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# A User Journey: Development of Drone-Based Medication Delivery—Meeting Developers and Co-Developers' Expectations

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**Abstract:** This study builds on initial ADApp research that identified the factors that influence the intention to use a pharmacy drone app for urgent medication delivery. While previous studies and theories have predominantly focused on user acceptance alone, the present qualitative study introduced a holistic model that integrates user acceptance theories as well as user-centered design principles and technology features. It focused on the user journey to derive core statements from the development of a drone-based application using a qualitative theory synthesis approach (study 1), and explored the perceived participatory collaboration between developers (software and drone developers) and co-developers (core group participants) using final tandem discussions and a qualitative content analysis method (study 2). Study 1 resulted in the identification of eight categories that serve as technical working goals for future participatory technology development. Study 2 identified five critical factors that provide insight into the unique challenges and goals of collaborative development. Both studies contribute to a better understanding of the essential factors that lead to successful participatory processes between developers and co-developers aimed at increasing usability and intention to use. Based on these findings, an integrated model is presented to support participatory design strategies in healthcare technology development.

**Keywords:** human drone interaction; medical supplies; participatory cooperation; user centered design; development process co-developers

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Academic Editors: Jinchao Chen, Jun Feng and Ruxandra Botez

Received: 20 January 2025
Revised: 17 February 2025
Accepted: 20 February 2025
Published: 27 February 2025

**Citation:** Lehmann, A.; Kalter, I.; Jahn, P.; Fink, F. A User Journey: Development of Drone-Based Medication Delivery—Meeting Developers and Co-Developers' Expectations. *Designs* **2025**, *9*, 27. https://doi.org/10.3390/designs9020027



## 1. General Introduction

Demographic trends are increasing the demand for healthcare, with rural areas being particularly affected. Challenges such as decreasing staff shortages in the healthcare sector and rural exodus exacerbate the situation, especially during crises such as the COVID 19 pandemic [1,2]. This has highlighted the need for innovative logistical solutions, with medication delivery via drones emerging as a prominent application in healthcare [1,3]. In addition to the increasing use of drones in the environmental, nature conservation, and agricultural sectors, the need for new logistical delivery routes has become clear, and delivery drones for medications have been listed as the most frequently mentioned application in the healthcare sector [1]. For example, in Germany, pilot projects such as the UAM-InnoRegion-SH and a wingcopter drone project in Hessen are exploring the potential of drone-based medication delivery to improve healthcare access in Germany [4,5].

These initiatives aim to address the challenges of long distances and limited transportation options that often hinder timely access to medications for patients in remote locations [6]. Studies emphasize the benefits of drones in reducing delivery times, cutting costs, and increasing logistical flexibility and sustainability [3,7,8].

Despite these advantages, barriers such as technological, organizational, and environmental (TOE) issues hinder drone adoption [7]. The existing literature has identified a lack of research that investigates the capabilities and barriers of drones [7]. In particular, there is a lack of studies focusing on identifying strategies to optimize last-mile deliveries by centering user acceptance. Furthermore, there are no empirical studies investigating the user acceptance of drone-based medication delivery under real environmental conditions [9]. This gap is surprising, giving that the existing studies highlight how factors such as usability and lack of user skills and knowledge, as well as negative perceptions, affect user acceptance and hinder drone usage [1,7,10]. In particular, the nature and extent of acceptance are critical to the success of technology adoption [11]. Acceptance refers to the positive decision to accept an innovation by its users, as described in the Technology Acceptance Model (TAM 1) [12]. It proposes that users are more likely to use a technology if they believe it will help them do a better job (perceived usefulness) and if they believe the system can be operated without effort (perceived ease of use). These variables were found to be correlated with the intention to use [12]. That means the greater the benefits of a technology and the easier it is to use, the more willing users are to use the new system. However, some other variables that influence user acceptance can be identified, such as social influences (subjective norm, image, and voluntariness), cognitive instrumental processes (job relevance, output quality, and result demonstrability; TAM 2) and psychological foundations (self-efficacy, external control, playfulness, anxiety, enjoyment, and usability; TAM 3) [13,14]. In other words, measuring user acceptance should take into account both technological and psychological factors for successful technology adoption (called "intention to use"). The Technology Usage Inventory Assessment (TUI; [15]), thus, complements the classic technology acceptance factors of TAM, such as perceived usability, usefulness, immersion, and accessibility (technology-specific), with important psychological constructs such as interest, curiosity, technology anxiety, and skepticism. However, Peters et al. [16] argued that the TAM model alone does not indicate whether people would actually use a technology because it does not take into account basic human needs according. Ryan and Deci [17–19] defined three basic psychological needs (autonomy, competence, relatedness) that explain whether a person is engaged or demotivated. Based on this, Peters et al. [16] defined the METUX model (Motivation, Engagement, Thriving in User Experience), which describes that users will be more engaged with a technology the more the interaction with the system satisfies basic psychological needs.

To aim the factors of user acceptance, the ADApp project used a monocentric, exploratory, mixed-method design. Based on the TOE barrier framework, TAM, and the intention to use model (TUI), as well as the Motivation, Engagement, Thriving in User Experience (METUX) model, the project aimed to design the human–technology interaction with the app and drone in such a way that the usability, acceptance, and satisfaction of basic psychological needs are considered in the development process in order to increase the effectiveness of the use of the app-accompanied, drone-based medication delivery method. Table S1 (Supplementary Materials S1) presents an overview of the models used in the ADApp project and compares their previously described characteristics, which analyze the acceptance, use, and experience of technology, as well as the ways of interacting with technical systems.

A key feature of the ADApp project was its equal involvement of partners from economy, science, and different social groups. However, the novelty of the project was the iterative, participatory, and co-creative process between developers and co-developers (civil persons) using the methodic guidelines of co-creative design according to Farao et al. [20]. In this evidence-based approach, users are involved in the development of technologies at an early stage and their needs are prioritized [20,21]. An introduction without user involvement can, therefore, lead to the results being changed, which in turn can change and distort the defined objectives [20,22,23].

The project took place from February 2021 to January 2024 and represents the entire development process, from the first prototypes of the app to the entire ordering and delivery process with app and drone over populated areas of Dessau (Germany). The data collection process employed qualitative techniques such as guided interviews, tandem discussions, and think-aloud protocols. This process comprised (1) a scoping review [9], (2) a needs analysis of users [24], and (3) four iterative development steps—three under experimental and one under real conditions [25].

The scoping review (1) identified the limited research on last-mile and human–drone interaction capabilities in humanitarian logistics, none of which involved users according to TAM theories [9,13,14,26–29]. The needs analysis (2) revealed that drone delivery currently holds a limited role in Germany's healthcare system, with little knowledge about its potential applications for medication delivery. However, the analysis indicated that users would use this technology if it incorporated communication features (e.g., telephony, chat) to enable tracking and tracing for a transparent delivery process and the safe delivery of medicines [24]. The final study in the ADApp project (3) identified several key factors related to the user acceptance of drone-based medication delivery: time spent using the technology, usefulness, skepticism, and curiosity and ease of use, as well as feelings of competence and autonomy. Additionally, the study highlighted the importance of incorporating a control group within iterative and participatory projects. Since the same individuals ("core group") are involved throughout the iterative development process, introducing a naive control group (an "ad hoc" group) for each development step is essential. This approach helps balance expectations and mitigates the learning effects of the core group [25]. The iterative approach involved the continuous participation of the core group, while biases such as learning effects and expectation biases influence the results [30]. The core group tended to evaluate the app better than the ad hoc group. Learning effects might lead to increased familiarity with the system, affecting critical feedback, while expectation biases could shape participants' views on its development. To counteract this, a naive ad hoc group was recruited for each iteration step. Their fresh perspectives ensured more objective feedback, which was systematically compared to that of the core group to maintain a balanced evaluation.

In the present study, the final phase of the ADApp project focused on analyzing the user journey with two primary objectives: (1) to derive core technical work goals, improvements, and achievements that emerged throughout the development process using a theory synthesis approach [31]; and (2) to explore the dynamics of participatory collaboration between developers and co-developers using final tandem discussions and a content analysis method [32]. Due to the different methodological approaches, they are described separately in this article and referred to as study 1 and study 2, respectively.

This research is particularly timely and significant, as technological, logistical, and social barriers are critical for the adoption of drone-based medication delivery. At the same time, there is a substantial knowledge gap in the literature and research concerning these systems [1,7,8,10]. This study addresses this gap by examining innovative solutions in a healthcare system that is under increasing pressure and where new, efficient logistics solutions are needed—particularly in contexts such as the coronavirus pandemic. The present study aimed to systematize the findings of the ADApp project, focusing on factors influencing the intention to use drone-based applications in healthcare using qualitative methods.

## 2. Study 1: Introduction

Embedded within the ADApp project, study 1 aimed to identify the core technical work goals (called "core statements"), improvements, and achievements that emerged throughout the development process of the application for the drone-based medication delivery service. The study focuses on deriving practical orientation points for participatory technology development (app), generated over four iterations of the ADApp project.

Study 1 followed the qualitative theory synthesis method [31] to integrate user feedback from both core and ad hoc groups across the project's iterations. Specifically, it built on the findings of Fink et al. [25], which covered three iteration loops, and incorporated a novel fourth iteration not previously published. The theory synthesis approach allows for the integration and systematization of fragmented findings into a cohesive conceptual framework. This approach allows for identifying commonalities and creating a more integrated perspective, rather than merely summarizing existing findings. By generating core statements across all four iterations, this study provides a holistic understanding of the technological development for a pharmacy drone app, which can be generalized and transferred to other similar projects.

Co-creation with users is emphasized as a critical element of the development process, as technical solutions often work well in localized contexts but face challenges when scaled to broader, more diverse settings [33]. This approach contributes to the research agenda by focusing on transferable outcomes [34] and to the practical agenda by offering generalized results to improve the efficiency of future projects.

