applied sciences

MDPI

Article

Making Complex Technologies Accessible Through Simple Controllability: Initial Results of a Feasibility Study

Pascal Müller [1,*], Hari Krishna Reddy Gali [2], Subashkumar Rajanayagam [2], Stefan Twieg [2], Patrick Jahn [1,*] and Sebastian Hofstetter [1]

[1] Health Service Research Working Group | Acute Care, Department of Internal Medicine, Faculty of Medicine, Martin-Luther-University Halle-Wittenberg, 06112 Halle (Saale), Germany
[2] Department of Electrical, Mechanical and Industrial Engineering, Anhalt University of Applied Sciences, 06366 Köthen, Germany; subashkumar.rajanayagam@hs-anhalt.de (S.R.)
* Correspondence: pascal.mueller@uk-halle.de (P.M.); patrick.jahn@uk-halle.de (P.J.); Tel.: +49-0345-557-4001 (P.M.); +49-0345-557-2220 (P.J.)

Abstract: Digital assistive technologies (DATs) present a significant opportunity to address the challenges of the healthcare system. However, they have not been designed for this purpose and are still in the process of further development. The objective of this study is to ascertain the extent to which a digital cross-device control and application platform for the simplified utilization of DATs alters the willingness of nurses to utilize them in the care process. An exploratory, longitudinal design with a mixed-methods approach was employed in this study. The co-creative design cycle was conducted in two long-term care facilities, with 25 caregivers participating in the form of testing for the platform's prototypes across multiple iteration loops. The preliminary results indicate a high intention to use DAT, suggesting that the actual use of DAT through a control and application platform will be considerable. The overall trend demonstrates an increase in acceptance, willingness, and intention to use DAT among the participants. One proposed solution to the usability issues of DAT is to develop a platform with an interface for non-programmers to create individual interventions using everyday controls and a few intuitive steps. This could facilitate the sustainable implementation of DAT in healthcare.

Keywords: digital assistive technologies; digital transformation; human–technology interaction; customization; user-centered design; co-creation; intention to use; healthcare; long-term care; feasibility study

Academic Editors: Richard Jaepyeong Cha and Chung Hyuk Park

Received: 20 December 2024
Revised: 18 January 2025
Accepted: 19 January 2025
Published: 20 January 2025

Citation: Müller, P.; Gali, H.K.R.; Rajanayagam, S.; Twieg, S.; Jahn, P.; Hofstetter, S. Making Complex Technologies Accessible Through Simple Controllability: Initial Results of a Feasibility Study. *Appl. Sci.* **2025**, *15*, 1002. https://doi.org/10.3390/app15021002

1. Introduction

In the context of demographic change, the associated increase in demand for care services and shortage of nursing staff present the healthcare system with urgent challenges that require immediate attention [1–3]. The number of people in need of care in Germany will increase from around five million in 2021 to 5.6 million in 2035 and more than 6.6 million in 2050 [4]. At the same time, it is predicted that the shortage of nursing staff will increase from the current figure of 135,000 to over 690,000 over the same period [5]. The digital transformation of healthcare and the integration of social robots or digital assistive technologies (DATs) present a pivotal opportunity to address these challenges and alleviate the burden on nursing staff [6–10]. Robotic assistants and exoskeletons have the capacity to alleviate the burden on caregivers by providing support in their daily tasks and physically demanding activities. Social companion robots, such as "Paro", support interpersonal interaction. Telepresence systems facilitate communication between individuals, enabling

relatives or care professionals to engage with those in need of care while maintaining mobility within their living environment [6].

According to the World Health Organization (WHO) [11], assistive technology is defined as devices or systems that maintain or improve an individual's functioning, thereby promoting their health, well-being, inclusion, and participation. These technologies encompass a range of products, including physical devices (e.g., wheelchairs, prosthetic limbs, hearing aids) and digital solutions (e.g., speech recognition, time-management software). DAT is a collective term for systems that are designed to support people in their various tasks with the aim of promoting independence and autonomy, enhancing personal capabilities, and promoting well-being [11,12]. It is also intended to improve quality of life when used in a planned, problem-oriented way [13,14]. However, initial work shows that DATs, like mobile applications, telemedical systems, and robotics, have not yet been implemented as sustainably as expected in the care process [15]. In the context of this study, the term is expanded to include DATs, with a particular focus on virtual reality (VR) technologies and robotic systems.

DATs have the capacity to facilitate a range of activities associated with daily living. These activities include, but are not limited to, smart medication management, digitally assisted fall prevention, and communication. DATs signify a progression in the field of assistive technologies, characterized by the integration of digital functionalities [16]. Within the domain of robotics, a limited number of commercially available options exist within the healthcare and medical sector, with a predominant focus on service-oriented applications such as food delivery and drug administration, in addition to surgical-related use cases. While certain commercially available robotic technologies hold promise in addressing these needs, they have not been designed and developed for this purpose or context and are still in the process of further development [17,18]. A survey of nurses has revealed a desire for robots to assist them in their work, particularly in service and logistics activities, as well as in physically demanding tasks such as patient positioning [19,20]. The utilization of VR is predominantly focused on communication and educational applications. The technology's applications extend to telepresence scenarios that do not require physical presence, novel treatment approaches for phobias, and motivation for physical activity, among others [21].

A comprehensive review of international research underscores that factors conducive to the successful implementation of DAT in nursing care can be broadly classified into three categories: the users, the systems themselves, and the research and development processes [22].

From the perspective of the users, a positive attitude towards technology has been identified as a significant contributing factor. Surveys of professional caregivers have demonstrated that their acceptance of these technologies is not a significant issue [23–25]. The perceived usefulness and intended use of DATs are predominantly viewed as advantageous and user-friendly. The majority of caregivers have been found to exhibit an openness, curiosity, and receptivity to new technologies.

The involvement of potential end users and the implementation of constructive accompanying research are beneficial from a research and development perspective. The incorporation of care professionals can serve to mitigate the risk of developing impractical and ill-suited DATs [14,26,27]. The field of implementation science is currently undergoing a transition from a linear, risk-averse approach to development in controlled laboratory settings to a more iterative, participatory, and complex model in which interventions are developed and evaluated directly in the field of intended application [28,29]. Participatory design approaches, such as co-creation or design-based research [30], have the potential to enhance usability and user acceptance. Usability, in this context, is defined as the context-specific, application-driven, and efficient interaction between people and technology [31].

Co-creation, a collaborative methodology, engages end users and relevant stakeholders throughout the project lifecycle, from the initial needs assessment and problem definition to the prototype evaluation and project completion [32]. The involvement of end users at the earliest stages of the development process has been identified as a strategy that may enhance acceptance and positively influence patient satisfaction and the quality of care [33,34].

The successful implementation of this methodology is contingent upon the device's ease of use and intuitive handling. The challenge for the system is to adapt DATs to the diverse and individual needs of the patients they care for and to integrate them into care processes that must be planned on a case-by-case basis [35]. It is, therefore, imperative to ensure that services are tailored to the specific functional limitations of those requiring care to realize the full potential of DATs. This approach enables the implementation of a strategic planning and problem-oriented approach to the utilization of DATs [13,14]. Furthermore, the nature of external control can vary significantly depending on the specific DAT and the nature of interaction with humans [36]. A uniform standard for the application of DATs remains to be established.

The subsequent sections present the initial findings of the EduXBot (Educational Exploration Robot Application Platform) project, which aims to develop and design a digital cross-device control and application platform for caregivers. A primary innovation of the platform is the creation of extended possibilities for the utilization and interaction with already available DATs by caregivers. The objective of the project is to create a flexible and open system architecture that will provide access to a range of robotic, sensor, and interaction systems via a single platform. The multi-part concept for using the platform allows for the utilization of DAT by individuals with varying degrees of technological expertise. Consequently, the EduXBot project is pioneering a new field of application for interaction platforms in the implementation of DAT in nursing practice [37].

2. Materials and Methods

The project commenced in January of 2023 and is scheduled to conclude in December of 2025. The subsequent sections present a selection of preliminary results from the project. These findings will undergo further testing and refinement in collaboration with caregivers throughout the project's duration. To ensure methodological quality, the TREND statement [38] was used for reporting the results.

2.1. Study Design

The project utilizes a co-creative design cycle to develop an innovative implementation concept that is useful, effective, and user-centered, thereby facilitating actual use [39]. Consequently, the project is united by a collaboration of developers from the domain of technology research, nursing scientists, and business partners from the realms of project management for digital work environments. Furthermore, nurses will be engaged as end users throughout the project's entirety, reflecting the co-creative nature of the project. This collaborative approach ensures that the project's goals are aligned with user needs and technological feasibility.

The "Motivation, Engagement, Thriving in User Experience" (METUX) model [40] is a framework that considers the expectations and experiences of the end users and encourages the intention to use (ITU). The primary objective of the project is to develop a functional, pertinent, and innovative platform for interaction with DAT, thereby facilitating its actual use and integration into nursing practice. The integration of user-centered design (UCD) and the co-creative design cycle [41] comprises three cycles (Figure 1): the relevance cycle, which incorporates the realities of end users; the rigor cycle, which incorporates the scien-

tific knowledge base; and the design cycle, which develops technical products [42–44]. This approach enables a more comprehensive and systematic process of theoretical formulation, data collection, and practical mapping of the requirements for the DAT utilized in the study, ultimately facilitating the determination of needs. Concurrently, the opportunity for collaboration between scientists and end users is enhanced. Furthermore, end users can be more actively engaged in the evaluation of the product throughout the test cycle. It is anticipated that this approach will yield positive outcomes, including improvements in identified outcomes and greater usability and user acceptance of DAT.

