles outlined by vom Brocke et al. (2022). We show that the development of design theory in this context is not a linear process but one that evolves through collaboration, unexpected challenges, and new opportunities. This iterative process, similar to a "dance" between theory and practice, ensures that our approach remains adaptable to the complexities of digital health and ethics.

Limitations & Future Research

In light of the overall positive evaluation of our theorized artifact, some limitations should be considered. First, design artifacts in the form of design requirements and principles, as well as their development, are tied to the subjective creativity of the researcher, even after various data collection episodes and theory grounding. However, not all design decisions can or should be derived from behavioral or mathematical theories, as some degree of creativity is essential to developing an innovative design artifact (Hevner & Chatterjee, 2010; Baskerville et al., 2016), whereas a certain degree of rigor can be implemented through methodological (Fu et al., 2016; Gregor et al., 2020; Möller et al., 2020) or theorizing approaches (Gregory & Muntermann, 2014; Lee et al., 2011). The iterative nature of DSR often means that the final artifact is the result of multiple refinements, which can lead to a divergence from the initial theoretical underpinnings. While this divergence is a natural part of the design process, it could limit the extent to which the final artifact embodies the theoretical constructs it was intended to. Therefore, maintaining a balance between theoretical fidelity and practical utility in the artifact becomes a critical consideration that we encourage future research to address. In this regard, our study acknowledges the potential for refinement in the abstraction and granularity of its design principles, as highlighted by one of the reviewers during the review process. We would like to take up this idea and see future research exploring strategies for optimizing the conciseness and specificity of design principles, depending on their use and actionability in theory and practice. We believe that initiating this ongoing dialogue is essential to advancing the theoretical and practical discourse on the use of synthetic image data in digital health and beyond.

Second, as with any evaluation, the results describe only one sample throughout two completed design cycles, meaning that different results might be expected if a different sample were chosen. It would be presumptuous to assume that design theory contains all the necessary design knowledge to use synthetic image data in digital health computer vision, although we have tried to provide high transparency and rigor with our theorizing approach. Therefore, we encourage other researchers to challenge, adapt, or refine the constructs of our design theory. Here, we aimed to make the design theory highly replicable by following the framework proposed by Brendel and Muntermann (2022), which emphasizes the

importance of a clear and structured approach when developing design theories. Future studies could extend our work by applying the design theory to different contexts or replicating the development of design requirements and principles. Furthermore, despite achieving theoretical, data, code thematic, and meaning saturation, we acknowledge that the specialized nature and size of our expert sample may limit the generalizability of our findings. Therefore, further research with diverse samples and in different contexts with different theoretical underpinnings is essential to validate and potentially extend the applicability of our design theory. Future studies should explore larger and more diverse samples to ensure broader applicability while maintaining the rigor of practitioner feedback within relevant subgroups (Iivari et al., 2021). In this context, the incorporation of organizational change management theories could significantly inform the application and refinement of the proposed design theory for synthetic image data in digital health. Theories such as Armenakis and Bedeian's (1999) organizational change framework, Kotter's (1996) eight-step process for leading change, and Lewin's (1947) change management model could provide valuable guidance on how healthcare organizations could effectively adopt and implement the design principles outlined in our study. Given the diverse contexts, cultures, and regulatory environments across countries and healthcare systems, we argue that these organizational change management frameworks are critical for understanding how to tailor change strategies to specific organizational and national contexts. Work such as that of Markus and Robey (1988) on the interaction between technology and organizational change highlights the importance of understanding the complex dynamics at play when implementing new technologies. These insights are particularly valuable in addressing the various challenges of change acceptance, stakeholder involvement, and alignment of new technologies with existing organizational cultures, especially in complex and culturally sensitive healthcare environments. Future studies could explore these aspects, grounding our design theory in practical organizational contexts and enhancing its applicability across diverse healthcare settings to ensure that the transition to synthetic data-driven AI systems is both smooth and sustainable in diverse global contexts.

Third, while the application of the reusability framework (Iivari et al., 2021) covered categories such as effectiveness, these were not empirically validated but only qualitatively through think-aloud sessions. Even after two completed DSR cycles and a certain degree of maturity, our design theory is at an early stage of development. Given the complexity of the topic, it was essential to focus on conceptual development, as theories in scientific research, particularly in DSR, are built on constructs and propositions that provide explanations and prioritize the utility of prescriptive theories over empirical confirmation (Baskerville & Pries-Heje, 2019; Gregor & Jones, 2007). While we propose testable propositions linking design requirements and design principles, validating these propositions relies on artifact instantiation rather than traditional hypothesis testing, which may limit generalizability. Future research should explore more empirical testing of these propositions in diverse real-world healthcare settings further to assess their applicability and effectiveness across different contexts. As such, we recognize the challenges posed by the rapidly evolving nature of digital health and AI, which means that certain aspects of the design theory may change as technology advances. We aim to validate the design theory longitudinally to ensure its continued relevance, adaptability, and feasibility. Specifically, we plan to implement the design theory in a real-world context (e.g., for fall detection, interaction design, or disease detection) to collect data on various metrics such as performance, user satisfaction, and adaptation. As the environmental contexts evolve, the design theory may be revised as we talk to experts and observe technological advances to ensure its validity. In this context, we plan to conduct a longitudinal case study over the lifetime of the aforementioned implementation. Thus, we will periodically reflect on the data collected and compare it to the original design objectives and any changes made to the design theory. Therefore, we encourage researchers, theorists, and practitioners to apply the design theory to new contexts to see if it remains effective. This could mean using the theory to solve different types of problems in different industries or under different conditions. The results of these applications serve as empirical evidence for or against the projectability of the theory. However, we also encourage future research to apply the design theory and compare the results in different case studies. Especially in deep learning, empirical testing of such items or model benchmarking (e.g., comparing synthetically trained models with ground truth models of real images) is an advisable choice.

Conclusion

The ongoing rapid development in both digital health and computer vision requires innovative and ethically inclusive solutions, which can be achieved, for example, through the generation and use of synthetic image data for model training. While the use of artificial imagery provides faster generation, infinite scalability, and photorealism, it often involves ethical concerns (i.e., bias or invasion of privacy) and error-prone application (i.e., poor domain adaptation). Therefore, it is crucial to design ethical, performant, and precise

computer vision models based on synthetic image data, especially in the digital health domain with a high emphasis on accuracy, privacy, and feasibility. By theorizing the causality of how to use such artificial data and what effects are to be expected, we demonstrated a design knowledge guidance that contributes to the field of digital health, computer vision, and digital ethics. Therefore, our design theory not only contributes by its feasibility but also serves as a starting point for future research within these domains.

References

Albrechtslund, A. (2007). Ethics and technology design. *Ethics and Information Technology*, *9*, 63–72.

Al-Dhaen, F. et al. (2021). Advancing the Understanding of the Role of Responsible AI in the Continued Use of IoMT in Healthcare. *Information Systems Frontiers*, 1–20.

Alzubaidi, L., Zhang, J. et al. (2021). Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions. *Journal of Big Data*, *8*, 1–74.

Aranjuelo, N. et al. (2021). Key strategies for synthetic data generation for training intelligent systems based on people detection from omnidirectional cameras. *Computers & Electrical Engineering*.

Aristotele, Brown, L., & Ross, D. (2009). *The Nicomachean Ethics*. Oxford University Press.

Armenakis, A. A., & Bedeian, A. G. (1999). Organizational change: A review of theory and research in the 1990s. *Journal of Management*, *25*(3), 293–315.

Baskerville, R., & Pries-Heje, J. (2010). Explanatory Design Theory, Business Information Systems and Engineering, 2(5), 271–282.

Baskerville, R., & Pries-Heje, J. (2019). Projectability in design science research. *Journal of Information Technology Theory and Application*, *20*(1), 3.

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with Computers*, *23*(1), 4–17.

Becker, L. C., & Becker, C. B. (2001). Encyclopedia of Ethics, 2. Routledge.

Bird, J. J. et al. (2020), From simulation to reality: CNN transfer learning for scene classification. *IEEE 10th International Conference on Intelligent Systems*, 619–625.

Bittmann, S., & Thomas, O. (2013). An argumentative approach of conceptual modelling and model validation through theory building. *Proceedings DESRIST 2013*, 242–257.

Böhmer, M. (2023). From Pixels to Generalization: Ensuring Information Security and Model Performance with Design Principles for Synthetic Image Data in Deep Learning. In *CIISR@ Wirtschaftsinformatik*, 49–61.

Bostrom, R. P., & Heinen, J. S. (1977). MIS problems and failures: A socio-technical perspective. Part I: The causes. *MIS Quarterly*, 17–32.

Bowen, G. A. (2008). Naturalistic inquiry and the saturation concept: a research note. *Qualitative Research*, *8*(1), 137–152.

Brendel, A. B., & Muntermann, J. (2022). Replication of design theories: Reflections on function, outcome, and impact. *Information Systems Journal*, *32*(6), 1158–1176.

Brendel, A. B., Lembcke, T. B., & Kolbe, L. M. (2022). Towards an Integrative View on Design Science Research Genres, Strategies, and Pivotal Concepts in Information Systems Research. *The DATA BASE for Advances in Information Systems*, *53*(4), 9–23.

Bryant, A., & Charmaz, K. (2007). Grounded theory in historical perspective: An epistemological account. *The SAGE Handbook of Grounded Theory*, 31–57.

Burton-Jones, A., Butler, B. S., Scott, S., & Xu, S. X. (2021). Next-generation information systems theorizing: A call to action. *MIS Quarterly*, *45*(1), 301–314.

Chandra, L., Seidel, S., & Gregor, S. (2015). Prescriptive knowledge in IS research: Conceptualizing design principles in terms of materiality, action, and boundary conditions. *HICSS 2015*, 4039–4048.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage Publications.

Chen, R. J., Lu, M. Y., Chen, T. Y., Williamson, D. F., & Mahmood, F. (2021). Synthetic data in machine learning for medicine and healthcare. *Nature Biomedical Engineering*, *5*(6), 493–497.

Dadgar, M., & Joshi, K. D. (2018). The role of information and communication technology in self-management of chronic diseases: An empirical investigation through value sensitive design. *Journal of the Association for Information Systems*, *19*(2), 2.

Darden, L., & Maull, N. (1977). Interfield theories. *Philosophy of Science*, *44*(1), 43–64.

Dehling, T., & Sunyaev, A. (2023). A design theory for transparency of information privacy practices. *Information Systems Research*.

Deng, X., Joshi, K. D., & Galliers, R. D. (2016). The duality of empowerment and marginalization in microtask crowdsourcing. *MIS Quarterly*, *40*(2), 279–302.

Denning, T., Borning, A., Friedman, B., Gill, B. T., Kohno, T., & Maisel, W. H. (2010). Patients, pacemakers, and implantable defibrillators: Human values and security for wireless implantable medical devices. *Proceedings of the*

SIGCHI Conference on Human Factors in Computing Systems, 917–926.

Denning, T., Kramer, D. B., Friedman, B., Reynolds, M. R., Gill, B., & Kohno, T. (2014). CPS: Beyond usability: Applying value sensitive design based methods to investigate domain characteristics for security for implantable cardiac devices. *Proceedings of the 30th Annual Computer Security Applications Conference*, 426–435.

Detweiler, C., & Hindriks, K. (2012). Value-sensitive design patterns for pervasive health care. *IEEE International Conference on Pervasive Computing and Communications Workshops*, 908–913.

Donia, J., & Shaw, J. A. (2021). Ethics and values in design: A structured review and theoretical critique. *Science and Engineering Ethics*, *27*(5), 57.

Düwell, M., Hübenthal, C., & Werner, M. H. (2011). Handbuch Ethik.

Emery, F. E., & Trist, E. L. (1960). Socio-technical systems. *Management Science, Models and Techniques*, *2*, 83-97.

Floridi, L. (2010). *The Cambridge handbook of information and computer ethics*. Cambridge University Press.

Floridi, L., & Taddeo, M. (2016). What Is Data Ethics? Philosophical transactions. Series A, Mathematical, Physical, and Engineering Sciences.

Floridi, L., & Cowls, J. (2019). A Unified Framework of Five Principles for AI in Society, Harvard Data Science Review.

Findeli, A. (1994). Ethics, Aesthetics, and Design. *Design Issues*, *10*(2), 49–68.

Friedman, B., Kahn, P., & Borning, A. (2002). Value sensitive design: Theory and methods. University of Washington Technical Report, 2(8).

Friedman, B., Kahn, P. H., Borning, A., & Huldtgren, A. (2013). Value sensitive design and information systems. Early Engagement and new Technologies: Opening up the Laboratory, 55–95.