Study 1 primarily addressed the technical development of the pharmacy drone app using the Technology Readiness Level (TRL) to describe the maturity level of the app [35]. In TRL 2, the application was initially discussed in focus groups. In TRL 3 (iteration 1), the functionality was demonstrated (initial feasibility in the laboratory). TRL 4 showed a laboratory test setup with complex tasks (iteration 2). In TRL 5, the first operational environment testing was held (iteration 3). In TRL 6, the app and drone were tested in a relevant environment with realistic, complex problems (iteration 4). These TRL levels ran along the iterations of the whole ADApp study.

### *2.1. Methods*

#### 2.1.1. Setting and Participants

This paper synthesizes the findings from the iterative loops of the third study within the ADApp project, with the inclusion of data from the fourth iteration loop. A detailed description of the earlier processes can be found in the study by Fink et al. [25]. In total, four iteration loops between 2022 and 2023 were conducted. The first iteration loop (March–April 2022) initially tested the usability of the app (TRL3) and an initial app demonstrator was adapted based on user feedback. The second iteration (June–July 2022) focused on designing the prototype and its technical development and evaluation (TRL4). During the third iteration (October 2022), the entire process—from registration to medication delivery—was tested under experimental conditions at the test site in Cochstedt (TRL5). Finally, the fourth and last iteration (February 2023) took place under real conditions in a populated area in Dessau, Germany (TRL6). For the first time, the entire ordering and delivery process—from submitting an e-prescription to drone delivery—could take place over populated areas. Participants initiated orders by transmitting electronic prescriptions via the ADApp to a simulated patient apartment. Once all data had been fully recorded and the delivery location confirmed, the drone could be loaded at the pharmacy and deliver the order. It was dropped from a height of around 10 m above the designated landing point.

During each iteration loop, participants were encouraged to think aloud while testing the technology. These sessions were audiotaped, transcribed, and coded following the content analysis method from Elo and Kyngäs [32], using a deductive approach to categorize data from specific to general [36]. See Figure 1 for an overview of the methodological process within the ADApp process.

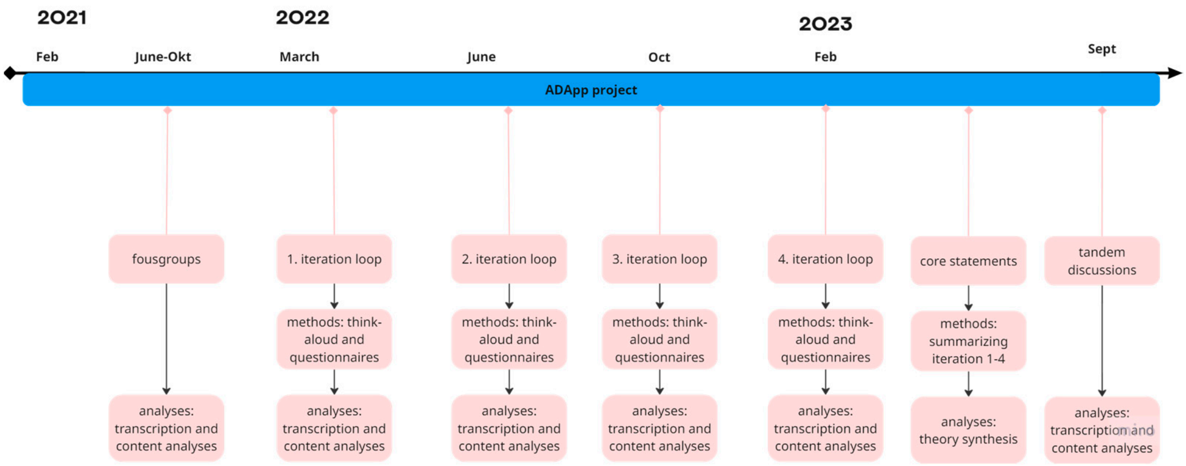


**Figure 1.** Flow diagram of the methodological process within the ADApp project.

The participants were selected as representatives of the potential users of the drone-based medication delivery service and its supply chain, included general practitioners, nurses, pharmacists, and interested users, especially SARS-CoV2 infected-patients and relatives of palliative care patients. General practitioners were selected because although they have limited involvement in the delivery process, they can indicate whether urgent delivery by drone is advisable by writing the prescription. Nurses were also included because they need to order medicines for patients who are unable to do so themselves. Pharmacists are critical to the supply chain. The patients were selected on the basis of a chronic illness or palliative care background, as they had experienced what it is like to be at home with a life-threatening illness and had experienced feelings of helplessness. For these reasons, age, gender, and region were less important in the selection of the study participants. The recruitment process followed a snowball sampling approach. First, the above-mentioned experts were contacted. These experts then disseminated the study information within their networks, allowing for the inclusion of diverse perspectives from both healthcare professionals and affected patients. The ad hoc group participants were recruited with the support of the Innovation and Technology Centre Merseburg and the ADApp project team, and were contacted by email or telephone. The core group participants were recruited from the focus group conducted in October 2021 [24]. All participants provided written informed consent and received detailed information about the study's goals and procedures before inclusion. The study was approved by the Ethics Committee of the Martin Luther University Halle-Wittenberg (protocol code 2021-069 and date of approval 6 May 2021).

#### 2.1.2. Data Analyses

During all iteration loops, the participants were instructed to think aloud while using the app demonstrator. When the participants stopped verbalizing their thoughts, the experimenter prompted them to continue [37,38]. The participants were not given any information about how the demonstrator was supposed to work. Instead, they received minimal instruction and interaction with the experimenter [38,39]. All think-aloud statements from the participants were digitally recorded (audio recordings) and then transcribed. All transcripts were analyzed according to Berelson's event sampling method [40], where each utterance represents an event. Nouns and noun phrases were identified, and utterances with a reference concept name were coded by the last author (F.F.), indicating the concept on which the participants focused. These concepts were then defined, forming a coding scheme that was used to code the participants' statements. A second researcher independently verified the coding, achieving substantial interrater reliability (K = 0.654, $p < 0.001$) [41,42]. Since the current study used the already transcribed and coded data from Fink et al. [25], the coding scheme can be found there. For the present study, two researchers (I.K., F.F.) independently summarized all coded categories used by Fink et al. [25] to inductively derived superordinate categories (called "core statements"). This step aimed to condense the user feedback into a manageable framework, reducing the complexity of individual statements [31]. Next, these summarized statements were integrated into a novel, higher-order perspective [31]. The researchers grouped the initial categories under broader headings, further reducing the number of categories by classifying the defined categories into more general ones. In case of disagreement between I.K. and F.F., discussions were held between the two examiners until a consensus was reached. The theory synthesis approach is particularly effective in identifying the objectively relevant and applicable elements for the implementation of participatory projects involving civil user groups. This method enabled the transformation of fragmented insights into a coherent and practical framework, providing a structured foundation for future participatory projects.

## *2.2. Results*

### 2.2.1. Participants

Data were collected from a total of 23 participants (ages 22–65 years, mean age 41.76 ± 12.34 years) over four iteration loops conducted between March 2021 and September 2024. The participants included two pharmacists, two nurses, one general practitioner, and one SARS-CoV2-infected patient. In general, the interest in the subject matter was limited, making participant acquisition difficult. Although the risk of 'positive selection' cannot be completely ruled out, it is unlikely because the topic of drone-assisted medication delivery was largely unknown. As a result, the perspectives of individuals who consistently reject technological systems in the context of care and delivery were poorly represented, as were those who chose not to participate in the surveys for other reasons. The reasons for this could include a general reluctance to take on additional work due to time constraints, heavy workloads, or other thematic priorities. In particular, the core group required a high level of commitment, as their participation demanded a significant time investment and long-term collaboration. Scheduling joint meetings posed an additional challenge, given the participants' professional obligations and varying availabilities. Furthermore, an imbalance in gender distribution was observed, with more male participants volunteering than female participants. These constraints limited the feasibility of a larger sample size but the selected participants provided valuable insights into the target group's perspectives. In addition, the ADApp study was designed as a predominantly qualitative study, so that larger groups of subjects would not have been possible for reasons of group dynamics, dialogue culture, and evaluation effort. The targeted sample size of each group was achieved through the creation of an 'optimal discussion atmosphere' and the moderator's ability to manage the focus of the topic and target interest [43].

The first three ad hoc groups consisted of four participants each; iteration one included two SARS-CoV2-infected patients, one general practitioner and one nurse, while iterations two and three included three SARS-CoV2-infected patients and one nurse. In the fourth iteration, the ad hoc group comprised five SARS-CoV2-infected patients. While efforts were made to balance the core and ad hoc groups, equal distribution was not always achievable.

### 2.2.2. Core Statements

In total, eight superordinate categories (core statements) were formed and are listed in Table 1.