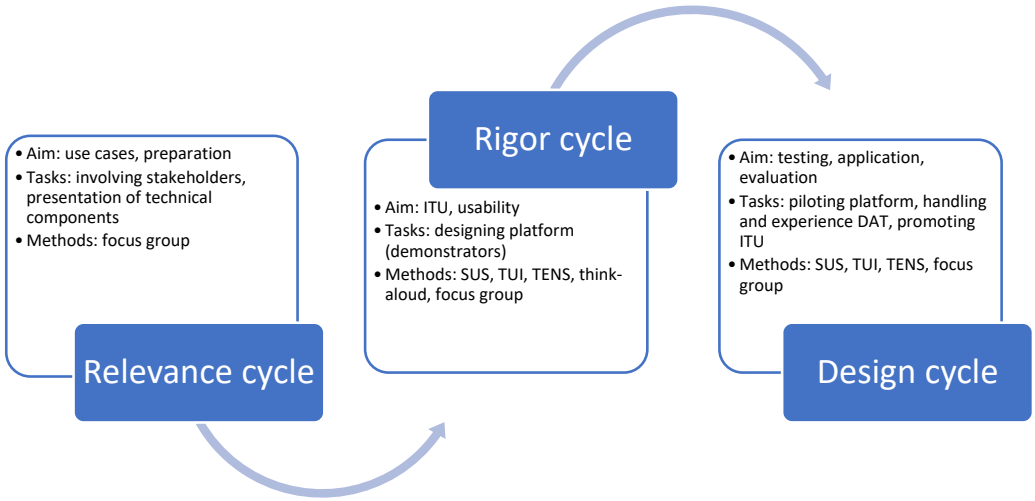

Figure 1. Description of the participatory design including the objectives, tasks, and methods employed at each of the three development cycles (based on Farao et al. [41]).

The methodology commences with the relevance cycle, wherein the needs, functionalities, and application scenarios of and with nurses are identified through focus groups. The selection of the DAT employed in the project is contingent upon the conditions of the cooperating institutions and the needs of the nursing staff. The selection of the DAT is predicated on the availability and readiness for use of those that are already in existence. The selection of the DAT is intended to span a broad spectrum, ranging from mobile telepresence systems to sophisticated humanoid robots. The outcomes of this procedure will be the delineation of concrete scenarios necessary for the implementation of a first demonstration model of the platform. Subsequent steps entail the development of prototypes through four iterations, with each iteration focusing on usability, user acceptance, and the satisfaction of fundamental psychological needs of the end users. This iterative process will reach its culmination in the testing of a preliminary prototype under both simulated and real conditions within designated facilities. The development of the prototype takes place schematically in four steps (Figure 2).

2.2. Participants

The practice partners are two health facilities in Germany. The first (Facility 1) is a regional health center that offers acute inpatient care, as well as outpatient and long-term inpatient services. The second (Facility 2) is a long-term inpatient care facility. The facilities were contacted as partners in previous projects and indicated their willingness to participate in this project.

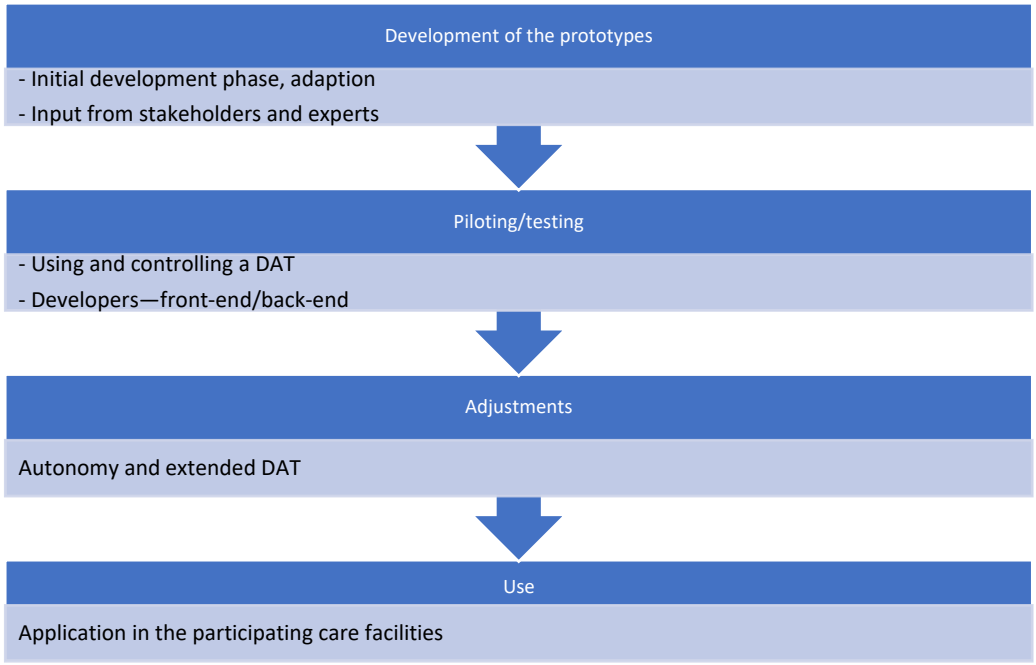

Figure 2. The development of the platform takes place in four steps.

Participants are invited to take part in the study as test subjects by the facilities with which they are affiliated. Both participants and facilities are provided with comprehensive information regarding the project plan. Additionally, the facility managers are tasked with acting as gatekeepers, encouraging the nurses within their respective facilities to participate in the research project. The sampling is as broad as possible in terms of age, gender, length of professional experience, and so forth [45]. The inclusion of a diverse sample of nurses from the facilities ensures a rich array of perspectives, providing a valuable contrast to the study. Participants who decline or withdraw from the study are excluded, as outlined in Table 1. It is important to note that no financial compensation is provided to participants. However, those who actively engage in the research will receive compensation in the form of complimentary beverages during workshops and, upon request, may have their institution and name acknowledged in the project acknowledgements.

Table 1. Description of the inclusion and exclusion criteria of the participants.

Inclusion Criteria	Exclusion Criteria
Nurses Support stuff Currently in a facility that belongs to the project's practice partner Sufficient written and spoken German	Those who do not want to participate at the beginning or withdraw after

The number of participants is determined by practical considerations, such as financial resources, the availability of participants, and the number required for a meaningful evaluation of the study objectives, as outlined in the Guideline for Designing and Evaluating Feasibility Pilot Studies [46]. The guideline indicates that saturation is reached when the number of participants reaches $n = 30$. The rule of thumb in statistics posits that a sufficient normal distribution can be assumed from a sample size of $n = 30$ [47,48]. Therefore, the objective is to obtain a minimum sample size of $n = 30$ caregivers. It should be noted that blinding is not possible, as the participants must actively engage with the DAT.

2.3. Intervention

In the practical implementation of the co-creative design, the potential end users are engaged at various stages of the project through the utilization of workshops [49]. The workshops are conducted in accordance with the SEQI approach [50]. Initially, the nursing staff is informed about DAT and the issues it presents. Subsequently, the developments are evaluated in four feedback loops until a product is created at the conclusion of the project, one that the nurses can integrate into their everyday lives. The objective of the workshops is to present the development progress and subsequently engage in discussion with the intention of further enhancing the platform for practical implementation.

The duration of the five workshops is approximately four hours, and at the outset of the project, the nurses are provided with a concise overview of the project's objectives and current status. Subsequently, participants are afforded the opportunity to evaluate the developments under the guidance of the think-aloud method in small groups comprising a maximum of three individuals. Following this, participants are invited to engage in a guideline-based focus group, where they are encouraged to discuss their experiences, aspirations, and requirements.

Prior to the initiation of the initial iteration loop, a comprehensive assessment of the necessary support for DAT by caregivers was conducted. The scenarios of conversational partner, walking partner, playing games, telepresence, and VR experience were identified as indispensable for the implementation of a demonstration model of the platform. In light of these considerations, the Double3 robot, designed for indoor use, the Go1 robot, suitable for outdoor environments, and the PICO 4 VR headset were selected by the developers and discussed with the caregivers for further consideration. These scenarios and related technical dependencies or selections can be seen in Table 2 below, which summarizes the respective hardware, DAT interventions, and applications required.

Table 2. Description of the selected use cases and technical requirements.

Intervention	Activities of Daily Living [51]	Customization Parameters	Hardware	Applications/Interfaces
Conversational partner	Communicate	Voice Character Topic	Double3	Speech To Text [52] Text Generation [53] Text To Speech [54] User Interface
Telepresence	Communicate		Double3	Mapping and Navigation with Obstacle Avoidance [55] User Interface
Playing rock-paper-scissors	Shaping space and time—work and play		Double3	Gesture Recognition [56] User Interface
Safe walking partner	To move	Active/passive mode Speed Duration	Go1 Edu Plus 3D LIDAR	Simultaneous Localization And Mapping [57,58] Robot Operating System Navigation [59] Human Detection And Tracking [60] Human Fall Detection [61]
Record/playback personal events	Find meaning in becoming, being, passing	Categories Rating Permissions	PICO 4	Image Stitching and Format Conversions [62]

As the objective of the project does not entail the evaluation of a market-ready product, the initial stages involve the use of click dummies and prototypes of a potential product. A click dummy signifies the preliminary phase of the development process, preceding the creation of the actual prototype. The absence of code does not preclude the possibility of individual functions being simulated initially, thereby reducing the risk of programming errors [63]. A prototype, in essence, constitutes a preliminary rendition of the eventual final product, thereby facilitating the evaluation and refinement of its fundamental characteristics and functional capabilities in the early stages of its developmental process [64].