Fu, K. K., Yang, M. C., & Wood, K. L. (2016). Design principles: Literature review, analysis, and future directions. *Journal of Mechanical Design*, *138*(10), 101103.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, *16*(1), 15–31.

Giuffrè, M., & Shung, D. L. (2023). Harnessing the power of synthetic data in healthcare: Innovation, application, and privacy. *NPJ Digital Medicine*, *6*(1), 186.

Glaser, B., & Strauss, A. (2017). *Discovery of grounded theory: Strategies for qualitative research*. Routledge.

Gonzales, A., Guruswamy, G., & Smith, S. R. (2023). Synthetic data in health care: A narrative review. *PLoS Digital Health*, *2*(1), e0000082.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly*, 337–355.

Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5).

Gregor, S., Chandra Kruse, L., & Seidel, S. (2020). Research perspectives: the anatomy of a design principle. *Journal of the Association for Information Systems*, *21*(6).

Gregory, R. W., & Muntermann, J. (2014). Heuristic theorizing: Proactively generating design theories. *Information Systems Research*, *25*(3), 639–653.

Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PloS One*, *15*(5), e0232076.

Habermas, J. (1987). *The philosophical discourse of modernity*. Blackwell Publishers.

Hansen, S., & Baroody, A. J. (2020). Electronic Health Records and the Logics of Care: Complementarity and Conflict in the U.S. Healthcare System, *Information Systems Research*, *31*(1).

Hennink, M. M., Kaiser, B. N., & Marconi, V. C. (2017). Code saturation versus meaning saturation: how many interviews are enough? *Qualitative Health Research*, *27*(4), 591–608.

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523.

Herwix, A., Haj-Bolouri, A., Rossi, M., Tremblay, M. C., Purao, S., & Gregor, S. (2022). Ethics in information systems and design science research: Five perspectives. *Communications of the Association for Information Systems*, *50*(1), 589–616.

Hevner, A. R. et al. (2004). Design Science in Information Systems. *MIS Quarterly*, *28*(1), 75–105.

Hung, P. C. K., & Cheng, V. S. Y. (2009). Privacy. Encyclopedia of Database Systems. Boston, MA, Springer US, 2136-2137.

Hwang, W. & Salvendy, G. (2010), Number of people required for usability evaluation: The 10±2 rule. *Communications of the ACM*, *53*(5), 130–133.

Iivari, J. (2015). Distinguishing and contrasting two strategies for design science research. *European Journal of Information Systems*, *24*(1), 107–115.

Iivari, J. (2020). A critical look at theories in design science research. *Journal of the Association for Information Systems*, *21*(3), 10.

Iivari, J., Rotvit Perlt Hansen, M., & Haj-Bolouri, A. (2021). A proposal for minimum reusability evaluation of design principles. *European Journal of Information Systems*, *30*(3), 286–303.

Kane, G. C., Young, A. G., Majchrzak, A., & Ransbotham, S. (2021). Avoiding an oppressive future of machine learning: A design theory for emancipatory assistants. *MIS Quarterly*, *45*(1), 371–396.

Kant, I. (1998). *Critique of pure reason*. Cambridge University Press.

Kern, C. J., Noeltner, M., & Kroenung, J. S. (2022). The case of digital ethics in IS research – A literature review. *International Conference on Information Systems (ICIS) 2022*.

Kotter, J. P. (1996). *Leading change*. Harvard Business Review Press.

Krump, M., Ruß, M., & Stütz, P. (2020), Deep learning algorithms for vehicle detection on UAV platforms: First investigations on the effects of synthetic training. *MESAS 2019*, Palermo, 50–70.

Kuechler, W., & Vaishnavi, V. (2012). A framework for theory development in design science research: Multiple perspectives. *Journal of the Association for Information Systems*, *13*(6), 3.

Kuhnke, F., & Ostermann, J. (2019). Deep head pose estimation using synthetic images and partial adversarial domain adaption for continuous label spaces. *IEEE/CVF International Conference on Computer Vision*, 10164–10173.

Lahiri, A., Agarwalla, A., & Biswas, P. K. (2018). Unsupervised domain adaptation for learning eye gaze from a million synthetic images: An adversarial approach. *Indian Conference on Computer Vision, Graphics and Image Processing*, 1–9.

Lee, J. S., Pries-Heje, J. et al. (2011). Theorizing in design science research. *DESRIST 2011*, 1–16.

Lee, S., Park, B., & Kim, A. (2019). Deep learning based object detection via style-transferred underwater sonar images. *IFAC*, *52*(21), 152–155.

Lewin, K. (1947). Frontiers in group dynamics: Concept, method and reality in social science; social equilibria and social change. *Human Relations*, *1*(1), 5–41.

Luhmann, N. (1996). The sociology of the moral and ethics. *International Sociology*, *11*(1), 27–36.

Lukyanenko, R., & Parsons, J. (2020). Research perspectives: Design theory indeterminacy: What is it, how can it be reduced, and why did the polar bear drown? *Journal of the Association for Information Systems*, *21*(5).

Lupton, D. (2018). Towards design sociology. *Sociology Compass*, *12*(1).

Magnani, G., & Gioia, D. (2023). Using the Gioia Methodology in international business and entrepreneurship research. *International Business Review*, *32*(2), 102097.

Mahieu, R., van Eck, N. J., van Putten, D., & van den Hoven, J. (2018). From dignity to security protocols: A scientometric analysis of digital ethics. *Ethics and Information Technology*, *20*(3).

Mandviwalla, M. (2015). Generating and justifying design theory. *Journal of the Association for Information Systems*, *16*(5).

Markus, M. L., & Robey, D. (1988). Information technology and organizational change: Causal structure in theory and research. *Management Science*, *34*(5), 583–598.

Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in qualitative research? A review of qualitative interviews in IS research. *Journal of Computer Information Systems*, *54*(1), 11–22.

McBride, N. (2014). Active ethics: An information systems ethics for the internet age. *Journal of Information*, *12*.

Meth, H., Mueller, B., & Maedche, A. (2015). Designing a requirement mining system. *Journal of the Association for Information Systems*, *16*(9).

Mingers, J., & Brocklesby, J. (1997). Multimethodology: Towards a framework for mixing methodologies. *Omega*, *25*(5), 489–509.

Mittelstadt, B. D., Allo, P., Taddeo, M., Wachter, S., & Floridi, L. (2016). The ethics of algorithms: Mapping the debate. *Big Data & Society*, *3*(2).

Möller, F., Guggenberger, T. M., & Otto, B. (2020). Towards a method for design principle development in information systems. *Proceedings DESRIST 2020*, Kristiansand, Norway, 208–220.

Möller, F., Schoormann, T., Strobel, G., & Hansen, M. R. P. (2022). Unveiling the cloak: Kernel theory use in design science research. *Proceedings International Conference on Information Systems 2022*.

Müller, M., Casser, V., Lahoud, J., Smith, N., & Ghanem, B. (2018), Sim4cv: A photo-realistic simulator for computer vision applications. *International Journal of Computer Vision*, *126*, 902–919.

Müller-Wienbergen, F., Müller, O., Seidel, S., & Becker, J. (2011). Leaving the beaten tracks in creative work–A design theory for systems that support convergent and divergent thinking. *Journal of the Association for Information Systems*, *12*(11), 2.

Mueller, M., Heger, O., & Niehaves, B. (2018). Exploring ethical design dimensions of a physiotherapeutic mHealth solution through value sensitive design. *Proceedings Americas Conference on Information Systems 2018*.

Mumford, E. (2006). The story of socio-technical design: Reflections on its successes, failures and potential. *Information Systems Journal*, *16*(4), 317–342.

Murtaza, H., Ahmed, M., Khan, N. F., Murtaza, G., Zafar, S., & Bano, A. (2023). Synthetic data generation: State of the art in health care domain. *Computer Science Review*, *48*, 100546.

Myers, M. D., & Venable, J. R. (2014). A set of ethical principles for design science research in information systems. *Information & Management*, *51*(6), 801–809.

Niederman, F., & March, S. (2019). The "theoretical lens" concept: We all know what it means, but do we all know the same thing? *Communications of the Association for Information Systems*, *44*(1), 1.

Noushad, B., Van Gerven, P. W., & De Bruin, A. B. (2024). Twelve tips for applying the think-aloud method to capture cognitive processes. *Medical Teacher*, *46*(7), 892–897.

O'Neil, P. M. (2004). Ethics, Ethics J.K. Roth (ed.). California, Salem Press.

Obermeyer, Z., Powers, B., Vogeli, C., & Mullainathan, S. (2019). Dissecting racial bias in an algorithm used to manage the health of populations. *Science*, *366*(6464), 447–453.

Offermann, P., Blom, S., Schönherr, M., & Bub, U. (2011). Design range and research strategies in design science publications. *Proceedings DESRIST 2011*, 77–91.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. (2013). A framework for responsible innovation. Responsible innovation: managing the responsible emergence of science and innovation in society, 27–50.

Panch, T., Szolovits, P., & Atun, R. (2018). Artificial intelligence, machine learning and health systems. *NPJ Digital Medicine*, *1*(1), 1–3.

Panch, T., Mattie, H., & Celi, L. A. (2019). The "inconvenient truth" about AI in healthcare. *NPJ Digital Medicine*, *2*(1), 77.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77.

Peffers, K., Tuunanen, T., & Niehaves, B. (2018). Design science research genres: Introduction to the special issue on exemplars and criteria for applicable design science research. *European Journal of Information Systems*, *27*(2), 129–139.

Raji, I. D., Gebru, T., Mitchell, M., Buolamwini, J., Lee, J., & Denton, E. (2020, February). Saving face: Investigating the ethical concerns of facial recognition auditing. *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society*, 145–151.

Rajkomar, A., Hardt, M., Howell, M. D., Corrado, G., & Chin, M. H. (2018). Ensuring fairness in machine learning to advance health equity. *Annals of Internal Medicine*, *169*(12), 866–872.

Rajkomar, A., Dean, J., & Kohane, I. (2019). Machine learning in medicine. *New England Journal of Medicine*, 380(14), 1347–1358.

Russell, S. J., & Norvig, P. (2021). *Artificial intelligence: A modern approach*. Pearson.

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179–183.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B. et al. (2018). Saturation in qualitative research: Exploring its conceptualization and operationalization. *Quality & Quantity*, *52*, 1893–1907.

Scheck, T., Seidel, R., & Hirtz, G. (2020). Learning from Theodore: A synthetic omnidirectional top-view indoor dataset for deep transfer learning. *IEEE/CVF Winter Conference on Applications of Computer Vision*, 943–952.

Schermann, M., Böhmann, T., & Krcmar, H. (2009). Explicating design theories with conceptual models: Towards a theoretical role of reference models. *Wissenschaftstheorie und gestaltungsorientierte Wirtschaftsinformatik*, 175–194.

Schlagwein, D. et al. (2019). Ethical norms and issues in crowdsourcing practices: A Habermasian Analysis. *Information Systems Journal*, *29*(4), 811–837.

Schoormann, T., Möller, F., Chandra Kruse, L., & Otto, B. (2024). BAUSTEIN - A design tool for configuring and representing design research. *Information Systems Journal*.

Seib, V., Lange, B., & Wirtz, S. (2020). Mixing Real and Synthetic Data to Enhance Neural Network Training - A Review of Current Approaches. arXiv:2007.08781.

Siponen, M., Klaavuniemi, T., & Xiao, Q. (2024). Splitting versus lumping: Narrowing a theory's scope may increase its value. *European Journal of Information Systems*, *33*(4), 561–570.

Sonnenberg, C., & vom Brocke, J. (2012), Evaluation patterns for design science research artefacts. *Practical Aspects of Design Science: EDSS 2011*, Leixlip, Ireland, 71–83.

Spiekermann, S. et al. (2022). Values and ethics in information systems. *Business & Information Systems Engineering*, *64*(2), 247–264.

Stilgoe, J., Owen, R., & Macnaghten, P. (2020). Developing a framework for responsible innovation. In The Ethics of Nanotechnology, Geoengineering, and Clean Energy, 347–359.

Thakur, R., Hsu, S. H., & Fontenot, G. (2012). Innovation in healthcare: Issues and future trends. *Journal of Business Research*, *65*(4), 562–569.

Topol, E. (2019). *Deep medicine: How artificial intelligence can make healthcare human again*. Hachette UK.

Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the longwall method of coal-getting: An examination of the psychological situation and defences of a work

group in relation to the social structure and technological content of the work system. *Human Relations*, *4*(1), 3–38.