**Table 1.** Core statements.

| Core Statement | Explanation | Examples |
|---|---|---|
| Automation | Quick and easy use to avoid redundancies | References as hyperlink; automatic suggestions such as city when entering postal code |
| Minimization | Provides only necessary information in language and design | Reducing symbols on maps, shortening texts |
| Differentiation | Clear distinctions between steps | Separate delivery and billing addresses |
| Control/Autonomy | Allows user choice | Preview function of the uploaded prescription |
| Guiding | Clear, concise instructions to navigate the app | Specifications for usernames and passwords, clear next steps |
| Conceptualization | Simple and precise, and uses non-technical language | Avoiding English or technical terms |
| Barrier-Free Design | Uniform and intuitive visualizations | Clear separation of registration and login buttons |
| Transparency | Clear information about disclosures and processes | Explains how user contact and data sharing are managed |

The users emphasized the importance of automation in simplifying processes and reducing redundancies. For example, they suggested features such as automatic address suggestions based on zip code, push notifications for updates, and the automatic activation of the camera for uploading e-prescriptions. Both the core and ad hoc groups expressed a strong preference for minimizing the language and design complexity of the app. Only as much information as necessary should be used to guide users effectively while avoiding overload or confusion. Symbols should be limited to the essentials and texts be kept as brief and concise as possible. Furthermore, clear differentiation was required; the users wanted a clear distinction between the delivery address and the billing address. Additionally, they valued features that provided control and autonomy, such as tracking the delivery by drone or previewing the uploaded e-prescription. They also wanted options for personalization, such as the ability to choose the type and frequency of contact. Guidance through the individual steps within the app was also important to both the core and ad hoc groups. The instructions should be short, concise, and easy to understand, with a short tutorial video available for more complex tasks. The users also preferred step-by-step navigation through the individual pages rather than continuous scrolling. Regarding the app's conceptualization, simple and precise language should be used, while avoiding technical terms and English words. They also highlighted the need for a barrier-free design that ensures uniformity across different steps and provides intuitive visualizations. For example, the users wanted the mailbox to be clearly highlighted as soon as a new message arrived. Above all, the approach should always be transparent, e.g., in the way information is provided and obtained, and all information should be openly accessible in order to build trust and acceptance.

However, there were also differences in the weighting of the key statements (see Figure 2). Most of the discussions focused on the guiding characteristics of the app. Minimization and control or autonomy are among the most important functions to be provided, while differentiation and transparency seem to be much less important in comparison.

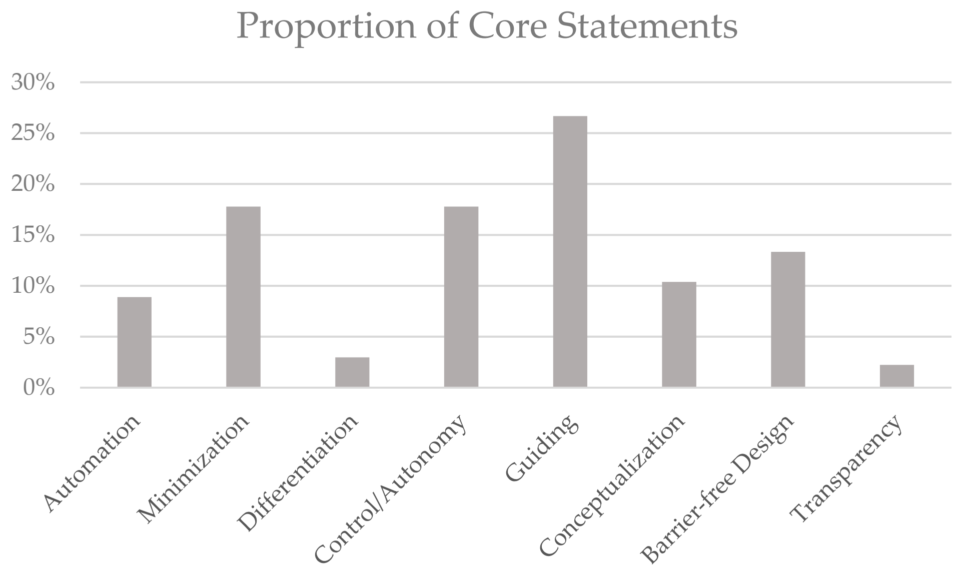


**Figure 2.** Relative proportions of core statements.

### 2.3. Discussion

Study 1 aimed to generalize specific findings from the development of a drone-based app to create guidelines applicable to future participatory projects. The goal was to identify technology features essential for successful technology development. Eight features have been identified as fundamental to the development of app-based technologies: automation, minimization, differentiation, autonomy, conceptualization, transparency, and barrier-free design. These features should be included in future studies to assess their impact on user acceptance.

A previous study within the ADApp project identified four main factors for user acceptance: (1) the time required to perform a task with the technology was negatively correlated with the usability; (2) usability and usefulness were the strongest predictors for the intention to use the technology; (3) skepticism and curiosity were also predictors for the intention to use; (4) increasing user competence led to improvements in both usability and the intention to use [25]. These findings align with the observations from the think-aloud approach conducted during the study.

It can, therefore, be assumed that meeting the eight identified core features improves user acceptance by enhancing usability. In other words, these eight core statements are integral to usability; when these criteria are met, the usability increases, which in turn fosters greater user acceptance. However, guidance, minimization, and autonomy or control are among the most important functions to be provided.

#### 2.3.1. Guidance and Usability

This means that when programming an application, guidance is one of the most important functions to be included in order for the user to use the application. The need for concise, easy-to-understand guidance throughout app processes is the most recurring theme. Users value clear instructions and the availability of tutorial videos for complex tasks. This suggests that while automation is appreciated, supportive elements remain crucial for effective navigation. The research by Lazar et al. [44] supports the use of multimedia tutorials to enhance learning and usability, especially for complex or unfamiliar tasks. Additionally, users prefer click-by-click navigation over one-page scrolling, as the former offers better cognitive segmentation and reduces task complexity [45].

#### 2.3.2. Minimizing Redundancies and Simplifying Interactions

Users' preferences for minimal language control and a simplified design highlight the need to avoid information overload. Users prefer applications that provide only the information they need, using concise, clear text and essential symbols. This approach aligns with the principles of minimalism in UX design, which emphasize eliminating unnecessary elements to focus on core functionalities [46]. A minimalist design prevents frustration and enhances navigability, especially for novice users [47].

#### 2.3.3. Control and Autonomy

The emphasis on user control and autonomy highlights the importance of trust and security in app design. Features such as drone delivery tracking and previewing uploaded e-prescriptions allow the users to monitor and verify critical steps, enhancing their sense of control. This aligns with the findings of Constantine [48], who highlights the role of user control in fostering trust and reliability in digital systems. Providing user options for the contact type and frequency also respects their autonomy and personal preferences, which is crucial for user satisfaction and long-term engagement.

The basic human needs for autonomy, competence, and connectedness [19] mediate the interaction between users and a system, influencing their well-being according to the basic psychological needs theory (BPNT) [18]. This was also demonstrated in a previous study in which increased autonomy led to enhanced user commitment, while greater competence led to an increase in user motivation, fostering a sense of connection that ultimately improves the well-being of all users [25].

#### 2.3.4. Language and Accessibility

The insistence on simple, non-technical, and non-English terminology highlights the need for accessibility and inclusivity in design. Avoiding jargon ensures that the application is usable by a broad audience, including those with limited technical proficiency [49]. The emphasis on barrier-free design aligns with universal design principles, advocating accessibility for all users, including those with disabilities [50]. Consistency in language and design across steps further contributes to a seamless user experience, reducing the learning curve and potential confusion.

#### 2.3.5. Automation and User Convenience

The users emphasized the importance of simplifying tasks through automation, indicating a preference for features such as automatic address suggestions and push notifications. This aligns with broader trends in user experience (UX) design, where automation reduces the cognitive load and streamlines user interactions [51]. By automating repetitive tasks, applications can enhance the efficiency and user satisfaction [52]. For example, integrating automatic address suggestions based on zip codes and mapping services for delivery location determination can significantly improve the user experience by minimizing manual inputs and potential errors.

2.3.6. Transparency and Trust

Transparency in information provision and access is crucial for building trust and fostering user acceptance. Users desire clear, openly accessible information regarding how their data are used and processed. This transparency is fundamental in mitigating privacy concerns and fostering a trustworthy relationship between the application and its users [53]. For example, visually highlighting new messages in the mailbox can enhance transparency and user awareness, ultimately improving the overall user experience.

## 3. Study 2: Introduction

The ADApp project employed an iterative participatory research design grounded in user-centered design (UCD), fostering close collaboration between developers (software and drone experts) and co-developers (core group participants). UCD is a methodology that prioritizes user needs, builds user empathy, and works in collaborative multidisciplinary teams to generate ideas, prototypes, and solutions aligned with user needs [20,54]. In this study, UCD served as a co-dependent approach that combined creativity and the creation of solutions, values, and prototypes, while developing a user-centered knowledge base relying on evidence primarily obtained from users [20].

In this approach, the users play an active role and are directly involved in the different stages of the design process (co-creation). Their ideas and thoughts are mainly provided while the users are rarely involved in the actual production of the product or service (co-design) [33]. In UCD, it is necessary to foster genuine collaboration, enabling all stakeholders (for the present study mainly developers, co-developers (i.e., users), scientists, and pharmacists) to share information and learn from one another as equals. A key challenge is to abandon the traditional roles of designers and scientists, moving from expert-based, top-down decision-making to bottom-up processes where active user participation is central [33]. This is particularly crucial for realizing a truly collaborative process.

Although this participatory approach has shown promising results in terms of harnessing collective creativity, little attention has been given to the role of co-design within the collaboration process [33]. To date, there is no research exploring the perception of collaboration between developers and co-developers in a UCD framework. Thus, the second study in the present paper addressed this gap by examining the iterative, participatory collaboration between these groups, following the methodological guidelines of co-creative design according to Farao et al. [20].

The qualitative study (study 2) aimed to explore how developers and co-developers perceived their collaboration throughout the project, their expectations, and the extent to which those expectations were fulfilled. For this purpose, a final tandem discussion workshop was conducted. This workshop aimed to generate recommendations for future projects, providing insights into the impacts of such collaboration and identifying ways to improve cooperation between developers and co-developers.

### *3.1. Methods*

3.1.1. Setting and Participants

In study 2, the qualitative method of tandem discussion between developers and co-developers was employed (a core group was used to gain an understanding of the participants' experiences, perspectives, and insights; see Table 2). Promoting active dialogue and reflexivity between participants, this method enriches and enhances the reliability of the collected data by allowing for balanced and in-depth discussions in a one-on-one setting.