2.4. Outcomes

The development process is accompanied by a longitudinal feasibility study based on a mixed-methods approach that combines aspects of quantitative and qualitative research [65]. The primary objective of EduXBot is to ascertain the extent to which a prototype for simplified control of existing DATs alters the willingness of nurses to utilize them in the nursing process. The measurement times are based on the development process shown in Figure 1, which allows changes in improving ITU to be measured. The researchers initiated the study with a quantitative phase, followed by a second qualitative phase that offered a more in-depth elucidation of the initial findings [66].

The primary objective of this study is to design the human–technology interaction between the platform and users in a manner that ensures a high level of usability for all users. The objective is to assess whether the accessible platform alters the intended use of DAT by offering a simplified application option for caregivers. This inquiry seeks to ascertain the potential for DAT to be integrated as a supplementary resource in the planning of individual care processes. The central question guiding this study is whether the EduXBot platform offers an interface that enhances the autonomy of DAT use by caregivers. The objective is to enhance usability by a minimum of one level over the course of the study. The primary objective is to ascertain the extent to which the platform affects the usability of DAT (System Usability Scale (SUS) [67]), the intention to use it (Technology Usage Inventory (TUI) [68]), and the satisfaction of caregivers' needs through DAT (Technology-Based Experience of Need Satisfaction (TENS) [40]).

The descriptive statistics of the quantitative data are presented in accordance with the distribution, as mean and standard deviation or median and quartile. The categorial data describing the sample are presented as both absolute and relative frequencies. In addressing the primary inquiry concerning the alteration in ITU, the discrepancy between the measurement periods of the individual test subjects, the facilities, and the overall sample is delineated as an absolute and relative mean difference.

The secondary objective is to develop a multi-level benefit concept for EduXBot. This will provide caregivers with different affinities for electronic media, as well as different levels of technical expertise, and will offer them windows of opportunity to use and experience the platform. The objective is to conduct a direct assessment of the EduXBot platform by the participating nurses and to evaluate the platform with the aim of continuously improving the content and application options of the platform. A secondary objective is to record user satisfaction in order to obtain information on potential improvements to the platform through the analysis of structured feedback. The collection of qualitative data will be facilitated through the implementation of the think-aloud method [69,70] and focus group approach [71]. The aim is to enable caregivers to describe their own impressions and experiences of using EduXBot in an unstructured manner.

The composition of the focus groups is carried out in accordance with pre-established theoretical selections, which are justified by the indicators outlined in the study. These criteria include health professionals such as nursing staff [72]. In addition to these criteria, it is of particular importance that participants are willing to discuss their respective needs and requirements in the context of app development. No additional criteria are predetermined; however, once the sample pool has been established, the composition is meticulously delineated with respect to the contrast between the groups. The number of participants in the focus groups is set at a maximum of eight, as recommended by Bohnsack et al. [73]. It is not the intention to achieve statistical representativeness [74].

All qualitative data were subjected to Kuckartz's qualitative content analysis [75], which provides a structured framework for the content. Given the nascent state of the research field, the material was coded inductively. This entailed the creation of categories based on the think-aloud protocols and focus groups, thereby facilitating an exploratory evaluation of the material. This approach enabled the organization of the data material in accordance with its content-related aspects.

The third objective is the long-term evaluation of the EduXBot platform, encompassing not only its readiness for implementation but also its potential for long-term integration, utilization, and management of DAT. A further objective is to examine the interrelationship between the perceived ITU, usability, and user acceptance of the platform, which is currently being developed for the application. The tertiary target variable is the long-term willingness to utilize DAT in a sustainable manner and to integrate the digital assistive support offering into the existing care provision framework.

3. Results

The project commenced with the identification of the caregivers' needs and the functionalities that DAT could provide in nursing practice. In consideration of the findings, particular scenarios were delineated, which are indispensable for the implementation of a demonstration model of the platform. Subsequent to this, the prototypes will be developed in iterative loops in collaboration with the caregivers. To date, three iteration loops have been conducted, with a further two planned. As the project remains in progress, only preliminary results are available for presentation at this time.

3.1. Participants

To date, 25 participants from the participating healthcare facilities have completed the three iteration loops (Table 3). The participants had an average age of over 45 years and had accumulated over 13 years of professional experience since obtaining their qualifications. The majority of participants were nurses with managerial responsibilities. However, other professional groups, including support staff and occupational therapists, also participated. Given that the primary objective of the DAT interventions is to influence participants' daily lives and social networks, the insights of these professionals are particularly valuable, as they may also be required to utilize the platform.

Table 3. Descriptive statistics of the participating caregivers of each iteration loop.

Characteristics		T0, *n* (%)	T1, *n* (%)	T2, *n* (%)
Participants		8 (100)	9 (100)	8 (100)
Age, mean (SD *)		45.6 (9,1)	47.8 (9,3)	50.1 (7,8)
Gender	Male	1 (12)	1 (11)	1 (12)
	Female	7 (88)	8 (89)	7 (88)

Table 3. *Cont.*

Characteristics		T0, *n* (%)	T1, *n* (%)	T2, *n* (%)
Qualification	3-year duration of training	-	1 (11)	-
	3-year duration with professional training	2 (25)	1 (11)	1 (12)
	Nursing service management	3 (38)	3 (34)	3 (38)
	Studies	1 (12)	2 (22)	2 (25)
	Other qualification	2 (25)	2 (22)	2 (25)
Professional experience, mean (SD *)		13.5 (9,0)	16.3 (10,8)	16.9 (10,8)
Facility	Facility 1	2 (25)	2 (22)	1 (12)
	Facility 2	6 (75)	7 (78)	7 (88)

* Standard derivation.

3.2. Quantitative Results

The ITU was evaluated through the utilization of the selected seven subscales of the TUI, with high subscale scores indicating a high level of the corresponding construct and low scores indicating a low level. The determined scale sum values were converted into standard values, which are expressed as stanines. The stanines range from 1 (strongly below average) to 9 (strongly above average) [68]. The results of the evaluation demonstrate that the participating caregivers exhibit a greater receptivity to DAT than the general population (Table 4). The participants rated DAT as more useful than average and were more inclined to use it, while their apprehension towards DAT is aligned with that of the general population, but less skepticism was exhibited by the caregivers in comparison to the average individual.

The mean ITU score was 251 (SD 38) out of 300 points at the commencement of the intervention (T0) and remained at a similar level throughout the remainder of the intervention (T1 and T2). With regard to the subscales, the participants evinced curiosity about DATs (20 out of 28 points), while exhibiting a relatively low level of skepticism about DATs (8 out of 28 points). Consequently, the intention to utilize DATs and, consequently, the predicted actual use in healthcare can be considered high.

One potential explanation for this phenomenon is the facility's involvement in a study aimed at assessing the efficacy of a structured and guided integration and education approach in facilitating the integration of DATs into nursing practices [50]. The participants have, therefore, been made aware of the digital transformation and have had experience with the subject matter. Conversely, participation in this study is voluntary, which suggests that nurses who are generally open to the topic are more likely to participate.

Table 4. Results for the intention to use DAT.

TUI Scales	Score Range	Score at T0		Score at T1		Score at T2	
		Mean (SD *)	Stanine	Mean (SD *)	Stanine	Mean (SD *)	Stanine
Intention to use	0 to 300	251 (38)	8	239 (42)	7	252 (28)	8
Curiosity	4 to 28	20 (4)	7	23 (4)	8	21 (4)	7
Fear of technology	4 to 28	10 (6)	5	9 (6)	5	8 (3)	5
Interest	4 to 28	17 (7)	6	20 (8)	6	20 (8)	6
Ease of use	3 to 21	17 (3)	6	15 (3)	5	14 (2)	4
Usability	4 to 28	22 (3)	9	23 (3)	9	23 (5)	9
Skepticism	4 to 28	8 (4)	3	10 (4)	4	10 (2)	4
Accessibility	3 to 21	11 (4)	6	10 (2)	5	11 (3)	6

* Standard deviation.

Preliminary assessments conducted with the SUS [67] indicate that the current iterations have been deemed usable by the caregivers. In the aforementioned tool, a score of 68 is considered to represent the mean usability score [76]. The results indicated that the SUS score for the DAT used in the workshops was in close proximity to the reference score, thereby suggesting that the customization parameters and control options via the platform could be described as usable (Figure 3). With regard to Double3, a slight increase in usability was also observed during the course of the co-creative development process.

In the latest iteration of the PICO 4 VR headset, there has been a notable reduction in the perceived usability of the device. This is due to the fact that the assessment was conducted on an initial iteration of a fully operational platform. This was the first instance in which caregivers were presented with a functional connection between the platform and the DAT, and the assessment was primarily focused on the technical viability of the proposed connection, with design considerations not yet being a factor. Consequently, the platform was described as unduly cumbersome, complex, and frustrating by the caregivers, as evidenced by the ease-of-use assessment within the TUI (Table 4). The subsequent phase of development will address the aforementioned design aspects, with the objective of enhancing usability.