Turja, T. et al. (2020). Robot Acceptance Model for Care (Ram-Care): A principled approach to the intention to use care robots. *Information & Management*, *57*(5).

Valtchev, S. Z., & Wu, J. (2021). Domain randomization for neural network classification. *Journal of Big Data*, *8*(1), 94.

Van Den Haak, M. et al. (2003), Retrospective vs. concurrent think-aloud protocols: Testing the usability of an online library catalogue. *Behaviour & Information Technology*, *22*(5), 339–351.

Vayena, E., Blasimme, A., & Cohen, I. G. (2018). Machine learning in medicine: Addressing ethical challenges. *PLoS Medicine*, *15*(11), e1002689.

Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: A framework for evaluation in design science research. *European Journal of Information Systems*, *25*, 77–89.

Venable, J. R., Pries-Heje, J., & Baskerville, R. L. (2017). Choosing a design science research methodology. *Proceedings ACIS 2017*.

Venkateswara, H. et al. (2017). Deep-learning systems for domain adaptation in computer vision: Learning transferable feature representations. *IEEE Signal Processing Magazine*, *34*(6), 117–129.

Vom Brocke, J., Winter, R., Hevner, A., & Maedche, A. (2020). Special issue editorial–Accumulation and evolution of design knowledge in design science research: A journey through time and space. *Journal of the Association for Information Systems*, *21*(3).

Vom Brocke, J., Weber, M., & Grisold, T. (2022). Design science research of high practical relevance: Dancing through space and time. In *Engineering the Transformation of the Enterprise: A Design Science Research Perspective*, 115–135.

Wan, L., Zhou, J., & Zhang, B. (2020). Data synthesis for document layout analysis. *International Symposium on Emerging Technologies for Education*, 244–252.

Walls, J. G., Widmeyer, G. R., & El Sawy, O. A. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research*, *3*(1), 36–59.

Walls, J. G., Widermeyer, G. R., & El Sawy, O. A. (2004). Assessing information system design theory in perspective: How useful was our 1992 initial rendition? *Journal of Information Technology Theory and Application*, *6*(2), 6.

Woo, C., Saghafi, A., & Rosales, A. (2014). What is a contribution to IS design science knowledge? *Proceedings International Conference on Information Systems (ICIS) 2014*, Auckland.

Yang, L., QI, L., & Zhang, B. (2022). Concepts and evaluation of saturation in qualitative research. *Advances in Psychological Science*, *30*(3), 511.

Yetim, F. (2011). Bringing discourse ethics to value sensitive design: pathways toward a deliberative future. *AIS Transactions on Human-Computer Interaction*, *3*(2), 133–155.

Young, A. G., Majchrzak, A., & Kane, G. C. (2021). Reflection on writing a theory paper: How to theorize for the future. *Journal of the Association for Information Systems*, *22*(5), 1212–1223.

Zhang, X. et al. (2018), Stacked multichannel autoencoder - An efficient way of learning from synthetic data. *Multimedia Tools and Applications*, *77*, 26563–26580.

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Appendix

Design Principle Scheme Following Gregor et al. (2020)

Table A.1. Design Principle 1

Design Principle Title	Ethical Healthcare Data Generation
Aim, interpreter, and user	To ensure that synthetic imagery complies with ethical and healthcare privacy regulations, maintaining alignment with both technical standards and social ethical frameworks.
Context	In digital health systems where synthetic image data is used for analysis, AI training, or decision support, while ensuring ethical values and the sociotechnical balance between innovation and ethical healthcare practices.
Mechanism	Incorporate ethical values and sociotechnical mechanisms to ensure that users account for both social and technical subsystems when making design decisions.
Rationale	Drawing on the theory of value-sensitive design (Friedman et al., 2002; 2013), ethical AI theories (Floridi & Cowls, 2019), and meta-level ethics (Myers & Venable; Herwix et al., 2022), this principle recognizes that healthcare data generation processes are not inherently private (Giuffrè & Shung, 2023) and must respect the ethical imperative to protect individuals' rights. Since design decisions are not neutral (Findeli, 1994), the principle stresses the balance between social and technical elements (Mumford, 2006), ensuring that ethical considerations, such as bias mitigation and privacy, are not overlooked in technical implementations.

Table A.2. Design Principle 2

Design Principle Title	Comprehensive Privacy Protection
Aim, interpreter, and user	To ensure the protection of sensitive healthcare data, upholding privacy, data security, and alignment with technical and social/ethical imperatives.
Context	In digital health systems where synthetic image data must adhere to strict privacy protection frameworks, ensuring compliance with healthcare privacy regulations and ethical values.
Mechanism	Apply robust monitoring techniques to ensure that the synthetically generated image data does not contain sensible real-world reference data to prevent re-identification or leakage of sensitive information, taking into account both technical and social aspects.
Rationale	Rooted in sociotechnical systems theory (Mumford, 2006) and based on flexible ethical designs (Albrechtslund, 2007) as well as privacy protection theories (Hansen & Baroody, 2020; Raji et al., 2020), this principle emphasizes that synthetic data, though artificial, is not inherently free from privacy risks. Rigorous privacy measures must be implemented to safeguard sensitive information, as mandated by meta-ethical frameworks (Myers & Venable, 2014).

Table A.3. Design Principle 3

Design Principle Title	Adaptive Data Governance
Aim, interpreter, and user	To establish adaptive governance frameworks that ensure the ethical and secure creation, use, and distribution of synthetic data in computer vision healthcare settings.
Context	In dynamic computer vision digital health environments where governance frameworks must respond to both technological changes and evolving social/ethical values.
Mechanism	Implement adaptive policies and governance mechanisms that can flexibly respond to emerging ethical challenges while ensuring compliance with both social imperatives and technical standards, recognizing that synthetic image data is not inherently free from risks related to privacy, security, and ethical concerns.
Rationale	Informed by socio-technical systems theory (Mumford, 2006) and adaptive ethical healthcare concepts (Panch et al., 2019; Rajkomar et al., 2018; 2019) for ethical values (Friedman et al., 2002; 2013), this principle emphasizes the need for ethical governance structures to address both privacy concerns and ethical dilemmas that arise during synthetic data generation and usage (Giuffrè & Shung, 2023; Vayena et al., 2018).

Table A.4. Design Principle 4

Design Principle Title	Synthetic Scene Diversity
Aim, interpreter, and user	To enhance model generalization and performance by incorporating diverse synthetic scenes that align with both social and technical learning imperatives.
Context	In computer vision models for healthcare, where synthetic scenes must be both technically proficient and represent a variety of social, cultural, and environmental contexts without reinforcing biases.
Mechanism	Introduce diverse textures, objects, and backgrounds into synthetic scenes to ensure models learn across a variety of scenarios, avoiding overfitting and social biases.
Rationale	Based on bias mitigation strategies (Obermeyer et al., 2019; Raji et al., 2020) and the need for cross-domain generalization (Scheck et al., 2020), this principle ensures that computer vision models trained on diverse data (i.e., scenes) perform well in varied real-world scenarios (Seib et al., 2020; Valtchev & Wu, 2021), reflecting socio-cultural variability (Donia & Shaw, 2021).

Table A.5. Design Principle 5

Design Principle Title	Controlled Scene Composition
Aim, interpreter, and user	To ensure that key features of synthetic scenes in healthcare are represented accurately, with a balance between scene randomness, diversity, and control.
Context	In the generation of synthetic image data for healthcare systems, where scene diversity is required, but important features must remain under control to prevent distortion and falsification.
Mechanism	Control object scale, orientation, and spatial relationships in synthetic scenes to ensure accurate representation of key healthcare factors, balancing randomness with precision and accuracy.
Rationale	Drawing on ethical-aesthetic aspects in design (Albrechtslund, 2007; Findeli, 1994) and scene composition techniques (Krump et al., 2020), this principle stresses that while randomness is beneficial, it must not overshadow core healthcare features, which are crucial for model generalization (Scheck et al., 2020).

Table A.6. Design Principle 6

Design Principle Title	Flexible Complexity Management
Aim, interpreter, and user	To optimize social and technical model learning by managing the complexity of synthetic scenes through gradual introduction and balancing.
Context	In computer vision models for healthcare, which require adaptive learning environments to handle the dynamic complexity of healthcare scenarios from both a social and technical perspective.
Mechanism	Gradually introduce synthetic scenes of varying social and technical complexity and monitor model performance to prevent overfitting and encourage robust learning.
Rationale	Drawing from the value trade-off between security needs and usability (Denning et al., 2014), this principle emphasizes the dynamic introduction of complex elements in synthetic scenes to help models build foundational learning before confronting more challenging, social or technical, scenarios (Alzubaidi et al., 2021; Bird et al., 2020). Based on adaptive complexity management in socio-technical systems theory (Mumford, 2006; Bostrom & Heinen, 1977), this principle ensures that models encounter diverse complexity levels, building robust learning mechanisms (Alzubaidi et al., 2021).

Table A.7. Design Principle 7

Design Principle Title	Data Augmentation
Aim, interpreter, and user	To enhance model robustness by applying augmentation techniques that simulate and promote variations in synthetic image scenes.
Context	In computer vision healthcare models where synthetic image data must simulate a range of real-world conditions to improve generalizability and reliability.
Mechanism	Use geometric transformations, colour modifications, noise introduction, and random elements to diversify synthetic scenes, ensuring that models learn to adapt to various conditions and focus on the key characteristics.
Rationale	Drawing from augmentation techniques in AI (Müller et al., 2018; Seib et al., 2020; Zhang et al., 2018), this principle highlights the importance of diverse data augmentation strategies to prevent overfitting and ensure robustness across different healthcare environments. It reflects the general socio-technical imperative to create synthetic data that can be generalized across different healthcare settings and patient populations, ensuring that computer vision models are adaptable and sustainable (Emery & Trist, 1960).

Table A.8. Design Principle 8

Design Principle Title	Responsible AI
Aim, interpreter, and user	To promote ethical and accountable AI practices in healthcare computer vision, focusing on bias detection, fairness, and explainability.
Context	In digital health systems where computer vision models must be both technically reliable and socially responsible, aligning with ethical healthcare practices.
Mechanism	Implement fairness assessments, bias detection, and transparency mechanisms to ensure that computer vision systems in healthcare operate ethically and are accountable to their users.
Rationale	Based on ethical AI practices (Floridi & Cowls, 2019; McBride, 2014; Russel & Norvig, 2021) and bias mitigation theories (Obermeyer et al., 2019), this principle emphasizes the importance of ensuring that healthcare AI models are fair, transparent, and free from bias, supporting trust in digital health technologies (Vayena et al., 2018). It emphasizes that while synthetic data is used in AI development, it does not inherently eliminate bias or ensure fairness, which is critical in value-sensitive environments (Friedmann et al., 2002; 2013; Herwix et al., 2022), where the responsibility of AI developers is balanced between technical and social/ethical imperatives (Mumford, 2006, Donia & Shaw, 2021; Luhmann, 1996).

Table A.9. Design Principle 9

Design Principle Title	Transfer Learning Guidelines
Aim, interpreter, and user	To guide the domain adaptation of models trained on synthetic data to real-world healthcare applications, ensuring they generalize and perform well.
Context	In healthcare settings where computer vision models must be fine-tuned for specific applications to ensure they perform effectively in real-world scenarios.
Mechanism	Provide protocols for domain adaptation and fine-tuning, ensuring that models trained on synthetic data and their parameters are optimized for real-world healthcare data and environments.
Rationale	Based on domain adaptation and transfer learning foundations (Murtaza et al., 2023; Kuhnke and Ostermann, 2019; Lahiri et al., 2018); Venkateswara et al., 2017), this principle ensures that models maintain high performance when transitioning from synthetic data environments to real-world healthcare applications. Its adaptability is based on socio-technical imperatives (Emery & Trist, 1960), which emphasize the need for systems to evolve and remain effective in dynamic environments.

Table A.10. Design Principle 10

Design Principle Title	Robustness Checks
Aim, interpreter, and user	To rigorously test the robustness of computer vision models against varying healthcare conditions and environmental inputs to align technical processes with social/ethical values.
Context	In healthcare computer vision models where reliability, adaptability, and resilience are critical to ensuring performance in unpredictable and ethically-sensitive real-world scenarios.
Mechanism	Conduct thorough model testing across a wide range of environmental conditions and healthcare scenarios to ensure computer vision model robustness and reliability.
Rationale	Based on technological marginalization concerns (Deng et al., 2016) and the need for robustness testing in models trained on synthetic data (Giuffrè & Shung, 2023), this principle emphasizes the need for extensive testing to ensure that computer vision systems can handle real-world healthcare variations without sacrificing accuracy/performance and ethical aspects (Floridi and Cowls, 2019; Giuffrè and Shung, 2023; Gonzales et al., 2023; Rajkomar et al., 2019; Russel and Norvig, 2021; Valtchev and Wu, 2021). In these scenarios, particularly in the digital health domain, and in light of a common utilitarian view that often overlooks social complexity (Lupton, 2017), it seems reasonable to stress test AI models to assess their resilience to extreme or rare scenarios.