**Table 2.** Overview of the question sets.

| Set of Questions | Topic |
|---|---|
| A | Initial motivation, changes over time, aims |
| B | Involvement in the participatory process |
| C | Impressions of the fourth iteration, further implementation |
| D | Optimizing drone-based medicine delivery: ideas, suggestions, wishes |
| E | Lessons learned |

Unlike traditional focus groups, which may inhibit individual expression due to dominant voices or group think, tandem groups create a dynamic and interactive environment where ideas and experiences can be exchanged more freely. This method aligns well with the principles of participatory research, which emphasize inclusivity, the co-creation of knowledge, and the empowerment of participants [55,56]. Each tandem group, consisting of one developer and one co-developer, discussed various topics, as listed in Table 2.

Three groups were formed, with one group comprising two developers and one co-developer. An external role was assigned to the project coordinator, who was also involved in a tandem group and is identified separately in the anchor quotations. Due to the higher proportion of male participants, the gender representation was unfortunately unequal, reflecting a broader trend of male affinity for technology. After the tandem rounds, the participants revisited all questions collectively, ensuring they could address and discuss the perspectives and comments of others. All of the group discussions were audio-recorded, transcribed, and coded using Maxqda software 2022. The key statements for each set of questions are listed below, along with anchor quotations from fictitious personas that represent the respective groups [57]. A tabular overview of the personas used can be found in Table 3.

**Table 3.** Fictitious personas of the developers and co-developers.

| Description | Gender | Age | Position |
|---|---|---|---|
| developer1 | m | 35 | drone operator |
| developer2 | m | 34 | scientist aerospace |
| developer3 | m | 32 | app developer |
| co-developer1 | m | 38 | pharmacist |
| co-developer2 | m | 28 | COVID-19 patient |
| co-developer3 | f | 28 | nurse |
| project coordinator | m | 56 | project coordinator/pharmacist |

In study 2, the use of personas as a qualitative method within the framework of participatory research was employed. Personas—fictional characters based on empirical data—serve as a powerful tool to encapsulate diverse participant experiences, needs, and behaviors. This method is particularly effective in participatory research and design thinking, as it facilitates deeper engagement and understanding among stakeholders [57]. Table 3 shows an overview of the fictitious personas used for the developers and co-developers.

#### 3.1.2. Data Analyses

The data analysis followed the qualitative content analysis method described by Elo and Kyngäs [32]. The transcripts were analyzed according to Berelson's event sampling method and coded using a deductive approach, moving from specific to general [36]. The categories were formed along the guideline-based question sets A–E (see Supplementary Materials S2) and coded for all transcripts using Maxqda software 2022. Each utterance represents an event, defined as a complete sentence, a sentence fragment, or a temporally (e.g., a pause of 2 s) or semantically (e.g., a change in content) separated speech sequence. The analysis was then carried out using a reference phrase analysis [38,58]. To validate the concept, randomly selected parts of the transcripts (20%) were coded by a second researcher (I.K.) familiar with the analytical framework. In case of discrepancies, discussions were held between the two reviewers until a consensus was reached. Cohen's d [59] was computed with MAXQDA for all variables. The interrater reliability was $_{K}$ = 0.84, $p < 0.001$, with an almost strong agreement [42].

## *3.2. Results*

### 3.2.1. Initial Motivation and Aims

This section explores the differing motivations of developers and co-developers in the ADApp project, highlighting their initial aims and how these evolved over time. However, motivations, goals, and their changes over time took up most of the discussions, with optimization suggestions playing a minor role (see Figure 3). The initial motivations of the developers and co-developers initially differed. The developers were driven by the novelty of the concept, emphasizing *"(. . .) that nobody is really looking into the topic of transporting medication by drone (. . .) or, above all, not to the end customer"* (developer 1). Particular attention was given to solving logistical challenges, particularly the "last mile," with the aim of freeing up healthcare workers' time. A secondary developer goal was to create a practical, cost-effective system that integrates with existing pharmacy logistics and e-prescriptions. This ambition was coupled with the desire to outperform traditional delivery methods: *"(. . .) it would be nice if we could get the whole thing to the point where it really beats the pill cab, and significantly so"* (developer 2). Moreover, the motivation to establish new supply structures in order to link app and drone logistics, which is linked to the pharmacy's merchandise management system and integrates the e-prescription, was very high from the outset.

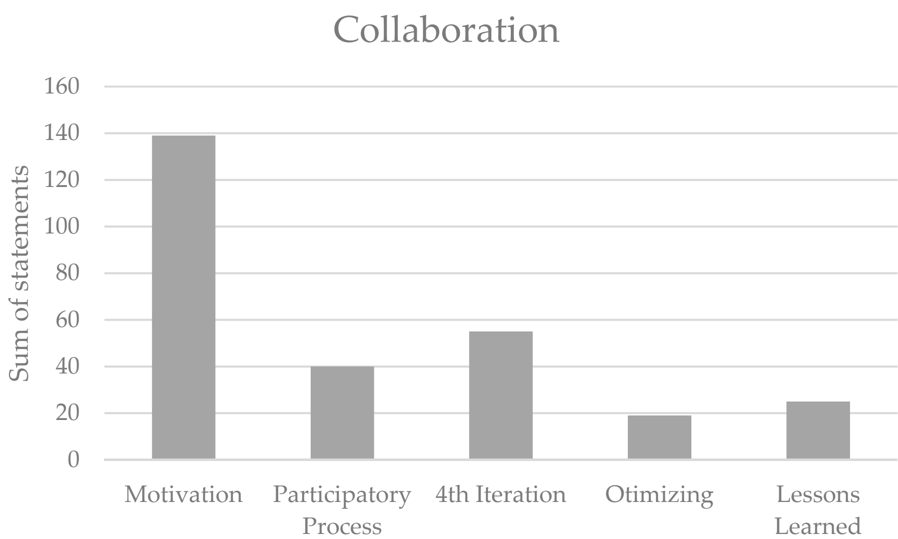


**Figure 3.** Absolute sum of statements per set of questions.

The co-developers' motivations, in contrast, were largely intrinsic; they were primarily motivated by curiosity and the desire to contribute meaningfully to the project. In addition, they expressed enthusiasm to be involved from the outset and to engage with like-minded individuals in exchange *"(. . .) and also get into discussions with people who are interested themselves"* (co-developer 1). This reflects the participatory nature of the research, which emphasizes user involvement as a crucial component of successful development. However, external challenges, such as regulatory hurdles, impacted their motivation over time. These obstacles were particularly frustrating for the developers, yet the project coordinator maintained enthusiasm throughout: *"(. . .) for me as the initiator, motivation is of course at the top and it hasn't diminished so far (. . .) and that hasn't changed either, so I'm still motivated."*

Despite these obstacles, the co-developers reported a growing sense of belonging and satisfaction as they observed the app's development progress. They valued their role in shaping the project and appreciated that their feedback was considered: "(. . .) *simply contributing my opinion was my goal (. . .) and you have the feeling that the feedback has also made a difference and is being incorporated"* (co-developer 3).

#### 3.2.2. Perception of the Participatory Cooperation

The aim of this part was to assess the dynamics of participatory co-operation and its impact on both groups. Both the developers and co-developers found the participatory collaboration very enriching and successful. The developers appreciated the open exchange, which led to design changes and improvements they might not have considered independently, such as the operator determining the delivery location: *"(. . .) the open exchange is also very, very important"* (developer 1). Similarly, the co-developers valued the opportunity to contribute ideas and see their feedback implemented, which fostered a sense of ownership and equality within the collaboration: "*Communicating face to face with the developers is basically the exciting thing about it. It was actually very enriching that it was set up like that*" (co-developer 1).

Both parties felt heard and the co-developers were able to iteratively express their ideas and witness changes implemented in subsequent iterations. They noted that their input was taken seriously, fostering a sense of equality and community: *"(. . .) there were changes from one meeting to the next, some of which came from us with the ideas and that surprised me positively"* (co-developer 2). This highlights the importance of iterative feedback loops, mutual learning, and a sense of community in participatory projects.

Both groups noticed that the participatory collaboration led to suggestions for changes that might otherwise not have been considered and that contributed significantly to improving the app and the process. However, a notable gap emerged in the co-developers' desire for deeper insight into the developers' work, suggesting a need for greater transparency about the technical and logistical constraints developers face. This could enhance their mutual understanding and manage expectations more effectively: *"As a tester, it might be good to get a better insight into the developer's point of view to see whether your ideas are realizable or not"* (co-developer 2).

The regular meetings in person were also perceived as enriching, although it was unanimously reported that dual events in person or digitally can vary depending on the situation. Another learning effect was the scientific setting of integrating control groups (ad hoc groups) as a new approach within the participatory process: *"So I definitely think it was a good approach with the two separate groups, the core, the ad hoc group, because you really had a good comparison. You also saw from the evaluations that the ad hoc groups lasted longer, but that was all logical, they didn't know the app, looked at it for the first time and it was an interesting approach, which I think also gave us interesting results"* (developer 3).

#### 3.2.3. Experiences of the Fourth Iteration—Flights over Populated Areas

Both the developers and co-developers were very satisfied with the fourth iteration, which involved test flights over the populated area of the city of Dessau Roßlau (Germany). The participants appreciated the preparations, the review of the previous iterations, and the final test flights, including the linked app ordering process: *"I thought it was a great concept, a bit like seeing what conditions you have to have there, how it works, how the goal setting* *works, that you don't have to do anything, it was also interesting to see. No, it actually informed me, as it should be, I would say*" (co-developer 1). Both groups valued receiving a summary of all development steps and changes, which allowed them to track all the changes once again.