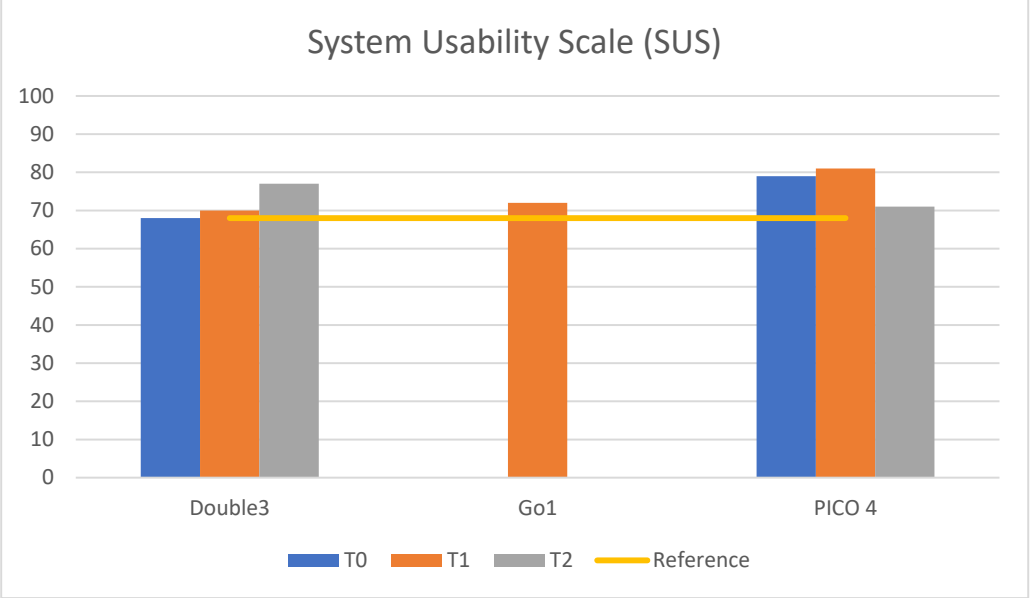

Figure 3. Development of the SUS for the DAT via the development process.

3.3. Qualitative Results

As indicated by the data presented in Table 3, 25 healthcare professionals participated in the workshops. The analysis of the data from think-aloud and focus groups resulted in the identification of three categories, comprising a total of 31 codes, for platform requirements within 12 subcategories (Table 5). The categories identified were as follows: User Experience (category 1), Interventions (category 2), and Framework Conditions (category 3). The first category delineates the requisite specifications for the platform in regard to the user experience, encompassing all aspects related to the utilization of an application, including the overall perception and satisfaction of the user [77]. The second category provides an overview of the fundamental requirements for the interventions to be assumed by DAT. The third category comprises the framework conditions for digital transformation in general and the implementation of DAT in particular. The codes are presented in detail in the Supplementary Materials.

Table 5. Evaluation of think-aloud and focus groups, arranged as per Kuckartz [75].

Category	Subcategory	Code
User Experience	Opportunities for Input	Interaction via tablet Using operating concepts from everyday life Interaction via voice without tablet
	Selection Process	As few steps as possible Adjustments to the individual needs of person being cared for
	Interface between Systems	Control of multiple DATs Connection to existing documentation systems and patient call systems
	Theoretical Training	Content preparation so that it can be used by everyone Manuals and step-by-step instructions for standard processes Background information and definitions related to care process
	Operating Exercise	Test DAT interaction in protected environment
Interventions	Automation	Autonomous as possible
	Planning	Booking system Individual and short-term planning Coordination of interventions by caregivers
	Personalization	Interventions individually adapted to person in need of care Prefabricated patient profiles with saved individualizations
	Meaningfulness	Interventions require an objective and benefit that emerge from the platform Caregivers need access to intervention content to support experience
Framework Conditions	Internet	Basic prerequisite: network infrastructure
	Technical Support	Technical support from external person
	Data Protection	Protecting privacy and personal data when leaving the facility

In addition to the focus groups, qualitative, guideline-based individual interviews of an exploratory nature were conducted with nursing facility managers in July 2024. The survey sought to ascertain which factors influence the implementation of research and development projects in the context of digital change processes, as perceived by companies involved in the project. The analysis was conducted using peer-group secured, multiple-iterating evaluation loops, with categories induced through content analysis in accordance with the approach outlined by Kuckartz [75]. The results (Table 6) indicate that the participants were primarily motivated by a desire to participate and to contribute to the shaping of the future of their profession. In their evaluation of the project, the participants indicated that the participatory development process afforded insights into the potential capabilities and constraints of DAT. These insights may have initially resulted in some degree of disappointment, as the pervasiveness of digital transformation in the media has led to the formation of expectations that are not always aligned with the actual capabilities of the technology in practical nursing applications.

Table 6. Evaluation of individual interviews, arranged as per Kuckartz [75].

Category	Subcategory	Code
Project Motivation		Participatory co-creation Participation in research project as advertising and positive external perception Future visions for optimized care against the shortage of skilled workers
Expectations of the Project		Participatory and benefit-oriented innovation process

Table 6. *Cont.*

Category	Subcategory	Code
Challenges in the Project		Too much participation prevents innovation
Evaluation of the Project	Benefits of the Project	Involvement of future users to increase user acceptance
	Lessons Learned	Insights into technology development: process, progress Comparison between expectations and state of the art technology
	Cooperation	Uncomplicated collaboration

3.4. Technical Results

A recent review of the literature revealed no studies that had compared the performance of speech-to-text (STT) applications on German language datasets. Consequently, we undertook an independent analysis to select the most suitable algorithm from the identified state-of-the-art applications. Additionally, the objective was to compare the performances of English and German STT systems. To this end, we selected two audio sources and manually transcribed them to create the necessary text annotations as ground truth. The selection of STT models for comparison included Google Cloud Speech-to-Text, Whisper-Base, Whisper-Small, Deepgram Nova-2, and Assembly AI. The performance of each model was evaluated based on metrics for both the English and German languages, with varying degrees of accuracy and error rates.

The graphs in Figure 4 present a comparison of the metrics for different models. These graphs visually represent the performance of each model using key evaluation metrics: These include the word error rate (WER), match error rate (MER), word information lost (WIL), and character error rate (CER). The analysis of these graphs underscores that Whisper-Small and Deepgram consistently deliver high accuracy and minimal error across both the English and German languages. Their superior performance across various metrics positions them as the most reliable choices for transcribing both English and German audio. In contrast, Assembly AI demonstrates variability in performance, exhibiting elevated error rates, particularly in the English language.

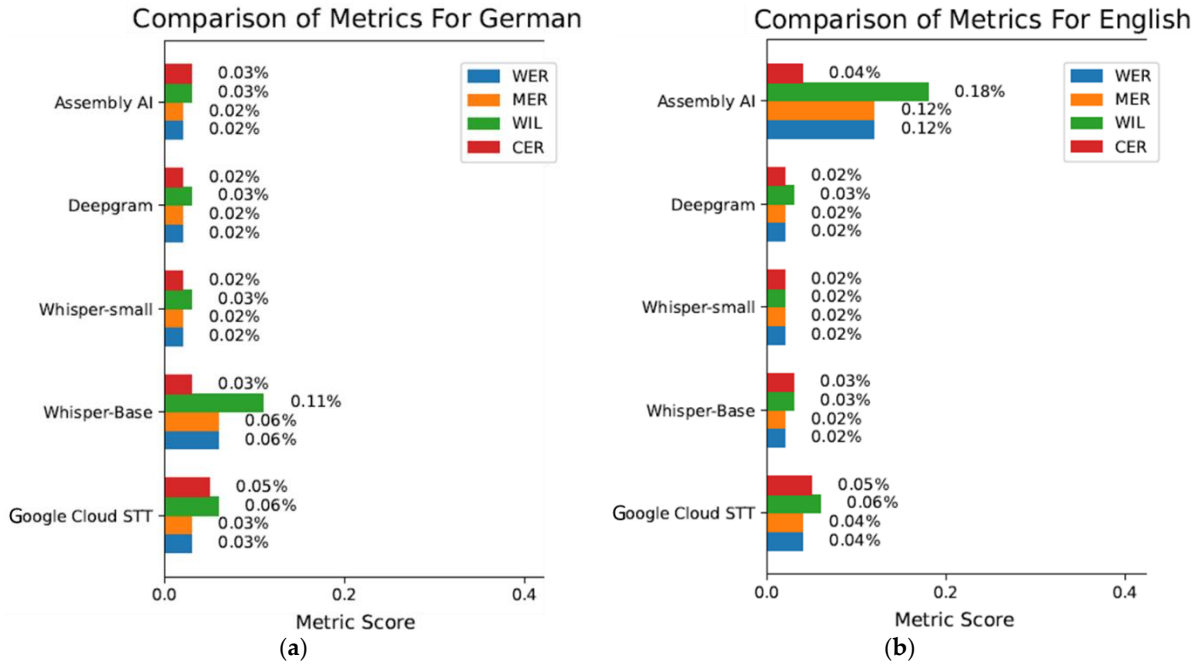

Figure 4. Evaluation and comparison of STT application between German and English languages: (**a**) evaluation of German language STT; (**b**) evaluation of English Language STT.

4. Discussion

This mixed-methods study was conducted to investigate the effects of a digital cross-device control and application platform in terms of its use and interaction with existing DAT in healthcare. This objective was pursued through an exploratory and co-creative development process. The preliminary findings suggest that a streamlined control of existing DATs can influence nurses' inclination to incorporate them into the nursing process. The integration of both qualitative and quantitative findings offers a comprehensive perspective on the EduXBot platform, highlighting its benefits and drawbacks. To facilitate a more nuanced examination of the findings, we will initially concentrate on the less intricate quantitative survey data before proceeding to the results of the qualitative interviews. To structure our approach, we utilize the categories for the successful implementation of DAT in care, as described above [22].