Appendix K

Author's statement on the work shares in the Article: "A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Neurodegenerative Diseases"

The article "*A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Neurodegenerative Diseases*" was co-authored. The following table gives an overview of the authors' contributions to the article.

Authors

Martin Böhmer	MB
Jennifer Kendziorra	JK
Stephan Kuehnel	SK

Aspekt	**Autor(en)**
Research concept	MB
Research methodology	MB
Problem definition and objective	MB, JK, SK
Literature review	MB
Conceptualization of the topic	MB, JK, SK
Conducting and evaluating the qualitative analysis	MB
Definition & conceptualization of the theory model	MB, JK, SK
Adaptation of the concepts and relationships of the theory	MB, JK, SK
Qualitative and taxonomic classification of the theory	MB
Visualization of the research methodology	MB
Visualization of the theory	MB
Theoretical implications	MB
Practical implications	MB
Discussion of limitations and further research	MB
Conclusion	MB
Preparation of the manuscript	MB
Revision of the manuscript and the argumentation	JK, SK
Review and revision before submission	MB, JK, SK
Revision after review	MB, JK, SK

Appendix L

Full text of the Article: "A Proposal for Theorizing the Cognitive Adoption of Digital Health Technologies for People with Neurodegenerative Diseases"

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A PROPOSAL FOR THEORIZING THE COGNITIVE ADOPTION OF DIGITAL HEALTH TECHNOLOGIES FOR PEOPLE WITH COGNITIVE IMPAIRMENTS

Completed Research Paper

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Abstract

This study addresses the emerging need for Information Systems research to understand the cognitive and social factors influencing the adoption of digital health technologies, particularly among vulnerable populations with cognitive impairments. We propose an integrative theoretical model that synthesizes Cognitive Load Theory and Social Cognitive Theory to explore this phenomenon. Our conceptual research bridges the gap between traditional technology acceptance models and cognitive theories, offering a more comprehensive framework for understanding digital health adoption and behavior change beyond mere acceptance. We developed a cognitive adoption theory model comprising relevant relationships and constructs by utilizing a theorizing from literature approach and grounded theory concepts. Therefore, the study's implications encompass a more holistic understanding of the dynamic interplay between cognition and social contexts in digital health adoption among people with cognitive impairments. While acknowledging the limitations of our model, we encourage challenges to the theory and lay the groundwork for future research in this domain.

Keywords: Cognitive Adoption, Digital Health, Health Behavior Change, IS Theorizing, Theory

1 Introduction

The rapid expansion of digital health into information systems (IS) research has led to extensive investigations in areas such as virtual medical agents (Weimann et al., 2022), health behavior change (Pak and Song, 2016), healthcare augmentation (Böhmer et al., 2022), wearable compliance (Rieder et al., 2020), and clinical decision support (Kenei and Opiyo, 2022). This growth underscores the transformative potential of digital health solutions in how healthcare is delivered, how patients engage with their health, and how medical data is managed (Mathews et al., 2019). As a result, we are seeing an increasing number of digital health studies targeting vulnerable populations, particularly those with *cognitive impairment* of different types and causes (Gauthier et al., 2006, Gazzaniga et al., 2018), where people often experience a decline in their cognitive abilities, such as memory loss, slower information processing speed, or changes in social cognition. While cognitive changes often occur with advancing age, neurodegenerative diseases such as Alzheimer's are among the most common causes. However, other external factors such as brain injuries or medication, can also lead to varying levels of cognitive impairment. Despite their diverse causes, all types of cognitive impairment share a commonality: the profound impact of social-cognitive factors on daily functioning and technology use. Previous research has shown that this group's technology adoption and usage behavior differs from that of the general population (Gazzaniga et al., 2018). Therefore, tailored approaches and interfaces that are more intuitive and less complex are often required, as cognitive factors such as task difficulty, cognitive load, or social

environment significantly influence technology adoption among people with cognitive impairments (Ienca et al., 2021). While there is growing awareness of their unique needs, research on technology adoption for this vulnerable population often neglects the specific impact of their cognitive impairments. Although research and design are beginning to address these needs (e.g., Böhmer et al., 2022), studies largely focus on older adults in general. This leaves a critical research gap in understanding the specific cognitive factors that shape adoption for people with cognitive impairments - a gap that merits further exploration (Singh and Varshney, 2020). Thus, the rapid evolution of digital health necessitates a comprehensive understanding of the cognitive and social factors that influence their adoption, especially among the patient side of vulnerable populations with varying cognitive impairments.

While individual theories have provided valuable insights into specific aspects of cognitive processes (Bandura, 1977; Sweller, 1988) and technology acceptance (Venkatesh et al., 2003), there is an emerging call for a more holistic approach that integrates multiple theoretical perspectives (Rodriguez et al., 2020). Following this, we aim to draw a theoretical picture of cognitive adoption for people with cognitive impairments due to their specific cognitive characteristics, such as reduced information processing speed, memory loss, altered social cognition, or impaired reasoning (Gazzaniga et al., 2018). These varying characteristics are such that the theories, considered individually, can only apply to a limited extent (Gazzaniga et al., 2018). Specifically cognitive kernel theories, such as Sweller's *Cognitive Load Theory* (CLT) (1988) or Bandura's *Social Cognitive Theory* (SCT) (1977), exceptionally address certain aspects of cognitive constructs in depth on their own and are individually applicable. However, cognitive adoption in the context of cognitive impairment requires a broader perspective and raises questions about the mechanisms of cognitive adoption and behavior change that cannot be explained by any one theory alone. In this paper, we define digital health adoption as the process of actively choosing to use a technology (e.g., a memory training app), while health behavior change refers to the subsequent lifestyle changes (e.g., increased memory training). An integrative perspective on these cognitive constructs and their influence on digital health adoption and health behavior change in IS has yet to emerge, leading to the following research question:

RQ: *How to theoretically model the influence of cognitive aspects on digital health adoption and health behavior change in the context of cognitive impairment by integrating cognitive load and social cognitive theory?*

This paper seeks to bridge the aforementioned research gap by integrating the two prominent cognitive theories of SCT and CLT. Both theories have been instrumental in shaping our understanding of human cognition and behavior in the context of psychology (Bandura, 1997; Chandler and Sweller, 1991; Paas et al., 2003), but also IS and digital health (Ifinedo, 2012; Melenhorst et al., 2001; Rieder et al., 2020; Weimann et al., 2022). By synthesizing these theories, we aim to provide a comprehensive framework for understanding the cognitive processes, which we term *cognitive adoption*, of digital health systems, moving beyond mere acceptance to a deeper exploration of adoption and behavioral changes, especially for people with cognitive impairments often caused by neurodegenerative diseases that can occur with aging. Drawing on *theorizing from literature* methodology (Leidner and Tona, 2021) and grounded theory constructs (Corbin and Strauss, 1990; Wiesche et al., 2017), we present an integrative cognitive adoption theory model for the dynamic field of digital health. This model highlights the shift towards performative and conversational theorizing (Burton-Jones et al., 2021) and provides a theoretical perspective on cognitive adoption among people with cognitive impairments. Classified as *explaining* (type II) IS theory type (Gregor, 2006), the proposed cognitive adoption theory for digital health borrows theory concepts (Jiang et al., 2022; Truex et al., 2006) from CLT and SCT, initiating a more nuanced theoretical and practical discourse on cognitive adoption in digital health that could enrich future IS research by theorizing about digital health solutions that cater to the specific cognitive needs of vulnerable populations, fostering holistic and interdisciplinary approaches in the field.

We begin by reviewing the theoretical foundations of cognitive theories in IS, particularly CLT and SCT, and explain our theorizing rationale and the need to integrate these two in particular. We then present our theorizing methodology and its main artifact, the cognitive adoption theory model. Finally, we discuss the implications, limitations, and future research of our study.

2 Theoretical Foundations

In IS research, theory utilization is vital for developing and evaluating new interventions and technologies, as per IS theory nature (Gregor, 2006). Thus, theories focused on cognitive aspects, often from the social sciences and psychology, have been used, extended, or integrated in various IS studies (Compeau and Higgins, 1995; Ifinedo, 2012; Lin et al., 2008; Melenhorst et al., 2001; Weimann et al., 2022), informing them or shaping research perspectives. In digital health in particular, technology acceptance (the willingness to consider a technology), adoption (the integration of that technology based on endorsement), or adaptation (the ongoing adjustment of that technology) plays a pivotal role concerning people with cognitive impairments (Mostaghel, 2016). When it comes to technology adoption in digital health, cognitive aspects are highly relevant, especially in light of the cognitive impairment that often accompanies aging (Gauthier et al., 2006), as addressed by theories such as CLT or SCT. The integration of these two is particularly relevant in the context of digital health, where the design and evaluation of interventions require a comprehensive understanding of both cognitive and social factors. Subsequently, we elaborate on these theories and "borrow" their conceptual views (Jiang et al., 2022; Truex et al., 2006) to describe the need for a theorizing rationale integrating them for digital health adoption and health behavior change.

2.1 Cognitive load theory

Cognitive Load Theory (CLT) comes from the social sciences and is an instructional theory that is grounded in the architecture of human cognitive structures, providing insights into how information is processed and emphasizing the limitations of working memory when dealing with novel information (Sweller, 1988). Hence, cognitive load refers to the amount of mental effort being used in the working memory at a given time. CLT is based on a model of human cognitive architecture that distinguishes between two types of memory: working memory and long-term memory. While working memory has a limited capacity, particularly when dealing with novel information, long-term memory's capacity is believed to be virtually limitless. Hereby, the interplay between these two types of memory is central to CLT (Baddeley, 1992). At its conceptual core, three main types of cognitive load have been identified: 1) *intrinsic cognitive load* which is inherent to the material being learned and depends on both the complexity of the information and the expertise of the learner (Paas et al., 2003); 2) *extraneous cognitive load* which is not essential for learning and is imposed by how information is presented to learners (Sweller et al., 1998); and 3) *germane cognitive load* which contributes to the construction of schemas to be effectively maximized through instructional designs (Sweller et al., 2011). The role of these schemas is central for CLT, as they are organized packets of knowledge that can be stored and retrieved as single units, allowing for efficient processing in working memory (Chi et al., 1982). With repeated exposure and understanding, these schemas can be automated, thus requiring less cognitive effort for recall and application (Ericsson et al., 1993). Recognizing the constraints of working memory and the importance of schema formation, CLT provides guidelines for instructional design, aiming at the optimization of learning by managing cognitive load and promoting the formation of schemas (Sweller et al., 1998).

CLT has been influenced by and has influenced a variety of other theories and research domains. For instance, work on problem-solving showed that experts and novices approach problems differently, largely due to the well-developed schemas experts possess (Chi et al., 1981). Similarly, research on split-attention and redundancy effects has informed CLT principles on the effective design of instructional materials (Chandler and Sweller, 1991). In the intersection of social sciences and IS, especially in the field of digital health, CLT can help to inform the design of virtual coaches to reduce cognitive load (Weimann et al., 2022); epitomizes the foundation for theory-driven research approaches in gamified Human-Computer Interaction (Treiblmaier et al., 2018); is used in clinical settings to reduce the cognitive load through electronic health records (Kenei and Opiyo, 2022) or in occupational respiratory illness studies (Jozan et al., 2023); or is used as kernel theory for telehealth intervention studies (Antonio et al., 2023). Moreover, the literature on CLT extends its applicability to various aspects of IS. For instance, the work of Paas and Van Merriënboer (1994) explores instructional control

of cognitive load in training for complex cognitive tasks, a topic highly relevant to the design of effective e-learning systems. Furthermore, cognitive load principles have been embraced in human-computer interaction research, where Melenhorst et al. (2001) have applied CLT concepts to understand older adults' technology usage patterns, a critical consideration in designing age-inclusive interfaces.