When discussing the broader applicability of drone-based deliveries, both groups agreed that drones would be most effective in rural areas or settings with limited access. Densely populated areas, especially those near airports or with strict airspace restrictions, were seen as less viable. *"(. . .) it would make sense wherever you can fly effectively. This means that only densely populated areas, full of hospitals and airports, such as the Ruhr area, would be excluded and anything that somehow falls within the rural area would make sense"* (developer 2). In addition to scheduled drug deliveries, the developers also see the use of emergency deliveries as useful, as well as the rapid transportation of laboratory and blood samples. It was also discussed whether threat-based medication deliveries could provide added value in palliative care. *"(. . .) so SAPV, emergency interventions always, in any case, if you need something new somewhere, for example on a highway, very quickly at the scene of an accident"* (co-developer 1). The developers emphasized the importance of optimizing the certification process to gain recognition from relevant authorities and professional bodies: *"(. . .) and we are currently optimizing this, it has to be a certified delivery process and I think it will then be recognized by all chambers and authorities" (coordinator).*

### 3.2.4. Optimization Suggestions

When asked about areas for improvement, both groups responded that the app and drone system should remain as simple and intuitive as possible; it should contain only as much information as necessary and as little as possible, as well as be self-explanatory throughout, to ensure the system can be used easily, even by individuals without prior experience. However, achieving a balance between user requirements and product simplicity remained challenging. One reason for that was the *"(. . .) balancing act between user requirements on the one hand and which of these you implement and how and how do you manage this without overloading the product. That's a tough act to follow"* (developer 2). The co-developers suggested enhancing the user-friendliness by improving the overall handling and ease of use, as well as by integrating push notifications directly into the operating system. The developers identified opportunities to optimize the drone's flight range, improve the battery performance, and incorporate safety-related features such as "(. . .) *a camera in the drone to document the handover process"* (developer 2).

### 3.2.5. Lessons Learned

Both the developers and co-developers recognized the complexity of the development process, which was more complex then they anticipated: *"(. . .) so it's incredibly small steps. Even small thoughts where you think, that's a quick improvement. (. . .) Everything is incredibly time-consuming, small steps, the test subjects have a great idea and then it takes a really long time until it's started and implemented. (. . .) There is an incredible amount of work involved in all the adaptations (. . .) but it's very, very time-consuming"* (co-developer 3). This realization highlights the importance of fostering mutual understanding between developers and co-developers. Insight into each other's work was important for the understanding between the developers and co-developers, thereby improving the overall collaboration: *"We also learned a lot about medication, including how a pharmacy works. How they earn their money,* etc. *These are topics that we hadn't dealt with that much before, of course, but we realized that it's a very, very exciting market environment and something that could definitely have potential"* (developer 1). Moreover, the developers had the opportunity to *"(. . .) see it from a developer's point of view"* (coordinator). The co-developers, on the other hand, gained a greater appreciation for the challenges of balancing customer demands with the need for a streamlined design. Overall, these findings highlight the significance of participatory collaboration in technology development, demonstrating how iterative feedback, mutual understanding, and a balanced approach to user and technical requirements can not only enhance the functionality and usability of innovative solutions but also foster trust and engagement.

### *3.3. Discussion*

Study 2 aimed to determine the perceived participatory collaboration between the developers (software and drone developers) and co-developers (participants of the core group) throughout the ADApp project. The objective was to generate participatory-specific factors for further implementation. Five key factors of participatory collaboration were identified: initial motivation, basic psychology needs (autonomy, competence, relatedness), iterative feedback, iterative review, and technology- and user-specific factors (see Table 4 for an overview).

**Table 4.** Key factors of participatory collaboration.

| Factor | Developers | Co-Developers |
|---|---|---|
| Motivation | Focused on solving research gaps, efficiency, and cost-effective solutions. | Driven by curiosity, excitement, and meaningful contribution. |
| Basic Psychological Needs | Competence boosted through overcoming challenges and technical learning. | Relatedness strengthened by seeing feedback valued and integrated. |
| Iterative Feedback | Benefited from fresh perspectives and insights into unnoticed issues. | Felt engaged and gained understanding of developers' challenges. |
| Iterative Review | Progress summaries clarified goals; increasing complexity improved real-world alignment. | Clear updates reinforced involvement and highlighted their role in the process. |
| Integration of Technology Features | Balanced functionality with simplicity to ensure usability. | Advocated for intuitive, user-friendly designs that met their needs. |

#### 3.3.1. Motivation

First, motivation emerged as a critical factor for sustained collaboration and scientific productivity, as well as the inclusion of different perspectives. The initial motivations of the developers and co-developers illustrate the various drivers behind technological innovation and participatory research. The developers were mainly motivated by a desire to close existing research gaps and for improved logistical efficiency, with a focus on the 'last mile' of drug delivery. These statements align with the research of Eskandaripour et al., who have demonstrated the efficiency and environmental benefits of using drones for small deliveries such as medical products [60]. For example, it highlights the importance of accessibility to remote areas, where drones can provide a solution for supplying remote, infrastructurally weak areas. In addition, drones enable the significantly faster delivery of medicines, especially in urban areas with heavy traffic or rural regions that are difficult to access, as is described here. Furthermore, a possible cost efficiency is discussed well, as drones cause lower operating costs and do not require a driver compared to conventional pharmacy delivery services. For example, potential time and cost savings also make it possible to reallocate staff resources to more patient-centered activities. This underlines the potential of technological innovations for healthcare. This view is in line with recent reports and research highlighting the potential benefits of healthcare automation in reducing the non-clinical workload of medical staff [61,62]. The research-driven motivation of the developers, aiming to develop new solutions in healthcare logistics, is in line with Rogers' innovation diffusion theory, which states that new ideas and technologies often arise from recognized gaps or unmet needs [63].

The co-developers, in contrast, were driven by curiosity, the excitement of working with innovative technology, and the desire to contribute meaningfully to the project. These intrinsic motivations align with the findings of Deci and Ryan's self-determination theory [18] and fit with the results of the latest study by Fink et al. [25], which shows that the basic psychological needs for competence, autonomy, and relatedness correlate positively with curiosity. These motivations reflect an intrinsic interest in new technologies and a desire to participate in pioneering work. This suggest that participatory research should always be accompanied by non-participatory test subjects in order to rule out the effects of familiarity and involvement. At the same time, co-developers are important in order to determine and integrate the needs anew in each development step. Participatory design methods often use such motivations to encourage user engagement and gather diverse contributions [64].

### 3.3.2. Basic Psychological Needs

Second, basic psychological needs such as competence and relatedness are important factors for sustained engagement, especially when challenges arise [23]. Such challenges might affect the initial motivation and should be considered during the project.

For developers, regulatory hurdles initially weakened the users' motivation. The difficulties in navigating the bureaucratic and regulatory landscape were a major demotivating factor for some developers, as also described in the studies by Hiebert et al. 2020 [1] and Rejeb et al. 2021 [7] using the environmental TOE barriers. However, improved knowledge and understanding of the regulatory environment helped to maintain a certain level of motivation among the developers (competence).

For the co-developers, relatedness played an important role for improving and maintaining motivation. They reported feeling increasingly connected to the project and team as they saw the technology evolve and their input valued (relatedness). This reflects the dynamic nature of motivation in participatory projects, where external challenges can both hinder and enhance engagement, depending on the participants' learning and adaptation experiences [65]. This highlights some practical implications. To ensure that the project remains focused and sustainable over the long term, it is essential to align the motivations of developers and co-developers. Developers must consider the needs-driven motivation of the co-developers, integrating their basic psychological needs during research and development. This includes designing technology that meets user requirements while fostering a sense of autonomy, competence, and involvement. The critical questions to address are as follows: How can the technology be designed to meet the needs of users? How can users be actively engaged throughout the development process to ensure they feel valued and empowered?

This also shows the importance of basic psychological needs in motivating users to participate in participatory projects and should, therefore, not be ignored. How can the needs of users be integrated into the entire process in such a way that they feel autonomous, competent, and involved?

Co-developers feel more engaged when their feedback is acknowledged and incorporated into the technology. This reinforces their sense of relatedness and purpose, showing that their contributions are meaningful. This highlights the importance of structures and mechanisms that promote exchange among each other and with the developers. On the other hand, co-developers should be aware that developers are often motivated by knowledge, research gaps, and economic interests. Developers aim to create functional, efficient technology that works in real-world settings, which is only possible with user involvement. At the same time, these need-driven and research-driven motivations are interdependent, because without development and research gaps there would be no technical mission, and without the co-developers' motivation to contribute, there would be no participative–collaborative users.

#### 3.3.3. Iterative Feedback

Third, iterative feedback loops were essential for the participatory processes. The iterative nature of participatory design allowed the co-developers to continuously express their wishes and ideas, fostering a sense of community and mutual respect among the participants [10]. Both the developers and co-developers regarded the participatory collaboration as enriching and successful, aligning with the principles of participatory design. This approach emphasizes co-design and iterative feedback to ensure that the final product meets the users' needs and expectations [20,66].

The ongoing integration of the co-developers' feedback from one iteration to the next was crucial, not only for their active involvement but also to help them feel genuinely integrated into the process. For the developers, this feedback provided insights into issues they might not have identified independently due to their different perspectives. Similarly, the co-developers had the possibility to see it from a developer's perspective, enabling a more holistic understanding of the challenges and opportunities in the project.

The ADApp project was both a technical development and a scientific project. The developers and co-developers gained insights into scientific approaches within participatory processes. For example, the integration of control groups (ad hoc group) was essential in identifying weaknesses in the technology. These issues, which might have been overlooked by the co-developers due to their familiarity with the app, were effectively highlighted by the ad hoc groups [25].

#### 3.3.4. Iterative Review

Thorough preparation and an iterative review of the development steps are important for transparency and fostering continuous feedback in participatory projects. Providing a clear summary of each developmental step helps both developers and co-developers understand the progress, identify necessary changes, and recognize improvements that have already been implemented. Moreover, gradually increasing the complexity of the technology and its context can simulate real-world conditions more accurately. One effective tool for this purpose is the Technology Readiness Level (TRL). This systematic metric categorizes the maturity of a technology according to nine levels, ranging from basic principles (TRL 1) to successful mission operations in a relevant environment (TRL 9) [12].