4.1. User Perspective

The survey's findings indicate that the reluctance of care staff to adopt DAT is not the primary underlying factor contributing to the identified issues. Instead, the survey results indicated that the perceived lack of user-friendliness and controllability emerged as a significant factor.

To this end, a survey employing the TUI method was conducted with 25 nurses at three distinct measurement time points, with the objective of determining their intention to utilize DATs. The results demonstrated a favorable trajectory in the intention to utilize DATs following the introduction of the platform and up to the present stage of its development. In the domain of statistical methodology, the mean is a prevalent measure of the central tendency of a given data set. The mean values determined in this study indicate a marginal increase in willingness to use, which is not apparent when interpreting the stanines. It is noteworthy that the study did not include sample size calculation or p values, which are essential elements for statistical analysis.

The overall trend suggests an increase in acceptance, willingness, and intention to use DAT among the participants. However, the user-friendliness factor exhibited a contrasting negative trend. This deviation can be attributed to the evolving developmental status of the platform. While the DATs in use were already established, the use cases for the prototype had to be developed anew. Consequently, the platform could only be discussed initially in the form of click dummies until a preliminary functional prototype was established.

The platform prototype continues to exhibit considerable deficiencies in terms of user-friendliness, as evidenced by the evaluation of the DAT. PICO 4, which is now controllable by the platform for the first time, was rated considerably less user-friendly on the SUS than the previous iteration loops. The controllability, usability in the care process, and ability to adapt to the individual needs of those in need of care are, therefore, directly related to the perceived usability. In the subsequent phase of the project, the feedback provided by the participants will be incorporated into an enhanced prototype, which will then be subjected to further discussion with the caregivers.

4.2. Participatory Development

The survey of facility managers on the co-creative development approach indicates a favorable attitude. Generally, the collaboration between researchers and practitioners is perceived as straightforward. The interviewees expressed a willingness to engage in technological development and a desire to contribute to the future direction of their professional field. Concurrently, the initiative confronted certain challenges related to motivation. The dissemination of technology, particularly in the form of multimedia and artificial intelligence, has contributed to an increase in public expectations regarding the

capabilities of technology. The inability of DAT to meet the demands of highly dynamic environments, such as the care setting, has resulted in a sense of disillusionment and disappointment among some caregivers.

Conversely, the target group may also exhibit deficiencies in the capacity for creativity and courageous imagination. It is imperative to recognize that the full potential of these developments may be hindered if the target group is not empowered to cultivate their own ideas and requirements. The target group is intimately acquainted with the opportunities and challenges of DAT, as they encounter these on a daily basis. They interpret their requirements in terms of these experiences. The nature of care is characterized by altruism [78], where the target group endeavors to alleviate the developers' workload by seeking compromise solutions. At this juncture, it is possible to clarify the technical possibilities and discuss a practical implementation based on concrete proposals.

4.3. Technical Implementation and Limitations

A comprehensive range of applications in the domains of speech, vision, and motion had to be identified and selected based on environmental and user-specific criteria (Table 2). For instance, the applications employed in the conversational partner use case are required to demonstrate high accuracy in the German language and rapid response times in indoor environments. Conversely, applications pertaining to human detection or simultaneous localization and mapping (SLAM) must exhibit robust performance in conditions involving variations in light intensity, reflections, and human behavior. Furthermore, the compatibility of the selected applications with the relevant hardware is taken into consideration.

The OpenAI ChatGPT API GPT (generative pre-trained transformer) model was selected based on the findings of a recent benchmarking study, which indicated that it outperforms other large language models (LLM), including LORA (language overlap relevance adaptor) and recurrent neural networks (RNNs) [79]. An evaluation of the generated text according to the METEOR criteria [80], which assesses in-accuracies and redundancies, yielded the highest score of 0.41. The hybrid machine learning-based MediaPipe framework [81] was selected on the basis of its benchmarked accuracy score of 97% on the hand sign language dataset [82]. The SLAM-toolbox mapping framework was selected on the basis of its superior performance relative to other state-of-the-art SLAM techniques, including ORB and Hector SLAM. It has demonstrated a benchmark of 100% completeness in mapping the environment with a precision of 15 cm [83]. The Roboter Operating System (ROS)-Navigation stack was selected due to its alternative localization and path planning algorithms, which can be adapted to different environments [84,85], and to take advantage of the unified approach of staying in the ROS ecosystem [86]. The single-shot object detection models YOLO (You Only Look Once) and ZED StereoLab were selected for human fall detection and human detection and tracking due to their real-time processing capabilities and accuracy rates exceeding 80% [87,88].

The evaluations for the STT applications (Figure 4) demonstrate the strengths and weaknesses of each model, providing a clear comparison of their capabilities in different linguistic contexts. For the present use case, the Whisper-Small model was selected due to its noteworthy performance in German, exhibiting a WER of 0.02%, and its seamless integration within the OpenAI ecosystem. A notable distinction emerges between the Whisper-Base and Assembly AI models when evaluated across both languages. However, as Whisper-Small and Deepgram demonstrate comparable WER values, further evaluations are necessary to ascertain if a substantial performance disparity exists between these languages for the identified STTs.

The applications selected for integration (Table 2) have been meticulously integrated, rigorously tested, and optimized for stable functioning. It is evident that multi-perspective human–technology–environment interaction applications, such as user recognition and context awareness, are crucial for the participating nurses to further optimize the platform, in view of the incremental advancement from the first to the third iteration loop. Despite the partial mitigation of the user recognition issue through manual assignment, errors in user content assignments can occur when multiple users are in proximity to a robot. The most advanced and reliable speaker-recognition methodologies are enrollment-based techniques that require user data in a range of environmental contexts to ensure optimal performance [89]. However, the implementation of such a model is not a viable option in the context of the project, as it would impose an undue burden on caregivers regarding data collection and registration. Consequently, the investigation and integration of non-enrollment-based speaker diarization with speaker linking is imperative for the subsequent prototypes and user evaluations [90,91].

The operation of a platform to utilize DAT in nursing care should be based on everyday interaction mechanisms, such as touch and swipe gestures on a screen or voice input. Additionally, activities should be synchronized and the associated documentation effort should be reduced via a connection to the care report or care plan. Additionally, the integration of the system with the patient call system could facilitate the incorporation of the system into existing processes.

The interventions offered should be planned, personalized, meaningful, and as autonomous as possible. The selection process should be streamlined to a maximum of three steps and seamlessly integrated into the care process via a booking system, for example. It is imperative to acknowledge that caregivers consistently asserted that interventions should not be merely conducted for the purpose of occupation. It is imperative that interventions are customized and refer to the patient's history, thereby facilitating an exchange about it. For instance, the content of the VR experience should be contextualized within the patient's personal history, such as through the inclusion of videos of their former place of residence or favorite travel destinations. This approach enables a shared exchange between caregivers and patients, aligning with the principles of memory care.

Furthermore, the platform should be leveraged for training purposes, particularly for newly employed personnel. The platform should also function as a secure venue for practicing, especially robot control, in a protected setting, thereby mitigating potential risks to individuals and patients. Furthermore, the provision of manuals and step-by-step instructions for standard processes in technological interaction was requested. The incorporation of technological elements into the care process was perceived as beneficial, with the provision of background information and definitions receiving a particularly positive rating.

5. Conclusions

The preliminary findings of this study suggest that caregivers are receptive to the utilization of DAT. For the implementation of DAT to be sustainable in nursing care practice, it is imperative that nurses perceive a meaningful use of DAT. A clear classification of the intervention in the care process must be established. The classification of interventions in the care process can be informed by the utilization of established care models, such as the activities of daily living according to Juchli [51]. Furthermore, the objective is to ascertain the additional benefit to the individual in need of care. The individual needs and preferences of the recipients of the intervention are of paramount importance to the caregivers.

It is imperative that the management of DAT does not constitute an additional burden for caregivers. The absence of development expertise among caregivers precludes them from programming the technologies independently. One potential solution to the usability issues of DAT is the development of a platform that provides an interface for non-programmers to create individual interventions using everyday controls and a few intuitive steps. This approach is expected to facilitate the sustainable integration of DAT into existing practices. EduXBot signifies an inaugural stride in this direction.

The integration of DAT and artificial intelligence has the potential to significantly reduce nursing care time, thereby allowing nurses to allocate a greater proportion of their attention to their patients, who represent the core of nursing. In the context of patient-centered nursing care, the completion of tasks such as medication administration and data interpretation from healthcare instruments are fundamental interventions that influence nurse staffing patterns and ensure the delivery of quality care. The advent of DAT holds great promise in light of its potential to liberate nurses from the burden of these tasks by leveraging machine learning and robotics technology. The delegation of such tasks to automated systems holds the promise of enhancing the efficiency and effectiveness of nursing operations. This shift enables professional nursing practice to concentrate on professional disciplinary practices that require creativity, inventiveness, and imagination. This paradigm shift has the ancillary benefit of enhancing patient satisfaction, a pivotal component in ensuring human health and well-being [92].

It is imperative to acknowledge that while DAT and artificial intelligence can streamline the completion of routine tasks by nurses, they cannot substitute for the personal and emotional support that nurses provide to patients. Moreover, it is implausible to presume that the integration of DAT can effectively supplant nurses in the evaluation of patients, the formulation of treatment plans, and the orchestration of care. Consequently, it can be deduced that the future of nursing will entail the integration of technology into nursing practice with the objective of enhancing patient outcomes, increasing efficiency, and reducing errors in care delivery. It is imperative for nurses to remain informed and adapt to new technologies and developments in the field of nursing. The integration of technology in nursing practice has the potential to benefit patients, enhance nurses' skills and knowledge, and facilitate more efficient and effective work [93].