2.2 Social cognitive theory

Social Cognitive Theory (SCT) is rooted in the understanding of human behavior as an interplay between individual, behavioral, and environmental factors. Initially stemming from the Social Learning Theory (Bandura, 1977), SCT emphasizes the idea that learning occurs in a social context and is influenced by observing others (observational learning or modeling). Hereby, individuals can learn new behaviors and acquire new information merely by observing others (Bandura, 2001), challenging behaviorist notions that learning solely occurs via direct experiences (Bandura, 1986). From a more conceptual perspective, the four key processes for observational learning are 1) *attention* (observers must pay attention to their environment); 2) *retention* (observers must remember features of the behavior); 3) *reproduction* (observers must have the ability to reproduce the behavior); and 4) *motivation* (observers must expect to receive positive outcomes from the behavior). SCT is characterized by the concept of triadic reciprocal determinism, in which personal factors, environmental influences, and behaviors mutually interact (Bandura, 1986). It posits that behavior is shaped by, and in turn shapes, the environment and the individual. A key aspect of SCT, self-efficacy, is the belief in one's ability to achieve certain outcomes, which is influenced by past experiences, vicarious learning, encouragement, and physiological states, with high self-efficacy increasing motivation and the likelihood of completing challenging tasks (Bandura, 1997). Here, contextual self-efficacy describes the phenomenon that users' task self-efficacy is influenced by internal or external contextual factors - one might have high task self-efficacy for cycling, but low self-efficacy for doing so in the rain (Rieder et al., 2020). SCT has further been utilized and expanded to research health promotion from its initial concept (Bandura, 2013).

Within the IS domain, SCT has been used to understand and predict user behaviors concerning system adoption, usage, and information sharing (Carillo, 2010). SCT or its concepts, particularly self-efficacy, have been pivotal in elucidating technology adoption behaviors, with notable work by Compeau and Higgins (1995) and Compeau et al. (1999) who leveraged the concept of computer self-efficacy to decipher an individual's capabilities and interactions with computers. The behavioral aspects of information security have also been explored through SCT, as exemplified by Ifinedo (2012), who highlighted the significance of elements such as self-efficacy, outcome expectations, and reinforcements in shaping employees' compliance with information security policies. Online collaborative environments have similarly been dissected through the SCT lens, with works like that of Hsu and Lu (2004) spotlighting the role of social interactions in online gaming participation. Additionally, SCT's insights have been instrumental in the sphere of knowledge management; Kankanhalli et al. (2005) found normative beliefs and outcome expectations to significantly mold knowledge-sharing propensities. Notably, in the expanding space of e-learning, Zhang et al. (2006) adopted SCT to determine key factors influencing e-learning outcomes, further emphasizing the theory's versatility and depth within IS. At the intersection of IS and digital health, social cognitive theory has also been used in the realm of virtual coaches (Weimann et al., 2022), as an underlying theoretical lens for studying the intention to use health apps among the elderly (Kim and Han, 2021), to inform health behavior change management studies (Pak and Song, 2016), or how self-efficacy influences behavior change in personal health wearable compliance (Rieder et al., 2020). In the context of health behavior change, Fallon et al. (2019) proposed a concept for mHealth applications, emphasizing features that support stimulus/forethought, self-regulation, incentivizing, and social interaction to facilitate behavior change, with potential benefits for individuals with neurodegenerative diseases. Given health behavior change, Singh and Varshney (2020) developed a taxonomy that can be used by IS researchers for developing theoretical models to study the effectiveness of interventions for improving medication adherence. Furthermore, the key constructs of SCT were used in the well-known *UTAUT* model, partly describing the social influence construct (Venkatesh et al., 2003).

2.3 Theorizing rationale

In the evolving landscape of IS research, particularly in digital health, theories and theorizing provide foundational pillars upon which interventions and technologies are designed and evaluated (Burton-Jones et al., 2021; Gregor, 2006; Young et al., 2021). Recent next-generation theorizing in IS research underscores a transition in IS theorizing from static, desk-bound perspectives to dynamic, engaged approaches that emphasize historical context, diverse lenses, field involvement, and the real-world impacts of theories (Burton-Jones et al., 2021). These shifts highlight the evolving nature of IS theory in terms of complexity and fluidity, both reflecting and influencing the reality it seeks to understand while borrowing kernel concepts from other fields (Jiang et al., 2022; Truex et al., 2006). While both CLT and SCT have informed numerous studies in the social sciences and IS (Carillo, 2010; Sweller, 2023; Weimann et al., 2022), integrating and synthesizing them may offer a more comprehensive understanding of the behavioral and cognitive dimensions involved in technology adoption and health behavior change, particularly in digital health for patients with cognitive impairments. Moreover, these theories have their roots in the 1970s and 80s, when digital health applications as we know them today were a mere fantasy and cognitive factors were difficult to facilitate. An integrative view of these theories offers a promising avenue, suggesting a more holistic approach to the design and evaluation of digital health solutions - one that simultaneously optimizes cognitive demands while harnessing the power of social learning mechanisms. Recent research advocates for incorporating and integrating kernel theories for theory extension (Sweller, 2023) or demonstrates their integration with other theories (Caprara et al., 2013; Lin et al., 2008). We recognized a crucial gap in the existing body of technology acceptance models, as traditional models often fail to simultaneously consider the cognitive processes and the social context influencing technology use, particularly among those with cognitive impairments.

However, it's crucial to delimit the term ‘adoption’ from ‘acceptance’ as proposed by TAM (Davis, 1989) or UTAUT (Venkatesh et al., 2003). In the realm of integrating technology into daily life and professional settings, the concept of ‘acceptance’ has long dominated discourse and analysis (Blut et al., 2022). Traditionally, acceptance indicates a passive receipt of what is being offered, akin to someone utilizing a health app even though they have no intrinsic motivation to do so. However, as we advocate for the seamless assimilation of technological tools and digital health systems, it becomes crucial to shift our vocabulary and mindset to that of ‘adoption’. Adoption, as opposed to mere acceptance, is inherently voluntary and involves a conscious decision to endorse, integrate, and incorporate technology (Karahanna et al., 1999). This nuance adds layers of complexity, suggesting a proactive engagement with the technology rather than a mere acquiescence. Therefore, emphasizing adoption over acceptance offers a richer and more comprehensive understanding of how individuals come to truly embrace technological innovations from a cognitive adoption perspective. While UTAUT provides a broad and excellent framework for explaining and predicting technology acceptance, usage intention, and behavior, our theorizing rationale leans towards a deeper, more nuanced understanding and explanation (Gregor, 2006) of the cognitive and social aspects that influence technology adoption, use, and learning, especially among people with cognitive impairments.

Our proposal for an integrated *cognitive adoption* perspective adds an SCT focus on self-efficacy, reciprocal determinism, and observational learning, which are critical constructs for individuals with cognitive impairments. CLT, in addition, addresses the specific issue of cognitive overload and how it can be managed to improve technology adoption among people with cognitive impairments. Thus, through the integration of SCT and CLT, we can dive deeper into the cognitive and social intricacies that underpin digital health behaviors, offering a more holistic, granular, and user-centric lens for digital health research among individuals with cognitive impairments, where SCT's emphasis on building self-efficacy through modeling and reducing cognitive demands with CLT directly addresses the unique challenges these individuals face. By strategically selecting CLT in conjunction with SCT for their complementary strengths in examining both the cognitive demands and social influences on technology adoption, a synthesized framework could emphasize the significance of designing digital health interventions that are both cognitively accessible and socially supportive. This enhances the likelihood of adoption, health behavior change, and sustained use.

3 Theorizing Methodology

Theorizing has a long tradition in IS research (Gregor, 2006) and current discussions are calling for rethinking, integrating, and developing new theories (Burton-Jones et al., 2021; Young et al., 2021). For our research purpose of integrating and extending existing theories, we used an *integrative theorizing* approach to shift from a single to a multi-level perspective (Klein and Kozlowski, 2000), combining elements of multiple theories to produce a more comprehensive or coherent theoretical framework. Since we use and borrow (Jiang et al., 2022; Truex et al., 2006) two kernel theories and scientific literature as our point of data origin, our study employs an inductive top-down theorizing approach, which is recognized for its efficacy in generating new or synthesize existing theories in situations marked by tensions and discrepancies among differing viewpoints and explanations of identical phenomena (Shepherd and Sutcliffe, 2011).

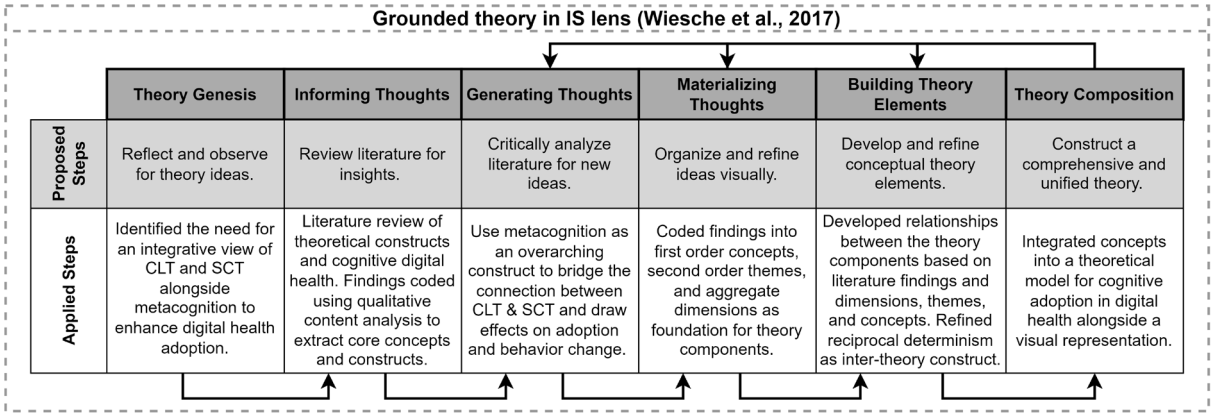


Figure 1. The methodological theorizing approach was adapted from Leidner and Tona (2021).

As aforementioned, cognitive adoption aspects have been examined across various disciplines and theoretical frameworks, reflecting diverse temporal periods and ontological practices. Using inductive top-down theorizing, we analyze literature, and especially the two kernel theories of CLT and SCT, on the phenomenon of digital health adoption among people with cognitive impairments to identify perceived theory discrepancies or synergies, from which abstract constructs and their interrelationships are derived, leading to the formation of a new, extended or synthesized theory. From a more methodological and phenomenological perspective, we chose the *Reformulate*-strategy proposed by Burton-Jones et al. (2021) since we are witnessing a changing world (i.e., demographic change and the need for innovative digital health solutions for patients with cognitive impairments), where existing phenomena in the form of theories (i.e., CLT and SCT) need to adapt to these circumstances and where we cannot assume that these theories will work as well as they did before. By modifying, synthesizing, or extending theories, this approach allows us to provide new and better insights into our coined field of cognitive adoption in digital health. Therefore, we follow the methodological framework of Leidner and Tona (2021) to theorize from literature, as depicted in Figure 1. This iterative model encompassed initial theorizing with clear and well-defined elements, theory composition with a focus on transitioning from literature-based to theory-based insights, and the incorporation of graphical illustrations to visually represent the developmental process. Further integrating grounded theory (Corbin and Strauss, 1990) into the theorizing from literature methodology, enriches the process of theory development by systematically grounding new theories in literature findings and constructs. Grounded theory in IS, as outlined by Wiesche et al. (2017), provides a structured approach to data analysis, including open, axial, and selective coding (as depicted by Table 1), which aligns well with the stages of informing, generating, and materializing thoughts in the theorize from literature model by Leidner and Tona (2021). Combining both methodologies enables a deeper exploration of the literature, facilitating the identification of key themes and gaps, and fostering the development of a more nuanced understanding of the subject matter. The consulted literature was systematically selected from publications addressing the cognitive and

adoption concepts in the *AIS Senior Scholars' List of Premier Journals*, top-tier IS conference proceedings (e.g., ICIS, ECIS), and selected digital health and social sciences databases (PubMed, JSTOR, EBSCO) using Scopus's advanced search. We adopted a multidisciplinary review methodology, covering different perspectives to holistically understand "cognitive adoption" in digital health. We selected articles that developed or used this concept, analyzing different perspectives on cognitive processes. Next, we examined how these works defined and approached cognitive adoption, identifying key viewpoints, foundational assumptions, and areas of debate, which we synthesized in the *informing thoughts* step. The initial theory genesis encompassed personal reflection on cognitive aspects in digital health research, which shaped the fundamental idea of an integrative perspective between CLT and SCT to provide a more holistic and adequate theoretical framework for understanding the complexities of digital health adoption among people with cognitive impairments.