#### 3.3.5. Integration of Technology Features

Participatory collaboration depends on the successful implementation of the particular technology. A recurring theme throughout the project was the balance between meeting user needs and maintaining the simplicity of the app's design. This challenge highlights the difficulty of integrating comprehensive functions while maintaining user-friendliness, an essential aspect of user-centered design [67,68]. Simplicity and clarity in the user interface were repeatedly emphasized as critical for achieving a positive user experience. This aligns with usability research, which indicates that intuitive and user-friendly designs are essential factors for the success of a product [51,68]. Thus, to ensure effective participatory collaboration, the technology should go along with technology features (see study 1) and intention-to-use-specific factors [25].

In conclusion, participatory approaches require enhanced communication, coordination, and iterative feedback loops between the groups involved. This can increase the complexity of the process, as highlighted by both the developer and co-developer groups, due to the need to accommodate multiple stakeholders' perspectives and requirements. This complexity, however, enriches the development process, making the development process more differentiated and comprehensive [69,70].

When different groups work together, especially in interdisciplinary or cross-sectoral teams, a better understanding of the respective challenges, methods, and goals, as experienced by our developers and co-developers, can be achieved. This advantage of participatory research projects can not only improve the technical components of the app but also the relationship between the two groups over the long term [55,71]. Furthermore, this approach supports the acceptance and implementation of the final product, as potential conflicts can be identified and resolved at an early stage. Nevertheless, it is also important to consider the challenges inherent in participatory methods; increased coordination efforts and the need to manage conflicts and power imbalances within the group require careful planning and facilitation [56].

## 4. Limitations

Studies 1 and 2 provide valuable insights into the technical aspects of the development process, as identified by the core and ad hoc groups (study 1), as well as the dynamics of participatory collaboration beyond the technical scope (study 2). However, several methodological limitations should be considered when interpreting these findings.

One notable limitation in study 2 was the unequal gender distribution among participants. The group of developers consisted exclusively of men, while the group of co-developers included only one woman. This can be attributed to the particular affinity for technology and interest in innovation of the men in our study. Moreover, the correlational analyses of Fink et al. [25] suggest that female participants may experience greater anxiety about technology, while men are more interested in technological systems. Nevertheless, the results reveal a consistent trend that highlights key findings, which is evident despite the unequal gender distribution.

Although the risk of "positive selection" cannot be completely ruled out, it is considered unlikely. This is due to the fact that the topic of drone-assisted drug delivery was largely unknown. The perspectives of participants who fundamentally opposed technical systems in healthcare and supply sectors or who declined to participate for reasons such as a lack of time, high workloads, or other thematic priorities were little represented. However, it can be stated that the results of the present studies have shown important aspects of technical development, as well as participatory cooperation.

## 5. General Conclusions

The present study focused on the user journey in order to (1) derive the core statements from the development of a drone-based app using a theory synthesis approach [31] and (2) explore the perceived participatory collaboration between developers (software and drone developers) and co-developers (participants of core group) using final tandem discussions and a content analysis method [32]. Due to the different methodological approaches of these two objectives, the data were analyzed and described separately but are now incorporated into one model. The project's development journey illustrates the complexities and dynamics of participatory design in healthcare technology. Both studies contribute to a better understanding of essential factors that lead to successful participatory processes between developers and co-developers, aiming to increase usability and the intention to use under a background of different theories and models (TAM, METUX, TUI, TOE) [8,12–16].

The studies identified eight technology features essential for user acceptance [25] and five critical factors for a successful participatory development process (study 2), while addressing organizational barriers according to the TOE model [8]. The technology features (see Figure 4) are crucial for usability, which is a primary predictor of the intention to use technology [12]. The type and extent of acceptance especially determine the success in the introduction of technology applications [11]. Acceptance refers to the positive decision for an innovation by its users [12].

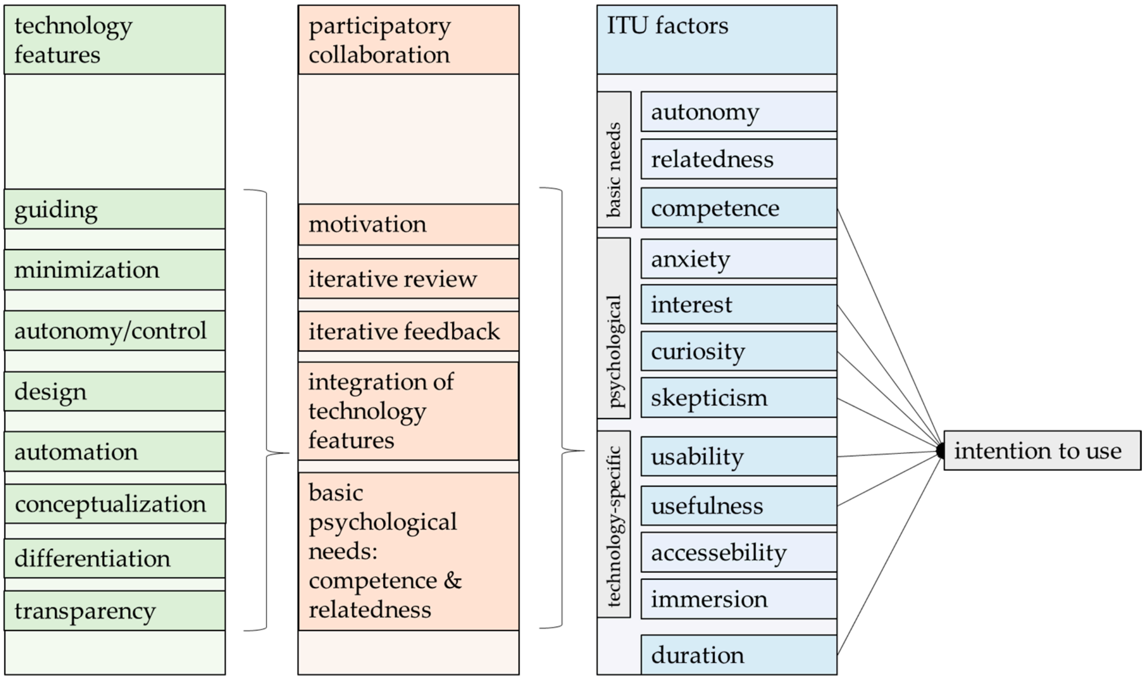


**Figure 4.** Integrated model of the results of the ADApp project based on the TAM, METUX, TUI, and UCD models [8,12–16,20,25]. The technology features are the results of synthesized and generalized user feedback within the ADApp project that contributed to better usability of a technology (core statements). The collaborative factors are the results of a tandem discussions at the end of the ADApp project. These factors were evaluated as drivers for successful collaboration between developers (technical) and co-developers (civil), which are essential for the integration of ITU (intention to use) factors that improve usability and the intention to use [25].

According to this theory (TAM), users adopt a technology if it is perceived as useful and easy to use. Based on this model and the resulting TUI assessment, we were able to create precise questions which led us to the insight that technology-specific factors, such as usefulness and ease of use, correlate with the intention to use a technology [12,25]. Additional psychological factors such as skepticism, curiosity, interest, and competence (METUX) also determine the intention to use a technology [16,25].

*Implications*

The findings from this project offer valuable guidance for future participatory research and development efforts. Combining technological and psychological factors is critical to understanding whether users will adopt a technology (see Figure 4 "ITU factors"). It is important to identify which technological features contribute to perceived ease of use in this context. Whereas the study by Fink et al. [26] identified technological and psychological factors that predict the intention to use (see Figure 4, "ITU factors"), it is important to determine technical features (so-called "core statements") that ensure usability and participatory integration (see Figure 4, "technology features"). Technology features are essential for fostering a clear understanding of the technology and its capabilities, as well as its broader applicability beyond isolated contexts. These core statements, derived from synthesized user feedback across four iterations of the ADApp project, ensure that applications are user-friendly and efficient. The aim was to obtain generalizable statements about the technical requirements for drone-based medication delivery, which can be used for further research and development projects to increase or ensure user acceptance. These technical features can also be transferred to other technical developments, which should be verified in further studies. Incorporating the eight identified features ensures usability and effectiveness, offering developers actionable guidelines grounded in the principles of minimalism and user autonomy. Simplified user interfaces and functionality that allow the tracking and control of application functions empower users, which is critical to fostering trust and long-term engagement. Moreover, by eliminating jargon and English terms, accessible design can be achieved that appeals to a broader demographic, including seniors or those with limited technical proficiency. Without integrating these features into the iterative collaboration process, the co-developers may not feel adequately involved into the developmental steps.

One key challenge identified within the TOE barriers was the impact of environmental barriers, such as regulatory barriers that slow down the project itself, as well its outcomes [8]. Addressing these challenges requires the active involvement of users as co-developers, as their participation plays a crucial role in maintaining engagement and motivation. The co-developers reported feeling more engaged, related, and competent the more they were involved [16]. Thus, iterative feedback not only supports technical development but also strengthens user involvement, fostering a participative environment. Similarly, iterative reviews ensure an understanding of developmental processes and deepen co-developers' sense of connection to the project. Although there are environmental barriers, such as regulatory barriers, which differ from country and culture, the participatory development approach itself is mostly globally transferable because it describes universal principles for successful co-creation, namely user involvement, the iterative adaptation of solutions, and equal knowledge sharing. These factors are important for all countries and areas of innovation in which technologies are developed with and for people.

The successful implementation of technology features identified in study 1 is important for creating a positive user experience and fostering acceptance. Integrating user needs, maintaining clear communication, and employing systematic feedback mechanisms can enhance the usability, as evaluated within study 2, ensuring the broader effectiveness of healthcare technologies (see Figure 4, "participatory collaboration").