The current study's sample size (small, with predominantly nursing-management-level participants and technology-open participants) is adequate to demonstrate the basic feasibility of a simplified control of DAT. To ensure the generalizability of these findings to the broader healthcare sector, future research should focus on expanding the demographic profiles of participants, including a more diverse range of healthcare stakeholders and technology-critical individuals, as well as examining additional DATs. Finally, the study focused on a limited number of DATs that participants found useful; examining a broader range of DATs, including less usable technologies, would improve the robustness of these findings.

Furthermore, the findings can serve as a foundation for exploring other use cases, technologies, and professions. The open system architecture facilitates the integration of additional technologies via a singular interface. The continuous integration of the target group of an intervention enables the identification of essential and appropriate individualization options, thereby ensuring the sustained generation of new content on the platform. In addition to the group of caregivers, other healthcare professionals may also be included in the platform's target group. For instance, medics, who are often non-programmers, require low-threshold access options to adapt technology such as surgical robots to their needs and the patient's circumstances. EduXBot facilitates access to the simplified and individualized usability of DAT for these healthcare professionals.

Ethical concerns play a pivotal role for nursing personnel in the utilization of DAT. A salient aspect pertains to the transformation in work processes that accompanies the integration of DAT. Caregivers articulate apprehensions that the discrete logic of the devices, which differs from their own, may culminate in heightened stress or a sense of influence from others. Additionally, there is a concern among caregivers that the integration of technology into their work processes may result in job loss due to the perceived threat of automation. Finally, there is a concern about the loss of interpersonal contact. A change in the psychosocial aspect of care work is associated with a reduction in the attractiveness of the profession for care workers and should, therefore, be avoided [35,94]. While these concerns have emerged in the discourse with nurses in this study and are being considered in the developmental process, they warrant explicit investigation in subsequent studies.

In addition to the anticipated social and public welfare-oriented benefits, the objective is to transform the system into a marketable product. The DAT hardware, the end devices required to program it, and the associated software are to be marketed collectively as a self-sufficient system. The potential exists for the distribution of supplementary software packages by participants in the future, thereby expanding the system's functional scope. Furthermore, the product will be adapted for alternative applications in order to tap into new target groups. The recently developed integration interfaces for nursing care have the potential for implementation at the national and regional scale. These interfaces can be further enhanced or expanded through collaboration with health insurance companies and for other application scenarios, such as incorporation into prevention and health promotion measures.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app15021002/s1, Table S1: Qualitative Data.

Author Contributions: Conceptualization, S.T., P.J. and S.H.; methodology, P.J. and S.H.; software, H.K.R.G. and S.R.; validation, P.M.; formal analysis, P.M.; investigation, P.M., S.R. and H.K.R.G.; resources, P.M. and S.R.; data curation, P.M. and S.R.; writing—original draft preparation, P.M.; writing—review and editing, P.M.; visualization, P.M. and S.R.; supervision, S.T., P.J. and S.H.; project administration, S.T., P.J. and S.H.; funding acquisition, S.T., P.J. and S.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Federal Ministry of Education and Research, grant number 03WIR3118B.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the Medical Faculty of the Martin-Luther-University Halle-Wittenberg (protocol code 2023-190 of 31 August 2023). The study was registered in the German Register of Clinical Studies (registration no. DRKS00034195).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Storm, A.; Klie, T. (Eds.) *Pflegereport 2017: Gutes Leben mit Demenz: Daten, Erfahrungen und Praxis*; Medhochzwei Verlag GmbH: Heidelberg, Germany, 2017; ISBN 978-3-86216-375-5.
2. Barmer, G.E.K. (Ed.) *Pflegereport 2018*; Medhochzwei Verlag GmbH: Heidelberg, Germany, 2018; ISBN 978-3-946199-19-9.

3. Karagiannidis, C.; Kluge, S.; Riessen, R.; Krakau, M.; Bein, T.; Janssens, U. Auswirkungen des Pflegepersonalmangels auf die intensivmedizinische Versorgungskapazität in Deutschland. *Med. Klin. Intensivmed. Notfmed.* **2019**, *114*, 327–333. [CrossRef] [PubMed]
4. Statistisches Bundesamt. Pflegevorausberechnung—Deutschland und Bundesländer: Berichtszeitraum 2022–2070. Available online: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/statistischer-bericht-pflegevorausberechnung-5124209229005.xlsx?__blob=publicationFile (accessed on 16 September 2024).
5. Statistisches Bundesamt. Pflegekräftevorausberechnung: Berichtszeitraum 2024–2070. Available online: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/statistischer-bericht-pflegekraeftevorausberechnung-2070-5124210249005.xlsx?__blob=publicationFile (accessed on 16 September 2024).
6. Krüger-Brand, H.E. Robotik in der Pflege: Ethikrat sieht großes Potenzial. *Dtsch. Ärzteblatt* **2020**, *117*, A591–A594.
7. Heinemann, S.; Matusiewicz, D. (Eds.) *Rethink Healthcare: Krise als Chance*; Medhochzwei: Heidelberg, Germany, 2021; ISBN 978-3-86216-744-9.
8. Kuhlmey, A.; Blüher, S.; Nordheim, J.; Zöllick, J. Ressource oder Risiko—Wie professionell Pflegende den Einsatz digitaler Technik in der Pflege sehen. In *Pflege und Digitale Technik*; Zentrum für Qualität in der Pflege (ZQP): Berlin, Germany, 2019; pp. 31–35, ISBN 978-3-945508-30-5.
9. Jacobs, K.; Kuhlmey, A.; Greß, S.; Klauber, J.; Schwinger, A. (Eds.) *Mehr Personal in der Langzeitpflege—Aber Woher?* Springer: Berlin, Heidelberg, 2019; ISBN 978-3-662-58934-2.
10. Buhtz, C.; Paulicke, D.; Hirt, J.; Schwarz, K.; Stoevesandt, D.; Meyer, G.; Jahn, P. Robotische Systeme zur pflegerischen Versorgung im häuslichen Umfeld: Ein Scoping Review. *Z. Evid. Fortbild. Qual. Gesundhwes.* **2018**, *137–138*, 1–8. [CrossRef] [PubMed]
11. World Health Organization. *Assistive Technology*; World Health Organization: Geneva, Switzerland, 2024. Available online: https://www.who.int/news-room/fact-sheets/detail/assistive-technology (accessed on 5 November 2024).
12. Alves-Oliveira, P.; Petisca, S.; Correia, F.; Maia, N.; Paiva, A. Social Robots for Older Adults: Framework of Activities for Aging in Place with Robots. In *Social Robotics*; Tapus, A., André, E., Martin, J.-C., Ferland, F., Ammi, M., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 11–20, ISBN 978-3-319-25553-8.
13. Krick, T.; Huter, K.; Seibert, K.; Domhoff, D.; Wolf-Ostermann, K. Measuring the effectiveness of digital nursing technologies: Development of a comprehensive digital nursing technology outcome framework based on a scoping review. *BMC Health Serv. Res.* **2020**, *20*, 243. [CrossRef] [PubMed]
14. Deutscher Ethikrat. *Robotik für Gute Pflege: Stellungnahme*; Deutscher Ethikrat: Berlin, Germany, 2020; ISBN 978-3-941957-89-3.
15. Hofstetter, S. Technikbildung für Pflegende als Teil der nationalen, japanischen Robotikstrategie. Eine L(e)ehrstelle. In *Genese und Folgen der Pflegerobotik: Die Konstitution eines Interdisziplinären Forschungsfeldes*, 1st ed.; Hergesell, J., Maibaum, A., Meister, M., Eds.; Beltz Juventa: Weinheim, Germany, 2020; pp. 121–142, ISBN 978-3-7799-3968-9.
16. Hofstetter, S.; Kraft, B.; Jahn, P. Roboter—Die neuen Kollegen im Team? *Gesundh. Und Sozialpolitik* **2023**, *77*, 38–46. [CrossRef]
17. Silvera-Tawil, D. Robotics in Healthcare: A Survey. *SN Comput. Sci.* **2024**, *5*, 189. [CrossRef]
18. Kyrarini, M.; Lygerakis, F.; Rajavenkatanarayanan, A.; Sevastopoulos, C.; Nambiappan, H.R.; Chaitanya, K.K.; Babu, A.R.; Mathew, J.; Makedon, F. A Survey of Robots in Healthcare. *Technologies* **2021**, *9*, 8. [CrossRef]
19. Babalola, G.T.; Gaston, J.-M.; Trombetta, J.; Tulk Jesso, S. A systematic review of collaborative robots for nurses: Where are we now, and where is the evidence? *Front. Robot. AI* **2024**, *11*, 1398140. [CrossRef]
20. Trainum, K.; Liu, J.; Hauser, E.; Xie, B. Nursing Staff's Perspectives of Care Robots for Assisted Living Facilities: Systematic Literature Review. *JMIR Aging* **2024**, *7*, e58629. [CrossRef]
21. Pawassar, C.M.; Tiberius, V. Virtual Reality in Health Care: Bibliometric Analysis. *JMIR Serious Games* **2021**, *9*, e32721. [CrossRef] [PubMed]
22. Garthaus, M.; Hoferichter, J.; Behrens, J.L.; Wirth, L.M.; Paluch, R.; Dorniok, D.; Müller, C.; Hülsken-Giesler, M. Robotische Systeme auf dem Weg in die Praxis. *Pflegez* **2024**, *77*, 56–59. [CrossRef]
23. Madi, M.; Nielsen, S.; Schweitzer, M.; Siebert, M.; Körner, D.; Langensiepen, S.; Stephan, A.; Meyer, G. Acceptance of a robotic system for nursing care: A cross-sectional survey with professional nurses, care recipients and relatives. *BMC Nurs.* **2024**, *23*, 179. [CrossRef] [PubMed]
24. Merda, M.; Schmidt, K.; Kähler, B. Pflege 4.0—Einsatz Moderner Technologien aus der Sicht Professionell Pflegender: Forschungsbericht. Available online: https://www.bgw-online.de/resource/blob/20346/3989e17a6bd235a1637fc16a4c71d84e/bgw09-14-002-pflege-4-0-einsatz-moderner-technologien-data.pdf (accessed on 2 December 2024).
25. Hofstetter, S.; Richey, V.; Jahn, P. Digitale Revolution—Survey zur Akzeptanz sozial assistiver Technologie in der Pflege. *Die Schwest. Der Pfleg.* **2019**, *9*, 32–33.