Aggregate Dimensions	2nd Order Themes (1st Order concepts)	Literature
Cognitive load *(AD1)*	• **Intrinsic cognitive load** [task complexity; prior knowledge; mental effort; cognitive schema] • **Extraneous cognitive load** [instructional design; cognitive interference; redundancy; information overload; navigation complexity] • **Germane cognitive load** [reflective processing; schema building; mental rehearsal; metacognitive awareness] • **Cognitive load management** [chunking; scaffolding; progressive disclosure]	Antonio et al. (2023); Baddeley (1992); Chi et al. (1982); Flavell (1979); Melenhorst et al. (2001); Paas et al. (2003); Paas and Van Merriënboer (1994); Sweller (1988); Sweller et al. (1998); Sweller et al. (2011); Treiblmaier et al. (2018); Weimann et al. (2022)
Social cognitive factors *(AD2)*	• **Observational learning** [modeling; vicarious reinforcement; attentional processes; retention and memory] • **(Contextual) Self-efficacy** [perceived competence; outcome expectations; mastery experiences; social persuasion; emotional states] • **Reciprocal determinism** [behavior; personal factors; environmental factors; interaction and feedback loops, self-regulation]	Bandura (1977); Bandura (1986); Bandura (1997); Bandura (2001); Carillo (2010); Compeau and Higgins (1995); Compeau et al. (1999); Fallon et al. (2019); Flavell (1979); Ifinedo (2012); Kankanhallo et al. (2005); Pak and Song (2016); Rieder et al. (2020); Weimann et al. (2022)
Digital health adoption *(AD3)*	• **Usability** [user interface design; task efficiency; error tolerance] • **Accessibility** [universal design, interaction, user-centeredness; accessibility features; user support] • **Learning curves** [ease of onboarding; learning resources; skill development; adaptability] • **Behavioral Compensation** [psychological effects; collateral behavioral consequences; intervention efficacy]	Flavell (1979); Jozan et al. (2023); Kenei and Opiyo, 2022); Kim and Han (2021); Kyratsis et al., (2022); Melenhorst et al. (2001); Pak and Song (2016); Rieder et al. (2020); Venkatesh et al. (2003); Wolf et al. (2023)
Health behavior change *(AD4)*	• **Adaptive behavior modification** [personalized goal setting; progressive goal adjustment; self-monitoring; behavioral flexibility] • **Treatment adherence** [medication and treatment plan compliance; digital health tool adherence; barrier identification] • **Lifestyle modification** [dietary adjustments; physical activity integration; stress management] • **Coping mechanisms and resilience** [emotional coping strategies; social engagement; resourcing]	Fallon et al. (2019); Flavell (1979); Jozan et al. (2023); Kenei and Opiyo, 2022); Kim and Han (2021); Melenhorst et al. (2001); Pak and Song (2016), Rieder et al. (2020); Singh and Varshney (2020); Wolf et al. (2023)

Table 1. Literature coding following the qualitative content analysis by Gioia et al. (2013). Note: 1st order concepts are shown in square brackets.

Within this phase, the psychological construct of *metacognition* has been identified, acting as an overarching meta-view on cognition (i.e., the thinking about thinking or cognition about cognition) as initially defined by Flavell (1979). In other words, metacognition serves as a reflective and adaptive layer atop the constructs of SCT and CLT. An integrative view posits that effective learners are not only socially influenced and cognitively attuned but also consistently reflective and strategic in their approach, making metacognition an indirect yet central pillar in this combined theoretical perspective as outlined by Flavell (1979).

Subsequently, for the first phase of literature-based theorizing, we followed a coding procedure of the relevant literature phenomena, subject to a qualitative content analysis following the well-known methodology of Gioia et al. (2013). Here, grounded theory's (Wiesche et al., 2017) approach to developing categories (i.e., the coded dimensions) and identifying relationships between them can help in organizing and structuring the new theory. This enabled us to extract the core constructs of both theories and their application in digital health research. As can be seen in Table 1, we developed first-order concepts, second-order themes, and aggregate dimensions, which embody the foundation of the integrative theory. For example, the 1st order concept of *task complexity* is grouped under the 2nd order theme of *intrinsic cognitive load* which itself is part of the aggregate dimension of *cognitive load (AD1)*. Grounded theory's iterative approach, moving back and forth between data (i.e., literature) and analysis, is crucial in this stage. The qualitative analysis findings can hereby be regarded as the result of the first theory composition phase (Leidner and Tona, 2021), with the aggregate dimensions being its key components which have been further informed by literature on a more profound and granular level. The preliminary results of the second theory composition phase will be explained in the subsequent chapter.

4 Proposal for a Cognitive Adoption Theory in Digital Health

The *cognitive adoption theory* model shown in Figure 2 is a comprehensive framework that integrates key constructs from CLT and SCT to elucidate the complex process of adopting digital health technologies and facilitating health behavior change among people with cognitive impairments, such as those with neurodegenerative diseases. Their distinctive and most prevalent aspects of cognitive impairment, such as reduced information processing speed, memory loss, changes in social cognition, or impaired reasoning (Gazzaniga et al., 2018) are also depicted in Figure 2 to demonstrate how these impairments frame the adoption and effective use of digital health technologies. Classified as *explanatory* IS theory (Gregor, 2006), the theorized model can further be described as midrange theory as it refines knowledge in the specific field of digital health to provide measurable relationships between constructs (Leidner and Tona, 2021). It has been meticulously developed from our structured literature theorizing approach utilizing a qualitative content analysis which resulted in four aggregate dimensions that integrated the initial cognitive theories and form the core component (AD3) and constructional foundation (AD1, 2, 4) of our theory proposal.

4.1 Constructs

The first construct, **Cognitive Load for Digital Health** (CL-DH), is influenced by the principles of cognitive load theory which stems from AD1. Therefore, it consists of three sub-dimensions that encompass cognitive load regarding digital health adoption: intrinsic cognitive load (associated with task complexity and prior knowledge), extraneous cognitive load (linked to digital interface presentation and information overload), and germane cognitive load (involving reflective processing and learning effort). Additionally, adaptive load management strategies such as chunking and scaffolding are integrated to help individuals optimize their cognitive resources while interacting with digital health tools (Antonio et al., 2023; Sweller et al., 2011; Weimann et al., 2022).

The second construct, **Social Cognitive Factors** (SCF), draws from social cognitive theory (AD2) and encompasses elements such as observational learning, (contextual) self-efficacy, and reciprocal determinism, representing manifestations of the individual's social learning capabilities and belief in their own effectiveness. It highlights the importance of modeling, self-perceived competence, and the

dynamic interplay between individual, personal, and environmental factors in shaping technology adoption behaviors (Bandura, 2001; Compeau et al., 1999; Ifinedo, 2012; Pak and Song, 2016). In the context of *reciprocal determinism* and through our "building theory elements" step (Leidner and Tona, 2021), we found that cognitive load is dynamically interwoven with behavioral, personal, and environmental factors, exhibiting a mutual influence among these elements. This relationship suggests that changes in cognitive load can both influence and be influenced by an individual's behavior, internal personal traits, and external environmental conditions. As defined in social cognitive theory, reciprocal determinism posits a bidirectional influence among behavior, personal factors, and environmental conditions (Bandura, 1977). This concept is consistent with the notion that cognitive load is dynamically intertwined with these elements, where it not only results from but also contributes to changes in behavior, personal characteristics, and environmental interactions (Sweller, 1988; Paas & Van Merriënboer, 1994). Thus, our theoretical model depicts it as detached from being solely associated with the SCF.

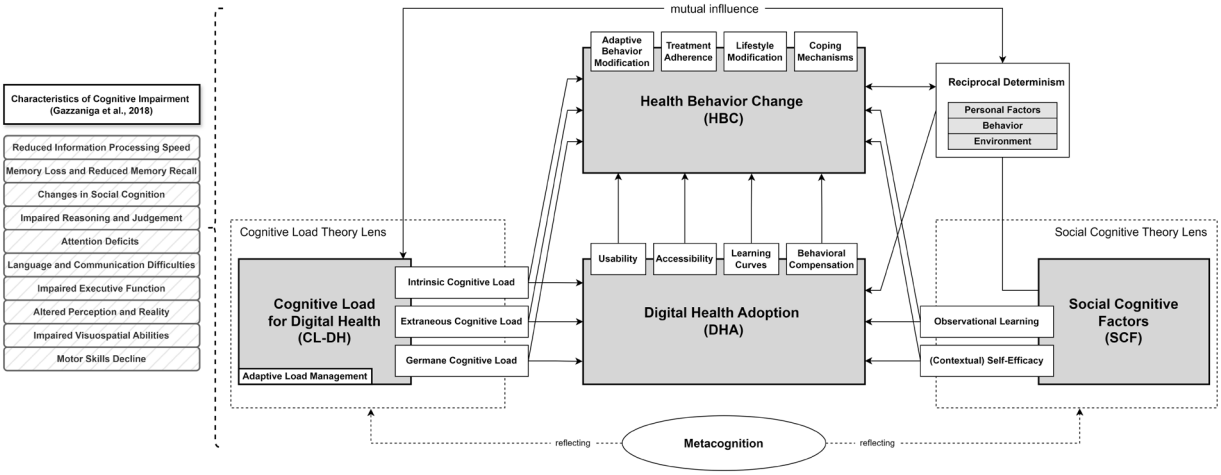


Figure 2. Proposal of a cognitive adoption theory model.

The third construct, **Digital Health Adoption** (DHA) is the core component of the theory and delves into factors that determine the adoption of digital health technologies among people with cognitive impairments (AD3). Usability, accessibility, and learning curves are key sub-dimensions considered within this construct. Therefore, the sub-dimensions embody different factors that together form the concept of how individuals with cognitive impairments adopt digital health. Unlike reflective indicators, these do not necessarily have to correlate (Kyratsis et al., 2022), e.g., an application could be very accessible but not particularly usable, and still be adopted. Usability encompasses elements like user interface design and task efficiency, while accessibility involves universal design principles and user-centeredness. Learning curves encompass the ease of onboarding, availability of learning resources, and the adaptability of digital health tools (Jozan et al., 2023; Venkatesh et al., 2003). Drawn from current literature, behavioral compensation plays a pivotal role in digital health adoption, potentially hindering or facilitating the process depending on how well the technology aligns with the users' cognitive and physical abilities, their environment, and the use of other digital health technologies (Wolf et al., 2023).

The fourth construct, **Health Behavior Change** (HBC), incorporates elements essential for fostering positive health-related transformations (AD4), assuming that changes in health behavior are reflective of underlying personal motivations, beliefs, and attitudes. The use of digital health technology is a means to an end, not an end in itself, as the ultimate goal is to achieve sustainable health outcomes, which is only possible if technology adoption leads to positive behavior change. Here, the various factors like usability, accessibility, learning curves, and behavioral compensation reflect changes in this latent health behavior change construct. This construct encompasses sub-dimensions such as adaptive behavior modification, treatment adherence, lifestyle modification, and coping mechanisms. These sub-dimensions are based on features that support stimulus/forethought, self-regulation, incentivizing, and

social interaction to facilitate behavior change (Fallon et al., 2019) and assess their effectiveness (Singh and Varshney, 2020). These are critical in shaping how individuals set and adjust personalized health goals, adhere to treatment plans, modify their lifestyles, and employ coping mechanisms to achieve better health outcomes (Kenei and Opiyo, 2022; Kim and Han, 2021, Wolf et al., 2023). Recent research already shows phenomena like *technology-behavioral compensation effects*, where users tend to reduce preventive health behaviors after adopting a specific health application that they find useful (Wolf et al., 2023) or experience context-dependent adoption or behavior change factors (Rieder et al, 2020). Our model addresses how digital health technologies can trigger these unintended behavioral adjustments that negate intended benefits, emphasizing the need for designs that manage cognitive load, integrate social learning for reinforcement, promote metacognitive awareness, and prioritize usability to encourage sustained, positive health behavior change. Learners' self-awareness (**metacognition**) and confidence (self-efficacy) influence their approach to tasks and technology use. Strong metacognition allows them to adapt strategies based on difficulty (cognitive load), and feedback helps calibrate these strategies for optimal learning (Flavell, 1979). In digital health design, understanding these factors provides a comprehensive perspective for user-centered tools. This includes intuitive interfaces, alignment with health goals, and consideration of user beliefs to promote adoption and integration into health routines for individuals with reduced cognitive function.

4.2 Construct relationships

Since midrange theories are embodied in measurable relationships, *cognitive adoption theory* postulates various relationships that can potentially be tested, validated, or challenged, all based on the theoretical groundwork established by previous publications and discovered through our qualitative content analysis. Our IS theory proposal is explanatory, and thus, unlike predictive theories, it doesn't require testable relationships (Gregor, 2006). We base our construct relationships on literature, some empirically validated, focusing on concept development rather than hypothesis testing. The relationships we describe are therefore directional and based on literature, not necessarily quantifiable or complete.