Both studies highlight the critical interplay between basic psychological needs and technology features within participatory and technological processes, which in turn drive usability. The findings suggest that the intention to use is not only determined by technological and psychological factors (ITU factors) but also arises from successful collaboration and the effective implementation of technology features. The inclusion of a user journey, in which the core group identifies themselves as co-developers, proves to be a valuable approach for developing technology from the user's perspective. This approach enhances the long-term acceptance and quality by aligning development with user needs and perspectives.

As the implementation of healthcare applications and drones matures in further research, the proposed integrated model of technological, psychological, and participatory-specific factors should be adapted and tested in diverse real-world settings. The model was created as a result of the ADApp project, with the aim of providing a blueprint for future app-based health projects with a participatory approach. The eight identified core functions can be seen as an integral part of user acceptance. This means that if these criteria are not met, the user acceptance level may be lower. Another important issue that plays a role in the acceptance of health technologies is the participatory process by which they are developed. Only through iterative feedback, iterative review, and consideration of basic psychological needs (participatory collaboration) can a technology be adapted to user needs (the technology features), which in turn increases the ITU factors. The scientific recommendations include further implementation and testing of the integrated model within clinical care studies in the healthcare sector or conducting multicenter care studies that holistically explore its applicability across multiple regions. Additionally, future research studies should investigate the adaptability of the integrated model to different target groups, healthcare settings, or treatment indications. Expanding the scope of research to different demographic, social, and medical needs could promote scalability and greater inclusivity.

As a practical recommendation, extending the network of stakeholders and promoting cross-sector collaboration is critical. For example, further cooperation with regional and national care providers, such as local authorities and healthcare insurance companies, should be pursued to create sustainable, practical solutions that integrate technology into existing care systems effectively.

The findings of this paper, along with the proposed integrated model, contribute significantly to the growing literature on user acceptance, participatory research, and technological development in drones, particularly in the domain of healthcare. This research fills an important gap by presenting an integrated model that can quantitatively and qualitatively evaluate the impacts of applications, drones, and other healthcare technologies in user-centered design studies and projects.

To the best of our knowledge, this study represents one of the first efforts to synthesize qualitative and quantitative results from an entire project on the intention to use healthcare-related drone applications. While prior studies and theories have predominantly focused on user acceptance alone, the present study introduces a holistic model that integrates user acceptance theories as well as user-centered design principles and technology features.

**Supplementary Materials:** The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/designs9020027/s1.

**Author Contributions:** Conceptualization, F.F., P.J. and I.K.; methodology, F.F. and I.K.; validation, F.F. and P.J.; formal analysis, A.L.; investigation, A.L.; resources, P.J.; data curation, A.L. and I.K.; writing—origin A.L. draft preparation, A.L. and I.K.; writing—review and editing, F.F.; visualization, A.L. and F.F.; supervision, F.F.; project administration, F.F.; funding acquisition, P.J. 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 Germany through the "TDG—Translational Region for Digitalised Healthcare" project [03COV25E]. P.J. received this funding. The funders did not partake in the study design, data collection, or analysis, nor in the preparation of the manuscript or the decision to publish.

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Martin Luther University Halle-Wittenberg (protocol code 2021-069, date of approval 6 May 2021).

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

**Data Availability Statement:** Data are contained within the article and supplementary materials.

**Acknowledgments:** The authors would like to thank the Apotheken-Drohnen-App team for their involvement in the participatory development of the drone, as well as the core group, which made an important contribution to the success of the work as a co-development team.

**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. Hiebert, B.; Nouvet, E.; Jeyabalan, V.; Donelle, L. The Application of Drones in Healthcare and Health-Related Services in North America: A Scoping Review. *Drones* **2020**, *4*, 30. [CrossRef]
2. Assche, S.B.-V.; Ferraccioli, F.; Riccetti, N.; Gomez-Ramirez, J.; Ghio, D.; Stilianakis, N.I. Urban-rural disparities in COVID-19 hospitalisations and mortality: A population-based study on national surveillance data from Germany and Italy. *PLoS ONE* **2024**, *19*, e0301325. [CrossRef]
3. Stierlin, N.; Risch, M.; Risch, L. Current Advancements in Drone Technology for Medical Sample Transportation. *Logistics* **2024**, *8*, 104. [CrossRef]
4. Michael, Z. Pilotprojekt zur Drohnenlieferung von Arzneimitteln: Per Luftpost ins hessische Hinterland. Available online: https://www.deutsche-apotheker-zeitung.de/news/artikel/2024/01/18/pilotprojekt-zur-drohnenlieferung-von-arzneimitteln (accessed on 18 January 2024).
5. UAM-InnoRegion-SH. Available online: https://www.uam-innoregion-sh.de/ (accessed on 8 December 2024).
6. Balasingam, M. Drones in medicine—The rise of the machines. *Int. J. Clin. Pract.* **2017**, *71*, e12989. [CrossRef] [PubMed]
7. Rejeb, A.; Rejeb, K.; Simske, S.; Treiblmaier, H. Humanitarian Drones: A Review and Research Agenda. *Internet Things* **2021**, *16*, 100434. [CrossRef]
8. Rejeb, A.; Rejeb, K.; Simske, S.J.; Treiblmaier, H. Drones for supply chain management and logistics: A review and research agenda. *Int. J. Logist. Res. Appl.* **2023**, *26*, 708–731. [CrossRef]
9. Stephan, F.; Reinsperger, N.; Grünthal, M.; Paulicke, D.; Jahn, P. Human drone interaction in delivery of medical supplies: A scoping review of experimental studies. *PLoS ONE* **2022**, *17*, e0267664. [CrossRef] [PubMed]
10. Eißfeldt, H.; Vogelpohl, V.; Stolz, M.; Papenfuß, A.; Biella, M.; Belz, J.; Kügler, D. The acceptance of civil drones in Germany. *CEAS Aeronaut. J.* **2020**, *11*, 665–676. [CrossRef]
11. Milchrahm, E. Entwicklung eines Modells zur Akzeptanzproblematik von Informationstechnologie. In *Information und Mobilität, Optimierung und Vermeidung von Mobilität durch Information. Proceedings des 8. Internationalen Symposiums für Informationswissenschaft (ISI 2002)*; Hammwöhner, R., Wolff, C., Womser-Hacker, C., Eds.; UVK Verlagsgesellschaft mbH: Konstanz, Germany, 2002; pp. 27–44.
12. Davis, F.D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q.* **1989**, *13*, 319. [CrossRef]
13. Venkatesh, V.; Bala, H. Technology Acceptance Model 3 and a Research Agenda on Interventions. *Decis. Sci.* **2008**, *39*, 273–315. [CrossRef]
14. Venkatesh, V.; Davis, F. A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Manag. Sci.* **2000**, *46*, 186–204. [CrossRef]
15. Kothgassner, O.D.; Felnhofer, A.; Hauk, N.; Kastenhofer, E.; Gomm, J.; Ryspin-Exner, I. (Eds.) *TUI: Technology Usage Inventory*; FFG: Vienna, Austria, 2012.
16. Peters, D.; Calvo, R.A.; Ryan, R.M. Designing for Motivation, Engagement and Wellbeing in Digital Experience. *Front. Psychol.* **2018**, *9*, 797. [CrossRef] [PubMed]
17. Deci, E.; Ryan, R.M. *Intrinsic Motivation and Self-Determination in Human Behavior*; Springer: Boston, MA, USA, 1985; ISBN 9781489922717.
18. Ryan, R.M.; Deci, E.L. *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*; Guilford Press: New York, NY, USA, 2017; ISBN 9781462538966.
19. Ryan, R.M.; Deci, E.L. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemp. Educ. Psychol.* **2000**, *25*, 54–67. [CrossRef] [PubMed]
20. 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]
21. McCurdie, T.; Taneva, S.; Casselman, M.; Yeung, M.; McDaniel, C.; Ho, W.; Cafazzo, J. mHealth Consumer Apps: The Case for User-Centered Design. *Biomed. Instrum. Technol.* **2012**, *46*, 49–56. [CrossRef] [PubMed]
22. Nilsen, W.; Kumar, S.; Shar, A.; Varoquiers, C.; Wiley, T.; Riley, W.T.; Pavel, M.; Atienza, A.A. Advancing the Science of mHealth. *J. Health Commun.* **2012**, *17*, 5–10. [CrossRef]