26. Kuhn, S.; Ammann, D.; Cichon, I.; Ehlers, J.; Guttormsen, S.; Hülsken-Giesler, M.; Kaap-Fröhlich, S.; Kickbusch, I.; Pelikan, J.; Reber, K.; et al. *Wie Revolutioniert die Digitale Transformation die Bildung der Berufe im Gesundheitswesen?* Careum: Zurich, Switzerland, 2019.
27. Buhtz, C.; Paulicke, D.; Hofstetter, S.; Jahn, P. Technikaffinität und Fortbildungsinteresse von Auszubildenden der Pflegefachberufe: Eine Onlinebefragung. *HeilberufeScience* **2020**, *11*, 3–12. [CrossRef]
28. Verloigne, M.; Altenburg, T.; Cardon, G.; Chinapaw, M.; Dall, P.; Deforche, B.; Giné-Garriga, M.; Lippke, S.; Papadopoulos, H.; Pappa, D.; et al. Making co-creation a trustworthy methodology for closing the implementation gap between knowledge and action in health promotion: The Health CASCADE project. *Perspect. Public Health* **2023**, *143*, 196–198. [CrossRef] [PubMed]
29. Gibbons, M. Mode 2 society and the emergence of context-sensitive science. *Sci. Pub. Pol.* **2000**, *27*, 159–163. [CrossRef]
30. Armstrong, M.; Dopp, C.; Welsh, J. Design-Based Research. In *The Students' Guide to Learning Design and Research*; Kimmons, R., Caskurlu, S., Eds.; EdTech Books: Provo, UT, USA, 2020; pp. 37–42.
31. Janda, V. Usability ist keine Eigenschaft von Technik. In *Berliner Schlüssel zur Techniksoziologie*; Schubert, C., Schulz-Schaeffer, I., Eds.; Springer Fachmedien: Wiesbaden, Germany, 2019; pp. 347–374, ISBN 978-3-658-22256-7.
32. Vargas, C.; Whelan, J.; Brimblecombe, J.; Allender, S. Co-creation, co-design, co-production for public health—A perspective on definition and distinctions. *Public Health Res. Pract.* **2022**, *32*, e3222211. [CrossRef]
33. Lyon, A.R.; Munson, S.A.; Renn, B.N.; Atkins, D.C.; Pullmann, M.D.; Friedman, E.; Areán, P.A. Use of Human-Centered Design to Improve Implementation of Evidence-Based Psychotherapies in Low-Resource Communities: Protocol for Studies Applying a Framework to Assess Usability. *JMIR Res. Protoc.* **2019**, *8*, e14990. [CrossRef]
34. Dopp, A.R.; Parisi, K.E.; Munson, S.A.; Lyon, A.R. Aligning implementation and user-centered design strategies to enhance the impact of health services: Results from a concept mapping study. *Implement. Sci. Commun.* **2020**, *1*, 17. [CrossRef] [PubMed]
35. Becker, H. Robotik in der Gesundheitsversorgung: Hoffnungen, Befürchtungen und Akzeptanz aus Sicht der Nutzerinnen und Nutzer. In *Pflegeroboter*; Bendel, O., Ed.; Springer Gabler: Wiesbaden, Germany, 2018; pp. 229–248, ISBN 978-3-658-22698-5.
36. Ragno, L.; Borboni, A.; Vannetti, F.; Amici, C.; Cusano, N. Application of Social Robots in Healthcare: Review on Characteristics, Requirements, Technical Solutions. *Sensors* **2023**, *23*, 6820. [CrossRef]
37. Müller, P.; Jahn, P. Cocreative Development of Robotic Interaction Systems for Health Care: Scoping Review. *JMIR Hum. Factors* **2024**, *11*, e58046. [CrossRef]
38. Des Jarlais, D.C.; Lyles, C.; Crepaz, N. Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement. *Am. J. Public Health* **2004**, *94*, 361–366. [CrossRef] [PubMed]
39. Hülsken-Giesler, M.; Daxberger, S. Robotik in der Pflege aus pflegewissenschaftlicher Perspektive. In *Pflegeroboter*; Bendel, O., Ed.; Springer Gabler: Wiesbaden, Germany, 2018; pp. 125–139, ISBN 978-3-658-22698-5.
40. Peters, D.; Calvo, R.A.; Ryan, R.M. Designing for Motivation, Engagement and Wellbeing in Digital Experience. *Front. Psychol.* **2018**, *9*, 797. [CrossRef]
41. Farao, J.; Malila, B.; Conrad, N.; Mutsvangwa, T.; Rangaka, M.X.; Douglas, T.S. A user-centred design framework for mHealth. *PLoS ONE* **2020**, *15*, e0237910. [CrossRef] [PubMed]
42. Gallupe, R.B. The tyranny of methodologies in information systems research 1. *SIGMIS Database* **2007**, *38*, 20–28. [CrossRef]
43. Hevner, A.R.; March, S.T.; Park, J.; Ram, S. Design Science in Information Systems Research. *MIS Q.* **2004**, *28*, 75–105. [CrossRef]
44. Schnall, R.; Rojas, M.; Bakken, S.; Brown, W.; Carballo-Dieguez, A.; Carry, M.; Gelaude, D.; Mosley, J.P.; Travers, J. A user-centered model for designing consumer mobile health (mHealth) applications (apps). *J. Biomed. Inform.* **2016**, *60*, 243–251. [CrossRef] [PubMed]
45. Glaser, B.G.; Strauss, A.L. *Grounded Theory: Strategien Qualitativer Forschung*, 3rd ed.; Unveränderte Auflage; Verlag Hans Huber: Bern, Switzerland, 2010; ISBN 978-3-456-84906-5.
46. Teresi, J.A.; Yu, X.; Stewart, A.L.; Hays, R.D. Guidelines for Designing and Evaluating Feasibility Pilot Studies. *Med. Care* **2022**, *60*, 95–103. [CrossRef]
47. Eid, M.; Gollwitzer, M.; Schmitt, M. *Statistik und Forschungsmethoden: Lehrbuch. Mit Online-Materialien, Deutsche Erstausgabe*, 3rd ed.; Beltz: Weinheim, Germany, 2013; ISBN 978-3-621-28201-7.
48. Wilcox, R.R. *Introduction to Robust Estimation and Hypothesis Testing*, 4th ed.; Academic Press: Amsterdam, The Netherlands, 2017; ISBN 9780128047330.
49. Kirchmair, R. Welche qualitativen Forschungsmethoden gibt es. In *Qualitative Forschungsmethoden*; Kirchmair, R., Ed.; Springer: Berlin/Heidelberg, Germany, 2022; pp. 9–53, ISBN 978-3-662-62760-0.
50. Hofstetter, S.; Zilezinski, M.; Behr, D.; Kraft, B.; Buhtz, C.; Paulicke, D.; Wolf, A.; Klus, C.; Stoevesandt, D.; Schwarz, K.; et al. Integrating Digital Assistive Technologies Into Care Processes: Mixed Methods Study. *JMIR Med. Educ.* **2024**, *10*, e54083. [CrossRef] [PubMed]
51. Schewior-Popp, S.; Sitzmann, F.; Ullrich, L. (Eds.) *Thiemes Pflege: Das Lehrbuch für Pflegende in der Ausbildung*, 15th ed.; Thieme: Stuttgart, Germany, 2020; ISBN 978-3-13-243766-1.