From a cognitive load perspective, intrinsic cognitive load, the inherent difficulty associated with a particular instructional topic, can facilitate the adoption of digital health tools if kept manageable (Paas et al., 2003; Treiblmaier et al., 2018; Weimann et al., 2022). However, when this load becomes excessive, it can inhibit health behavior change by overwhelming users, especially those with cognitive impairments (Paas and Van Merriënboer, 1994). On the other hand, extraneous cognitive load, often resulting from confusing digital interfaces, can deter users from both adopting digital health tools and changing their health behaviors (Melenhorst et al., 2001). Yet, the germane cognitive load, which embodies the effort one invests in learning, can positively enhance both digital health adoption and health behavior change, by fostering a profound understanding of health behaviors (Antonio et al., 2023; Paas and Van Merriënboer, 1994, Sweller et al., 2011).

Incorporating social cognitive factors, observational learning can be leveraged as a significant asset that positively impacts both digital health adoption and health behavior change. Seeing others successfully use digital health tools can inspire and guide individuals with cognitive impairments (Bandura, 2001; Kim and Han, 2021). Being a core construct within the social cognitive lens, high self-efficacy, or belief in one's ability to perform tasks, can increase confidence in adopting digital health tools and increase motivation to change health behaviors (Bandura, 1997; Compeau and Higgins, 1995, Compeau et al., 1999; Ifinedo, 2012; Pak and Song, 2016). Interestingly, contextual self-efficacy, which describes one's task self-efficacy regarding internal and external contexts, can negatively affect health compliance and therefore health behavior (Rieder et al., 2020) by creating overconfidence in individuals' ability to navigate the complex environment of health interventions without the necessary resources or support. Since personal factors, environmental influences, and behaviors all interact and influence one another, the relationship of reciprocal determinism with cognitive load, digital health adoption, and health behavior constructs is complex and characterized by both reinforcing and counteracting dynamics (Bandura, 1986; Venkatesh et al., 2003).

Digital health adoption impacts health behavior change through technology design and functionality. Enhanced usability and accessibility promote broader demographic adoption and intuitive use (Kim and Han, 2021; Melenhorst et al., 2001; Pak and Song, 2016; Venkatesh et al., 2003). Additionally, a manageable learning curve encourages sustained tool usage, aiding in long-term health behavior change. Nonetheless, technology-behavioral compensation negatively affects health behavior change as users reduce other preventive health behaviors if they find one solution highly useful (Wolf et al., 2023).

4.3 Theory classification

Following Whetten's (1989) concept of theory, and in line with Gregor's (2006) *explanatory* type of IS theory (type II), our cognitive adoption theory aims to explain the *what*, *how*, and *why*. Through this type of theorizing, we try to explain the phenomenon of cognitive adoption regarding digital health applications and health behavior change of people with cognitive impairments and decreased cognitive performance. Such theories often lead to the development of process-type theories, which are essentially designed to improve the understanding of various phenomena (Gregor, 2006). They can be viewed as theories aimed at enhancing comprehension and providing insights into the world. In our case, the cognitive adoption theory proposal analyzes the contributing load and social factors of cognitive processes to explain their effect on digital health adoption and health behavior change. These analyses provide valuable insights, especially when borrowing concepts from different fields (Jiang et al., 2022; Truex et al., 2006) and integrating these perspectives into next-generation IS theories (Burton-Jones et al., 2021; Young et al., 2021).

Theory Overview	
We developed a new theoretical model, the *cognitive adoption theory*, which claims that both cognitive load and social cognitive factors simultaneously influence digital health adoption and health behavior change.	
Theory Component	**Instantiation**
Means of representation	Words (Chapter 4), diagram (Figure 2), tables (Tables 1 and 2).
Primary constructs	Cognitive load theory and social cognitive theory as main lenses. Conceptual features of intrinsic, extraneous, and germane cognitive load as well as observational learning, self-efficacy, and reciprocal determinism including metacognition as an overarching construct. The theory's primary constructs encompass DHA, HBC, CL-DH, and SCF.
Statements of relationship	Derived from literature (Chapter 4.2), depicted as a model (Fig. 2). An example: "[…] intrinsic cognitive load, the inherent difficulty associated with a particular instructional topic, can facilitate adaptation to digital health tools if kept manageable […]. However, when this load becomes excessive, it can inhibit health behavior change by overwhelming users, especially those with cognitive impairments […]".
Scope	The statements of relationships include modal qualifiers to draw boundaries to the digital health domain and cognitive impairment. Still, a high level of generality ensures applicability in general healthcare environments.
Causal Explanations	The statements of relationship (Chapter 4.2) include causal explanations, for example: "Enhanced usability and accessibility can both significantly promote health behavior change, catering to a broader demographic and making the adoption process more intuitive […]".
Testable propositions	Not present. The theory is explanatory in nature, and the model should be applied conceptually, but provides a basis for deductive, hypothesis-driven research.
Prescriptive statements	Not present.

Table 2. Taxonomic theory perspective according to Gregor (2006).

As shown in Table 2, our theory aims to shift the perspective of the observer, offering a new way to see and understand digital health adoption, its actionable effects, and its phenomena, rather than predicting future occurrences or testing propositions (Gregor, 2006). Such a theory closely corresponds to some views of interpretivist theory as our artifact can be seen as a preliminary end product of the theorizing

process and is not expected to lead to deterministic and predictive theory, aligning with the interpretivist paradigm by emphasizing meaning, understanding, and context rather than prediction and control (Klein and Myers, 1999). This approach is particularly beneficial in digital health, where complex human behaviors and technology interactions converge, as it allows for a more nuanced and empathetic understanding of vulnerable populations and their dynamic interactions with technology, providing a fresh lens through which to examine and understand digital health adoption and behavior.

5 Discussion

With our theorizing study on cognitive adoption of digital health applications among people with cognitive impairments, we were able to develop an integrative theoretical model that synthesizes perspectives on cognitive load and social cognitive factors. Our proposal for a *cognitive adoption theory* in digital health, developed using a literature-based approach and grounded theory, rethinks core IS theories, incorporating both existing literature and idea synthesis to create an explanatory IS theory. Thus, this study proposes an integrative theory model that can be adopted, challenged, and utilized by further research in the digital health domain or even beyond in various research fields where cognitive aspects play a crucial role in explaining phenomena. Our study enriches the IS literature and guides the design of digital health applications by highlighting the role of user cognition in technology adoption, particularly for people with cognitive impairments, such as older adults affected by neurodegenerative diseases, and ensuring that digital health solutions address the unique needs of vulnerable populations.

5.1 Theoretical and practical implications

Our research in cognitive adoption and digital health unveils several theoretical implications. Inspired by next-generation theorizing (Burton-Jones et al., 2021), we view theory as a dynamic intellectual conversation rather than a mere intellectual product, enabling its evolution with emerging trends and technologies. Our findings indicate that digital health technology integration requires not just technical proficiency, but also an understanding of the psychological, cognitive, and sociocultural aspects of technology adoption. This aligns with Whetten's (1989) emphasis on the *What*, *How*, and *Why* of theory development and Sutton and Staw's (1995) definition of theory, where our integrative theoretical model is not just a set of ideas, but a living conversation that adapts and evolves over time, meaning that our theory must be open to evolution and refinement based on new findings and insights. Our integrative theory model in the IS domain blends concepts from various disciplines for coherent application to IS phenomena, aligning with Gregor's (2006) theoretical taxonomy and providing comprehensive perspectives through borrowing (Jiang et al., 2022; Truex et al., 2006). This further follows the view that theory development should be conscious of the broader socio-political contexts, ensuring theoretical relevance, practical utility, and ethical considerations in their application to real-world IS settings (Burton-Jones et al., 2021; Gregor, 2006; Young et al., 2021). Our theorized model is thus not static, but rather a dynamic entity that evolves with new knowledge and insights, reflecting the fluid nature of theories in IS research as described by Wiesche et al. (2017).

Interdisciplinary integration, as we brought psychological concepts from social sciences into IS research, highlights the importance of multifaceted approaches in tackling complex issues (Leidner and Tona, 2021; Young et al., 2021), resonating with Whetten's (1989) call for theories that explain, not just describe, phenomena. Our study underscores the value of merging technical and human-centric approaches in digital health, benefiting both researchers and users. Integrating SCT and CLT, our model promotes interdisciplinary collaboration among clinical, psychological, and IS researchers, bridging behavioral theories and usability studies. This approach fosters more comprehensive research and deeper insights into the rapidly evolving field of digital health that only existed to a limited extent 40-50 years ago. Hence, we extend the current literature conversation on cognitive IS research through psychological aspects and contribute to the intersection of social and behavioral sciences (Fallon et al., 2019; Kenei and Opiyo, 2022; Kim and Han, 2021; Melenhorst et al., 2001; Pak and Song, 2016; Rieder et al., 2020; Singh and Varshney, 2020; Wolf et al., 2023) by providing a novel integrative theory that can be adapted, utilized, or challenged. Despite cognitive research having social science roots, we posit that the IS field

possesses the expertise to delve into the cognitive aspects of technology design, adoption, and use, particularly within the context of cognitive impairment and assistive technology interventions. This study aims to initiate the theoretical discourse on cognitive adoption among individuals with cognitive impairments and serves as a starting point for building a dedicated theoretical framework in IS to guide future research.

Moreover, the integration of cognitive load and social cognitive factors suggests that not only do individual cognitive capacities and processes matter, but also the social and environmental factors that influence them, reflecting Whetten's (1989) notion that theories should provide a cogent explanation for expected relationships in data. This broadens the lens through which we view adoption challenges and could lead to more holistic intervention strategies, shifting the paradigm from mere acceptance (Venkatesh et al., 2003) to comprehensive adoption of digital health solutions. Our shift from a purely representational to a performative view of theory (Burton-Jones et al., 2021) means our integrative model isn't just a depiction of cognitive-social interactions in digital health adoption for people with cognitive impairments; it's an active influencer with potential real-world impact, necessitating the translation of theoretical insights into effective digital health adoption strategies.

Our study further underscores Whetten's (1989) perspective that good theory involves more than just a list of variables or relationships; it requires a deep understanding of the underlying dynamics. In the context of digital health adoption for individuals with cognitive impairments, our research underlines that successful technology adoption depends on its fit with the user's cognitive abilities, social environment, and unique medical challenges. This contributes to a deeper understanding of technology use in healthcare. This aligns with IS research's grounded theory-based studies, emphasizing the importance of detailed descriptions for gaining and documenting new insights (Wiesche et al. 2017).

Bridging the gap between theory and practice, our findings may inform user-centered applications and health policies. Understanding cognitive demands and social learning can lead to intuitive, tailored digital health tools, especially among vulnerable populations like those with neurodegenerative diseases or the elderly with cognitive decline. Our theory model may guide policymakers and healthcare institutions in deploying effective digital health strategies, considering the patient environment, caregiver roles, and cognitive profiles. Incorporating observational learning, self-efficacy, and feedback from SCT, along with cognitive load considerations, can make digital platforms more adoptable, user-friendly, and less intimidating. This approach may boost adoption rates and sustain usage, vital for successful digital health interventions and health behavior change. These strategies are essential in addressing the complex needs of individuals with cognitive impairments, who require solutions that cater not only to their medical needs but also to their cognitive and social contexts. Integrating cognitive adoption theory into digital health applications can enhance patient-centered care, allowing healthcare providers to tailor interventions to individual cognitive needs and impairments. This can increase patient engagement and adherence to treatment plans, thereby improving digital health intervention effectiveness and healthcare quality during the ongoing demographic change.