23. 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]
24. Fink, F.; Paulicke, D.; Grünthal, M.; Jahn, P. "Of course, drones delivering urgent medicines are necessary. But I would not use them until. . ." Insights from a qualitative study on users' needs and requirements regarding the use of medical drones. *PLoS ONE* **2023**, *18*, e0285393. [CrossRef]
25. Fink, F.; Kalter, I.; Steindorff, J.-V.; Helmbold, H.K.; Paulicke, D.; Jahn, P. Identifying Factors of User Acceptance of a Drone-Based Medication Delivery: User-Centered Design Approach. *JMIR Hum. Factors* **2024**, *11*, e51587. [CrossRef] [PubMed]
26. Claesson, A.; Fredman, D.; Svensson, L.; Ringh, M.; Hollenberg, J.; Nordberg, P.; Rosenqvist, M.; Djarv, T.; Österberg, S.; Lennartsson, J.; et al. Unmanned aerial vehicles (drones) in out-of-hospital-cardiac-arrest. *Scand. J. Trauma Resusc. Emerg. Med.* **2016**, *24*, 124. [CrossRef]
27. Sanfridsson, J.; Sparrevik, J.; Hollenberg, J.; Nordberg, P.; Djärv, T.; Ringh, M.; Svensson, L.; Forsberg, S.; Nord, A.; Andersson-Hagiwara, M.; et al. Drone delivery of an automated external defibrillator—A mixed method simulation study of bystander experience. *Scand. J. Trauma Resusc. Emerg. Med.* **2019**, *27*, 40. [CrossRef] [PubMed]
28. Rosamond, W.D.; Johnson, A.M.; Bogle, B.M.; Arnold, E.; Cunningham, C.J.; Picinich, M.; Williams, B.M.; Zègre-Hemsey, J.K. Drone Delivery of an Automated External Defibrillator. *N. Engl. J. Med.* **2020**, *383*, 1186–1188. [CrossRef]
29. Zègre-Hemsey, J.K.; Grewe, M.E.; Johnson, A.M.; Arnold, E.; Cunningham, C.J.; Bogle, B.M.; Rosamond, W.D. Delivery of Automated External Defibrillators via Drones in Simulated Cardiac Arrest: Users' Experiences and the Human-Drone Interaction. *Resuscitation* **2020**, *157*, 83–88. [CrossRef]
30. Oort, F.J.; Visser, M.R.M.; Sprangers, M.A.G. Formal definitions of measurement bias and explanation bias clarify measurement and conceptual perspectives on response shift. *J. Clin. Epidemiol.* **2009**, *62*, 1126–1137. [CrossRef] [PubMed]
31. Jaakkola, E. Designing conceptual articles: Four approaches. *AMS Rev.* **2020**, *10*, 18–26. [CrossRef]
32. Elo, S.; Kyngäs, H. The qualitative content analysis process. *J. Adv. Nurs.* **2008**, *62*, 107–115. [CrossRef]
33. Durall, E.; Bauters, M.; Hietala, I.; Leinonen, T.; Kapros, E. Co-creation and co-design in technology- enhanced learning: Innovating science learning outside the classroom. *Interact. Des. Archit.* **2020**, 202–226. [CrossRef]
34. Falk-Krzesinski, H.J.; Contractor, N.; Fiore, S.M.; Hall, K.L.; Kane, C.; Keyton, J.; Klein, J.T.; Spring, B.; Stokols, D.; Trochim, W. Mapping a research agenda for the science of team science. *Res. Eval.* **2011**, *20*, 145–158. [CrossRef]
35. Mankins, J. Technology Readiness Level—A White Paper. 1995. Available online: https://www.researchgate.net/publication/247705707_Technology_Readiness_Level_-_A_White_Paper (accessed on 18 January 2024).
36. Denney, R.; Berelson, B. Content Analysis in Communication. *Audio Vis. Commun. Rev.* **1954**, *2*, 64–67.
37. Jaspers, M.W.; 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]
38. Marsha, E.; Kuipers, B.; Susan, J.G. A Description of Think Aloud Method and Protocol Analysis. *Qual. Health Res.* **1993**, *3*, 430–441. [CrossRef]
39. Roberts, J.P.; Fisher, T.R.; Trowbridge, M.J.; Bent, C. A design thinking framework for healthcare management and innovation. *Healthcare* **2016**, *4*, 11–14. [CrossRef]
40. Berelson, B. *Content Analysis in Communication Research*; Free Press: New York, NY, USA, 1952.
41. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates, Publishers: Hillsdale, NJ, USA, 1988.
42. Landis, J.R.; Koch, G.G. The Measurement of Observer Agreement for Categorical Data. *Biometrics* **1977**, *33*, 159–174. [CrossRef]
43. Bohnsack, R.; Przyborski, A.; Schäffer, B. (Eds.) *Das Gruppendiskussionsverfahren in der Forschungspraxis*; 2., vollständig überarbeitete und aktualisierte Auflage; Budrich: Opladen, Germany, 2010; ISBN 9783866491779.
44. Lazar, J.; Feng, J.H.; Hochheiser, H. *Research Methods in Human-Computer Interaction*; Elsevier: Amsterdam, The Netherlands, 2017.
45. Bender, J.L.; Yue, R.Y.K.; To, M.J.; Deacken, L.; Jadad, A.R. A Lot of Action, But Not in the Right Direction: Systematic Review and Content Analysis of Smartphone Applications for the Prevention, Detection, and Management of Cancer. *J. Med. Internet Res.* **2013**, *15*, e287. [CrossRef] [PubMed]
46. Norman, D.A. *The Design of Everyday Things: Das Design Alltäglicher Dinge*; The MIT Press: Cambridge, MA, USA; London, UK, 2013; ISBN 978-0-262-52567-1.
47. Gupta, K.; Roy, S.; Poonia, R.C.; Nayak, S.R.; Kumar, R.; Alzahrani, K.J.; Alnfiai, M.M.; Al-Wesabi, F.N. Evaluating the Usability of mHealth Applications on Type 2 Diabetes Mellitus Using Various MCDM Methods. *Healthcare* **2022**, *10*, 4. [CrossRef] [PubMed]
48. Constantine, L.L. Trusted Interaction: User Control and System Responsibilities in Interaction Design for Information Systems. In *Advanced Information Systems Engineering*; Dubois, E., Pohl, K., Eds.; Springer: Berlin/Heidelberg, Germany, 2006; pp. 20–30, ISBN 978-3-540-34653-1.
49. Redish, J.G. *Letting Go of the Words: Writing Web Content that Works*, 2nd ed.; Morgan Kaufmann Publishers Inc.: San Francisco, CA, USA, 2012; ISBN 9780123859303.
50. Mace, R. Universal design: Barrier-free environments for everyone. *Des. West* **1985**, *33*, 147–152.

51. Nielsen, J. The Usability Engineering Lifecycle. In *Usability Engineering*; Elsevier: Amsterdam, The Netherlands, 1993; pp. 71–114, ISBN 9780125184069.
52. Dix, A.; Finlay, J.; Abowd, G.; Beale, R. Human-Computer Interaction. 2004. Available online: https://paragnachaliya.in/wp-content/uploads/2017/08/HCI_Alan_Dix.pdf (accessed on 18 January 2024).
53. Acquisti, A.; Adjerid, I.; Brandimarte, L. Gone in 15 Seconds: The Limits of Privacy Transparency and Control. *IEEE Secur. Privacy* **2013**, *11*, 72–74. [CrossRef]
54. Altman, M. Design Thinking in Health Care. *Prev. Chronic Dis.* **2018**, *15*, E117. [CrossRef]
55. Jarg, B.; Stefan, T. Partizipative Forschungsmethoden: Ein methodischer Ansatz in Bewegung. *Forum Qual. Sozialforschung/Forum Qual. Soc. Res.* **2012**, *13*, 33.
56. Cornwall, A.; Jewkes, R. What is participatory research? *Soc. Sci. Med.* **1995**, *41*, 1667–1676. [CrossRef] [PubMed]
57. Gerstbach, I.; Gerstbach, P. *Design Thinking in IT-Projekten: Agile Problemlösungskompetenz in Einer Digitalen Welt*; Hanser: München, Germany, 2020; ISBN 9783446459595.
58. Winsler, A.; Fernyhough, C.; Mcclaren, E.; Way, E. *Private Speech Coding Manual*; Unpublished Manuscript; George Mason University: Fairfax, VA, USA, 2005.
59. Cohen, J. A Coefficient of Agreement for Nominal Scales. *Educ. Psychol. Meas.* **1960**, *20*, 37–46. [CrossRef]
60. Eskandaripour, H.; Boldsaikhan, E. Last-Mile Drone Delivery: Past, Present, and Future. *Drones* **2023**, *7*, 77. [CrossRef]
61. Bundesministerium für Gesundheit. Digitale Gesundheit 2025. Available online: https://www.bundesgesundheitsministerium.de/fileadmin/Dateien/5_Publikationen/Gesundheit/Broschueren/BMG_Digitale_Gesundheit_2025_Broschuere_barr.pdf (accessed on 18 January 2024).
62. Stachwitz, P.; Debatin, J.F. Digitalisierung im Gesundheitswesen: Heute und in Zukunft. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* **2023**, *66*, 105–113. [CrossRef] [PubMed]
63. Rogers, E.M. *Diffusion of Innovations*, 3rd ed.; Free Press: New York, NY, USA, 1983; ISBN 0029266505.
64. Robertson, T.; Simonsen, J. Challenges and Opportunities in Contemporary Participatory Design. *Des. Issues* **2012**, *28*, 3–9. [CrossRef]
65. Bødker, K.; Kensing, F.; Simonsen, J. Participatory Design in Information Systems Development. In *Reframing Humans in Information Systems Development*; Isomäki, H., Pekkola, S., Eds.; Springer: London, UK, 2011; pp. 115–134, ISBN 978-1-84996-347-3.
66. Schuler, D.; Namioka, A. *Participatory Design: Principles and Practices*; CRC: Boca Raton, FL, USA; London, UK, 2009; ISBN 9780203744338.
67. Scalea, J.R.; Pucciarella, T.; Talaie, T.; Restaino, S.; Drachenberg, C.B.; Alexander, C.; Qaoud, T.A.; Barth, R.N.; Wereley, N.M.; Scassero, M. Successful Implementation of Unmanned Aircraft Use for Delivery of a Human Organ for Transplantation. *Ann. Surg.* **2021**, *274*, e282–e288. [CrossRef]
68. Norman Donald, A. *The-Design-of-Everyday-Things-Don-Norman*; MIT Press: Cambridge, MA, USA, 2013.
69. Arnstein, S.R. A Ladder Of Citizen Participation. *J. Am. Inst. Plan.* **1969**, *35*, 216–224. [CrossRef]
70. Cornwall, A. Unpacking 'Participation': Models, meanings and practices. *Community Dev. J.* **2008**, *43*, 269–283. [CrossRef]
71. Cargo, M.; Mercer, S.L. The value and challenges of participatory research: Strengthening its practice. *Annu. Rev. Public Health* **2008**, *29*, 325–350. [CrossRef] [PubMed]