52. OpenAI. Speech to Text: Learn How to Turn Audio into Text. Available online: https://platform.openai.com/docs/guides/speech-to-text (accessed on 11 December 2024).
53. OpenAI. Models. Available online: https://platform.openai.com/docs/models/gp (accessed on 11 December 2024).
54. OpenAI. Text to Speech: Learn How to Turn Text into Lifelike Spoken Audio. Available online: https://platform.openai.com/docs/guides/text-to-speech (accessed on 11 December 2024).
55. Double Robotics. Double 3—Overview. Available online: https://www.doublerobotics.com/double3.html (accessed on 11 December 2024).
56. Google Developers. Aufgabenanleitung zur Gestenerkennung. Available online: https://ai.google.dev/edge/mediapipe/solutions/vision/gesture_recognizer?hl=de (accessed on 11 December 2024).
57. Macenski, S. On Use of SLAM Toolbox, A Fresh(er) Look at Mapping and Localization for the Dynamic World. 2019. Available online: https://roscon.ros.org/2019/talks/roscon2019_slamtoolbox.pdf (accessed on 11 December 2024).
58. Macenski, S.; Jambrecic, I. SLAM Toolbox: SLAM for the dynamic world. *JOSS* **2021**, *6*, 2783. [CrossRef]
59. Open Robotics. Navigation. Available online: https://wiki.ros.org/navigation (accessed on 11 December 2024).
60. StereoLabs. Body Tracking Overview. Available online: https://www.stereolabs.com/docs/body-tracking (accessed on 11 December 2024).
61. Ultralytics. Schätzung der Pose. Available online: https://docs.ultralytics.com/de/tasks/pose/ (accessed on 11 December 2024).
62. Insta360. Insta360 STUDIO: 360 Bearbeitungssoftware. Available online: https://www.insta360.com/de/download/app/studio2019 (accessed on 11 December 2024).
63. Pioch, S. Entwickeln eines Prototyps. In *Digital Entrepreneurship*; Pioch, S., Ed.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2019; pp. 29–42, ISBN 978-3-658-24067-7.
64. Bruhn, M. Markteinführung von Dienstleistungen—Vom Prototyp zum marktfähigen Produkt. In *Service Engineering*; Bullinger, H.-J., Scheer, A.-W., Eds.; Springer: Berlin/Heidelberg, Germany, 2006; pp. 227–248, ISBN 3-540-25324-6.
65. Leech, N.L.; Onwuegbuzie, A.J. A typology of mixed methods research designs. *Qual. Quant.* **2009**, *43*, 265–275. [CrossRef]
66. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; Sage: Los Angeles, CA, USA; London, UK; New Delhi, India; Singapore; Washington, DC, USA; Melbourne, Australia, 2018; ISBN 9781483344379.
67. Brooke, J. SUS: A 'quick and dirty' usability scale. In *Usability Evaluation in Industry*; Jordan, P., Thomas, B., Weerdmeester, B., McClelland, I.L., Eds.; Taylor & Francis: London, UK, 1996; pp. 189–194.
68. Kothgassner, O.D.; Felnhofer, A.; Hauk, N.; Kastenhofer, E.; Gomm, J.; Kryspin-Exner, I. *Technology Usage Inventory: Manual*; ICARUS (Information- and Communication Technology Applications: Research on User-Oriented Solutions): Wien, Austria, 2012.
69. Fonteyn, M.E.; Kuipers, B.; Grobe, S.J. A Description of Think Aloud Method and Protocol Analysis. *Qual. Health Res.* **1993**, *3*, 430–441. [CrossRef]
70. Jaspers, M.W.M.; Steen, T.; van den Bos, C.; Geenen, M. The think aloud method: A guide to user interface design. *Int. J. Med. Inform.* **2004**, *73*, 781–795. [CrossRef] [PubMed]
71. Mayerhofer, W. Das Fokusgruppeninterview. In *Qualitative Marktforschung*; Buber, R., Holzmüller, H.H., Eds.; Gabler: Wiesbaden, Germany, 2009; pp. 477–490, ISBN 978-3-8349-0976-3.
72. Lamnek, S. *Gruppendiskussion: Theorie und Praxis*, 2nd ed.; Beltz: Weinheim, Germany; Basel, Switzerland, 2005; ISBN 3-8252-8303-8.
73. Bohnsack, R.; Przyborski, A.; Schäffer, B. (Eds.) *Das Gruppendiskussionsverfahren in der Forschungspraxis*, 2nd ed; Verlag Barbara Budrich: Opladen, Germany; Farmington Hills, MI, USA, 2010; ISBN 978-3-86649-177-9.
74. Zwick, M.M.; Schröter, R. Konzeption und Durchführung von Fokusgruppen am Beispiel des BMBF-Projekts "Übergewicht und Adipositas bei Kindern, Jugendlichen und jungen Erwachsenen als systematisches Risiko". In *Fokusgruppen in der empirischen Sozialwissenschaft: Von der Konzeption bis zur Auswertung*; Schulz, M., Mack, B., Renn, O., Eds.; Springer: Wiesbaden, Germany, 2012; pp. 24–48, ISBN 978-3-531-19396-0.
75. Kuckartz, U.; Rädiker, S. *Qualitative Inhaltsanalyse: Methoden, Praxis, Umsetzung mit Software und künstlicher Intelligenz*, 6th ed.; Beltz Juventa: Weinheim, Germany; Basel, Switzerland, 2024; ISBN 978-3-7799-7912-8.
76. Sauro, J. *A Practical Guide to the System Usability Scale: Background, Benchmarks & Best Practices*; Measuring Usability LLC.: Denver, CO, USA, 2011.
77. Eichstädt, T.; Spieker, S. User Experience. In *52 Stunden Informatik*; Eichstädt, T., Spieker, S., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2024; pp. 423–429, ISBN 978-3-658-41837-3.
78. Pettersen, T. Conceptions of Care: Altruism, Feminism, and Mature Care. *Hypatia* **2012**, *27*, 366–389. [CrossRef]
79. Lommatzsch, A.; Llanque, B.; Rosenberg, V.S.; Tahir, S.A.M.; Boyadzhiev, H.D.; Walny, M. Combining Information Retrieval and Large Language Models for a Chatbot that Generates Reliable, Natural-style Answers. In Proceedings of the LWDA 2023 Workshops: BIA, DB, IR, KDML and WM, Marburg, Germany, 9–11 October 2023.
80. Schneider, P.; Klettner, M.; Simperl, E.; Matthes, F. A Comparative Analysis of Conversational Large Language Models in Knowledge-Based Text Generation. 2024. Available online: http://arxiv.org/pdf/2402.01495v1 (accessed on 11 December 2024).

81. Lugaresi, C.; Tang, J.; Nash, H.; McClanahan, C.; Uboweja, E.; Hays, M.; Zhang, F.; Chang, C.-L.; Yong, M.G.; Lee, J.; et al. MediaPipe: A Framework for Perceiving and Processing Reality. 2019. Available online: https://arxiv.org/abs/1906.08172 (accessed on 11 December 2024).
82. Yaseen; Kwon, O.-J.; Kim, J.; Jamil, S.; Lee, J.; Ullah, F. Next-Gen Dynamic Hand Gesture Recognition: MediaPipe, Inception-v3 and LSTM-Based Enhanced Deep Learning Model. *Electronics* **2024**, *13*, 3233. [CrossRef]
83. Du, Y.; Feng, S.; Cort, C.G.; Vela, P.A. Task-Driven SLAM Benchmarking. 2024. Available online: http://arxiv.org/pdf/2409.16573v1 (accessed on 11 December 2024).
84. Schena, F. Development of an Automated Benchmark for the Analysis of Nav2 Controllers. Ph.D. Thesis, Dissertation, Politecnico di Torino, Turin, Italy, 2024.
85. Perille, D.; Truong, A.; Xiao, X.; Stone, P. Benchmarking Metric Ground Navigation. In Proceedings of the 2020 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), Abu Dhabi, United Arab Emirates, 4–6 November 2020; pp. 116–121, ISBN 978-1-6654-0390-0.
86. Stanford Artificial Intelligence Laboratory et al. Robotic Operating System. Available online: https://www.ros.org (accessed on 11 December 2024).
87. Shotton, J.; Fitzgibbon, A.; Cook, M.; Sharp, T.; Finocchio, M.; Moore, R.; Kipman, A.; Blake, A. Real-time human pose recognition in parts from single depth images. In Proceedings of the 2011 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Colorado Springs, CO, USA, 20–25 June 2011; pp. 1297–1304, ISBN 978-1-4577-0394-2.
88. Ye, M.; Zhang, Q.; Wang, L.; Zhu, J.; Yang, R.; Gall, J. A Survey on Human Motion Analysis from Depth Data. In *Time-of-Flight and Depth Imaging. Sensors, Algorithms, and Applications*; Hutchison, D., Kanade, T., Kittler, J., Kleinberg, J.M., Mattern, F., Mitchell, J.C., Naor, M., Nierstrasz, O., Pandu Rangan, C., Steffen, B., et al., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 149–187, ISBN 978-3-642-44963-5.
89. Mohammadi, M.; Sadegh Mohammadi, H.R. Weighted X-Vectors for Robust Text-Independent Speaker Verification with Multiple Enrollment Utterances. *Circuits Syst. Signal Process.* **2022**, *41*, 2825–2844. [CrossRef]
90. Leung, T.-Y.; Samarakoon, L.; Lam, A.Y. Incorporating Prior Knowledge into Speaker Diarization and Linking for Identifying Common Speaker. In Proceedings of the 2019 IEEE Automatic Speech Recognition and Understanding Workshop (ASRU), Singapore, 14–18 December 2019; pp. 697–703, ISBN 978-1-7281-0306-8.
91. Ohi, A.Q.; Mridha, M.F.; Hamid, M.A.; Monowar, M.M. Deep Speaker Recognition: Process, Progress, and Challenges. *IEEE Access* **2021**, *9*, 89619–89643. [CrossRef]
92. Rony, M.K.K.; Parvin, M.R.; Ferdousi, S. Advancing nursing practice with artificial intelligence: Enhancing preparedness for the future. *Nurs. Open* **2024**, *11*, 1–9. [CrossRef] [PubMed]
93. Gunawan, J. Exploring the future of nursing: Insights from the ChatGPT model. *Belitung Nurs. J.* **2023**, *9*, 1–5. [CrossRef] [PubMed]
94. Vandemeulebroucke, T.; Dierckx de Casterlé, B.; Gastmans, C. The use of care robots in aged care: A systematic review of argument-based ethics literature. *Arch. Gerontol. Geriatr.* **2018**, *74*, 15–25. [CrossRef] [PubMed]