5.2 Limitations and future research

Our study has limitations to be considered. The subjective and creative nature of the theorizing from literature process (Leidner and Tona, 2021) means different researchers might develop different constructs, though we aimed for transparency in deriving these constructs. Shifting from theory as truth to theory as a lens (Burton-Jones et al., 2021), it's vital to remember that our theory, based on CLT and SCT, is one of many possible perspectives on this IS phenomenon. Our approach emphasized building a robust theoretical foundation by prioritizing conceptual development in the early stages. From this perspective, theories go beyond mere collections of data or findings; they provide logical, systematic, and coherent explanations of phenomena based on interrelated constructs and propositions (Bacharach, 1989). As an explanatory type of IS theory, empirically testable propositions and relationships are not present nor necessary for prediction (Gregor, 2006), thus paving the way for conceptual theory to be challenged or tested by subsequent research efforts. Thus, our approach aligns with the need for next-generation theorizing in IS research (Burton-Jones et al., 2021), especially in the context of rapidly

evolving digital health systems, where understanding and navigating complexity is paramount. The inherent complexity of this research area requires that theoretical development be prioritized to provide a strong foundation for empirical testing (Whetten, 1989). While we acknowledge the importance of empirical validation, we focused on building a comprehensive theoretical artifact that can then be tested and refined through future research. This approach ensures a more mature and conceptually robust theory for future empirical investigation. Recognizing the changes in the contemporary world, next-generation theorizing becomes necessary when new phenomena push the boundaries of existing theories, emphasizing the development of robust theoretical frameworks that can address both existing and emerging phenomena before empirically validating the theorized artifact (Bacharach, 1989; Burton-Jones et al., 2021). The rich theoretical traditions in the IS field, evolving and improving over time, often in interplay with empirical traditions, further support our approach. This history underscores the importance of theory development as a foundation for meaningful empirical research (Burton-Jones et al., 2021; Young et al., 2021). We strategically prioritized theoretical and conceptual development, setting the stage for future empirical validation and knowledge advancement. The proposed cognitive adoption theory invites scholarly critique and refinement to guide subsequent research. As we move toward empirical testing and case studies, it is critical to recognize the importance of diverse cultural and socioeconomic contexts in digital health adoption.

6 Conclusion

In conclusion, while our study provides insights into the cognitive adoption of digital health applications among people with cognitive impairments, we encourage researchers to challenge, adapt, or empirically test our conceptual theoretical model to enrich the body of knowledge on digital health adoption in IS. Such collaborative efforts will pave the way for the creation of more effective and user-centered digital health solutions that lead to better health outcomes and improved health behavior change - not only in theory but also in practice. These solutions, tailored to the unique needs of people with cognitive impairments, can significantly improve quality of life and empower patients to change their health behaviors for the better, contributing to a more inclusive and responsive digital health ecosystem that addresses the complex and diverse needs of vulnerable populations.

References

Antonio, M. G. et al. (2023). "Targeting patients' cognitive load for telehealth video visits through student-delivered helping sessions at a United States federally qualified health center: equity-focused, mixed methods pilot intervention study," *Journal of Medical Internet Research*, 25.

Bacharach, S. B. (1989). Organizational theories: Some criteria for evaluation. *Academy of Management Review.*, 14(4), 496-515.

Baddeley, A. (1992). "Working memory," *Science*, 255(5044), 556-559.

Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. New York: Freeman.

Bandura, A. (2001). "Social cognitive theory: An agentic perspective," *Annu Rev Psychol*, 52(1), 1-26.

Bandura, A. (2013). "Health promotion from the perspective of social cognitive theory," *Understanding and changing health behavior,* Psychology Press, 299-339.

Blut, M. et al. (2022). "Meta-analysis of the unified theory of acceptance and use of technology (UTAUT): challenging its validity and charting A research agenda in the red ocean," *Journal of the Association of Information Systems.*

Böhmer, M. et al. (2022). "Preserve Autonomy – Developing and Implementing a Design Theory for Augmented Living Spaces," Proceedings of Pacific Asia Conference on Information Systems.

Burton-Jones, A., Butler, B. S., Scott, S., and Xu, S. X. (2021). "Next-generation information systems theorizing: A call to action," *MIS Quarterly*, 45(1), 301-314.

Caprara, G., Vecchione, M., Barbaranelli, C. and Alessandri, G. (2013). "Emotional stability and affective self–regulatory efficacy beliefs: Proofs of integration between trait theory and social cognitive theory," *European Journal of Personality*, 27(2), 145-154.
Carillo, K. D. (2010). "Social cognitive theory in is research–literature review, criticism, and research agenda," ICISTM 2010 Proceedings 4, 20-31.
Chandler, P. and Sweller, J. (1991). "Cognitive Load Theory and the Format of Instruction," *Cognition and Instruction*, 8(4), 293-332.
Chi, M. T., Glaser, R. and Rees, E. (1982). "Expertise in problem solving," *Adv Psych Hum Intel*, 1(7).
Chi, M. T., Feltovich, P. J. and Glaser, R. (1981). "Categorization and representation of physics problems by experts and novices," *Cognitive Science*, 5(2), 121-152.
Compeau, D. R. and Higgins, C. A. (1995). "Computer self-efficacy: Development of a measure and initial test," *MIS Quarterly*, 189-211.
Compeau, D., Higgins, C. A., & Huff, S. (1999). "Social cognitive theory and individual reactions to computing technology: A longitudinal study," *MIS Quarterly*, 145-158.
Corbin, J. M. and Strauss, A. (1990). "Grounded theory research: Procedures, canons, and evaluative criteria," *Qualitative Sociology*, 13(1), 3-21.
Davis, F.D. (1989). "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly* (13:3), pp. 319-340.
Ericsson, K. A., Krampe, R. T. and Tesch-Römer, C. (1993). "The role of deliberate practice in the acquisition of expert performance," *Psychological review*, 100(3), 363.
Fallon, M., Spohrer, K., & Heinzl, A. (2019). „Deep structure use of mHealth: a social cognitive theory perspective," European Conference on Information Systems (ECIS).
Flavell, J. H. (1979). "Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry," *American Psychologist*, 34(10), 906.
Gauthier, S. et al. (2006). "Mild cognitive impairment," *The Lancet*, 367(9518), 1262-1270.
Gazzaniga, M., Ivry, R. and Mangun, G. (2018). *Cognitive Neuroscience: The Biology of the Mind.* WW Norton & Co, 5th Edition.
Gioia, D. A., Corley, K. G. and Hamilton, A. L. (2013). "Seeking qualitative rigor in inductive research: Notes on the Gioia methodology," *Organizational Research Methods*, 16(1), 15-31.
Gregor, S. (2006). "The nature of theory in information systems," *MIS Quarterly*, 611-642.
Hsu, C. L. and Lu, H. P. (2004). "Why do people play on-line games? An extended TAM with social influences and flow experience", *Information & Management*, 41(7), 853-868.
Ienca, M., Schneble, C., Kressig, R. W. and Wangmo, T. (2021). „Digital health interventions for healthy ageing: a qualitative user evaluation and ethical assessment," *BMC Geriatrics*, 21, 1-10.
Ifinedo, P. (2012). "Understanding information systems security policy compliance: An integration of the theory of planned behavior and the protection motivation theory," *Computers & Security*, 31(1).
Jiang, L., London, J., Grover, V. and Sun, H. (2022). "Everything Old Can Be New Again: Reinvigorating Theory Borrowing for the Digital Age," *MIS Quarterly*.
Jones, R. N. et al. (2011). "Conceptual and measurement challenges in research on cognitive reserve," *Journal of the International Neuropsychological Society*, 17(4), 593-601.
Jozan, M. M. B., Ghorbani, B. D., Khalid, M. S., Lotfata, A. and Tabesh, H. (2023). "Impact assessment of e-trainings in occupational safety and health: a literature review," *BMC Public Health*, 23.
Kankanhalli, A., Tan, B. C. and Wei, K. K. (2005). "Contributing knowledge to electronic knowledge repositories: An empirical investigation," *MIS Quarterly*, 113-143.
Karahanna, E., Straub, D. W. and Chervany, N. L. (1999). "Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs," *MIS Quaterly,* 23(2).
Kenei, J. K. and Opiyo, E. (2022). "Using classification and visualization to support clinical texts review in electronic clinical documentation," ICMHI 2022 Proceedings, 78-84.
Kim, E. and Han, S. (2021). "Determinants of continuance intention to use health apps among users over 60: A test of social cognitive model," *Int J Environ Res Public Health*, 18(19), 10367.
Klein, K. J. and Kozlowski, S. W. (2000). "From micro to meso: Critical steps in conceptualizing and conducting multilevel research," *Organizational Research Methods*, 3(3), 211-236.

Klein, H. K. and Myers, M. D. (1999). "A set of principles for conducting and evaluating interpretive field studies in information systems," *MIS Quarterly*, 67-93.
Kyratsis, Y., Scarbrough, H., Begley, A. and Denis, J. L. (2022). "Digital health adoption: Looking beyond the role of technology," *Frontiers in Digital Health*, 4, 989003.
Leidner, D. E. and Tona, O. (2021). "A thought-gear model of theorizing from literature," *Journal of the Association for Information Systems*, 22(4), 10.
Lin, T.C. and Huang, C. (2008). "Understanding knowledge management system usage antecedents: An integration of social cognitive theory and task technology fit," *Information & Management*, 45(6).
Mathews, S.C., et al. (2019). "Digital health: a path to validation," *NPJ Digital Medicine*, 2(1), 38.
Melenhorst, A. S. et al. (2001). "The use of communication technologies by older adults: Exploring the benefits from the user's perspective," HFES Proceedings (4)1, 1682-1686). Sage Publications.
Mostaghel, R. (2016). "Innovation and technology for the elderly: Systematic literature review," *Journal of Business Research*, 69(11), 4896-4900.
Paas, F., Renkl, A. and Sweller, J. (2003). "Cognitive Load Theory and instructional design: Recent developments," *Educational Psychologist*, 38(1), 1-4.
Paas, F. and Van Merriënboer, J. J. (1994). "Instructional control of cognitive load in the training of complex cognitive tasks," *Educational Psychology Review*, 6(4), 351-371.
Rieder, A. et al. (2021). "Why users comply with Wearables: The role of contextual self-efficacy in behavioral change," *International Journal of Human–Computer Interaction*, 37(3), 281-294.
Rodriguez, F. S. et al . (2020). "Interdisciplinary and transdisciplinary perspectives: on the road to a holistic approach to dementia prevention and care," *J. Alzheimers Dis. Rep.*, 4(1), 39-48.
Shepherd, D. A. and Sutcliffe, K. M. (2011). "Inductive top-down theorizing: A source of new theories of organization," *Academy of Management Review*, 36(2), 361-380.
Singh, N., & Varshney, U. (2020). "IT-based reminders for medication adherence: systematic review, taxonomy, framework and research directions," *European Journal of Information Systems*, 29(1).
Stern, Y. (2002). "What is cognitive reserve? Theory and research application of the reserve concept," *Journal of the International Neuropsychological Society*, 8(3), 448-460.
Sutton, R. I. and Staw, B. M. (1995). "What theory is not," *Administrative Science Quarterly*, 371-384.
Sweller, J. (1988). "Cognitive load during problem solving: Effects on learning," *Cognitive Science*.
Sweller, J. et al. (2011). "Cognitive load theory," *Springer Science & Business Media*.
Sweller, J., Van Merriënboer, J. J. and Paas, F. G. (1998). "Cognitive architecture and instructional design," *Educational Psychology Review*, 10(3), 251-296.
Sweller, J. (2023). "The Development of Cognitive Load Theory: Replication Crises and Incorporation of Other Theories Can Lead to Theory Expansion," *Educational Psychology Review*, 35(4), 95.
Treiblmaier, H., Putz, L. M. and Lowry, P. B. (2018). "Setting a definition, context, and theory-based research agenda for the gamification of non-gaming applications," *AIS THCI*, 10(3), 129-163.
Truex, D., Holmström, J. and Keil, M. (2006). "Theorizing in information systems research: A reflexive analysis of the adaptation of theory in information systems research," *Jorunal of the Association of Information Systems*, 7(1), 33.
Venkatesh, V. et al. (2003). "User acceptance of information technology: Toward a unified view" *MISQ*.
Weimann, T. G., Schlieter, H. and Brendel, A. B. (2022). „Virtual coaches: Background, theories, and future research directions," *Business & Information Systems Engineering*, 64(4), 515-528.
Whetten, D. A. (1989). "What constitutes a theoretical contribution?," *Acad Manag Rev*, 14(4).
Wiesche, M., Jurisch, M. C., Yetton, P. W. and Krcmar, H. (2017). „Grounded theory methodology in information systems research," *MIS Quarterly*, 41(3), 685-A9.
Wolf, T., Trang, S., Weiger, W. H. and Trenz, M. (2023). "The technology-behavioral compensation effect: Unintended consequences of health technology adoption" *Journal of Information Technology*.
Young, A. G., Majchrzak, A. and Kane, G. C. (2021). "Reflection on writing a theory paper: How to theorize for the future," *Journal of the Association for Information Systems*, 22(5), 1212-1223.
Zhang, D., Zhou, L., Briggs, R. O. and Nunamaker Jr, J. F. (2006). "Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness," *Inf. Manag. J.*, 43(1), 15-27.