Enhancing Fracture Aftercare Through a Human-Centered Mobile App Design

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Abstract: The rehabilitation process after fractures is crucial for achieving full recovery and maintaining patients' quality of life, yet it faces growing obstacles due to demographic changes and healthcare resource shortages. This paper proposes a mobile app prototype for physiotherapy aftercare, integrating features like exercise assistance, load monitoring, and collaborative documentation to enhance patient support and accessibility. Employing a Human-Centered Design approach, requirements were gathered initially through a comprehensive literature review, followed by the creation of user personas. Final requirements were then refined through semi-structured interviews with physiotherapists and clinical staff. The prototype was subsequently evaluated in a user study with 16 participants using the Think-Aloud method and the User Experience Questionnaire (UEQ). Results indicated high user satisfaction with features such as education, exercise guidance, and progress tracking, though minor usability improvements were identified. By providing real-time feedback, clear progress tracking, and personalized guidance, the app aims to improve patient compliance with rehabilitation protocols, ensuring more consistent engagement throughout the recovery process. Future iterations will focus on expanding functionality and validating the solution across diverse demographics, emphasizing its potential to significantly improve rehabilitation outcomes.

1 INTRODUCTION

Effective fracture aftercare is essential for restoring full mobility. This can prevent long-term complications and significantly improve the patients' quality of life. However, the ongoing demographic shift, including an aging population and fewer health insurance contributors, is making access to necessary physiotherapy increasingly challenging. Additionally, there is a growing shortage of skilled professionals in the healthcare sector, further aggravating these issues. By 2035, an estimated 1.8 million jobs in the german healthcare sector may remain unfilled due to staffing shortages (Kreuzenbeck et al., 2023).

Moreover, access to necessary aftercare is particularly challenging for patients in rural areas or those with limited mobility. In these regions, healthcare facilities and physiotherapy practices may be far from patients' homes, making it difficult to maintain regular in-person appointments (Barton et al., 2021). For patients with mobility issues, traveling to therapy sessions can be a significant barrier to consistent rehabilitation.

One potential solution to address the shortage of healthcare professionals and the accessibility of physiotherapy is the integration of digital medical products, such as mobile apps and telehealth platforms, into aftercare practices (Grodon et al., 2024). In addition to features designed for healthcare professionals, such as documentation and remote monitoring, apps can also offer patient-centered functions (Schaaff and Kittel, 2023). These features may include personalized rehabilitation exercises, real-time guidance, and interactive support to enhance the recovery experience. By reducing the need for in-person appointments, digital solutions can help alleviate the strain on healthcare providers while maintaining or even improving the quality and accessibility of fracture aftercare for patients.

Digital aftercare solutions also provide patients with enhanced transparency about their own recovery progress. Features such as progress tracking, personalized dashboards, and data summaries allow patients to actively monitor their improvements over time. This level of insight not only increases patient engagement and motivation but also builds confidence by allowing them to see the results of their rehabilitation efforts (Lang et al., 2022).

Furthermore, a digital system allows for faster response to complications during the treatment process

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(Ebrahimian et al., 2022). With real-time monitoring and continuous data collection, healthcare providers can quickly identify any deviations from the expected recovery trajectory. As patient data - such as pain levels, mobility progress, or exercise compliance - are updated regularly, clinicians can intervene at an earlier stage if issues arise, reducing the risk of complications. This immediate access to up-to-date information ensures that treatment adjustments can be made swiftly, and patients can receive timely support.

For a complete and swift recovery following a fracture, the exercises patients perform at home are just as crucial as the in-person physical therapy sessions. While therapy sessions provide essential guidance and supervised practice, consistent at-home exercises have the most significant impact on recovery outcomes. However, many patients feel uncertain about whether they remember the exercises correctly or are performing them with proper technique once they return home from a therapy session. This lack of confidence and fear of re-injury can hinder adherence to prescribed exercises and, consequently, slow down the rehabilitation process.

Overall, an effective app for fracture aftercare must be designed to be intuitively usable regardless of the patients technological knowledge. This ensures accessibility for both younger users and older patients who may have less experience with digital tools. Given the extended duration of the recovery process, it is equally important to ensure patient motivation to engage with the app consistently throughout the entire aftercare period. Unlike recreational apps such as games, medical apps are typically used out of necessity rather than for enjoyment, resulting in a lower tolerance for frustration. If features do not work as expected, users may quickly abandon the app, undermining its intended benefits. Therefore, it is crucial to focus on delivering an app that not only meets but also simplifies patients' needs, offering all essential functions required for a seamless and effective rehabilitation journey.

2 RELATED WORK

The fundamental need for and benefits of therapy support apps were identified by Benignus et al. (Benignus et al., 2022), with potential features already explored and evaluated in various publications. The findings by Kim et al. (Kim et al., 2022) on the development of a health app with exercise support indicate that self-guided exercise and maintaining motivation pose significant challenges for users. Other apps, such as those developed by Krainer et al. (Krainer et al., 2022) for stroke rehabilitation and by Kim et al. (Kim et al., 2022) for supporting self-guided exercises, include features that could also be relevant for a post-trauma surgical therapy app. Features such as exercise support, appointment scheduling, and patient education were well-received and positively evaluated by participants in these studies. For some of these features, studies have already shown their impact on therapeutic outcomes, such as Wittink et al.'s (Wittink and Oosterhaven, 2018) study on patient education.

Studies, such as the one conducted by Kalmet et al. (Kalmet et al., 2018), investigate the role of tracking and adjusting weight-bearing during rehabilitation. Their findings suggest that carefully monitored weight-bearing protocols can lead to improved recovery outcomes by allowing patients to gradually apply weight, thus enhancing daily activities and quality of life without increasing pain or complications. This underscores the potential of integrating weight-bearing tracking as a feature in therapy support tools.

Health apps, in particular, bear the risk of being overly complex, incorporating features that patients may find confusing or structured to align with medical professionals' needs but unintuitive for users. (An et al., 2023) A key challenge in developing health applications is tailoring them to the individual needs of the users. Therefore, it is important to include patients as the future users of such systems in the design process. The potential of applying the Human-Centered Design (HCD) approach to health apps has already been explored by Altman et al. (Altman et al., 2018), who demonstrated how this methodology can drive innovation, improve user experience, and create

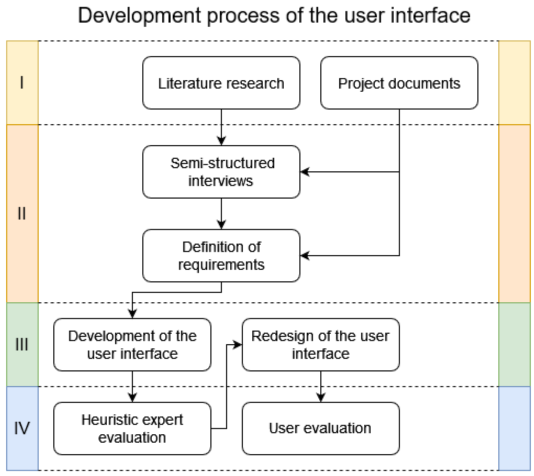

Figure 1: The figure shows the four phases of the Human-Centered Design process. Phases three and four are repeated twice: the prototype is first improved based on expert feedback, and the second version is then evaluated in a user study.

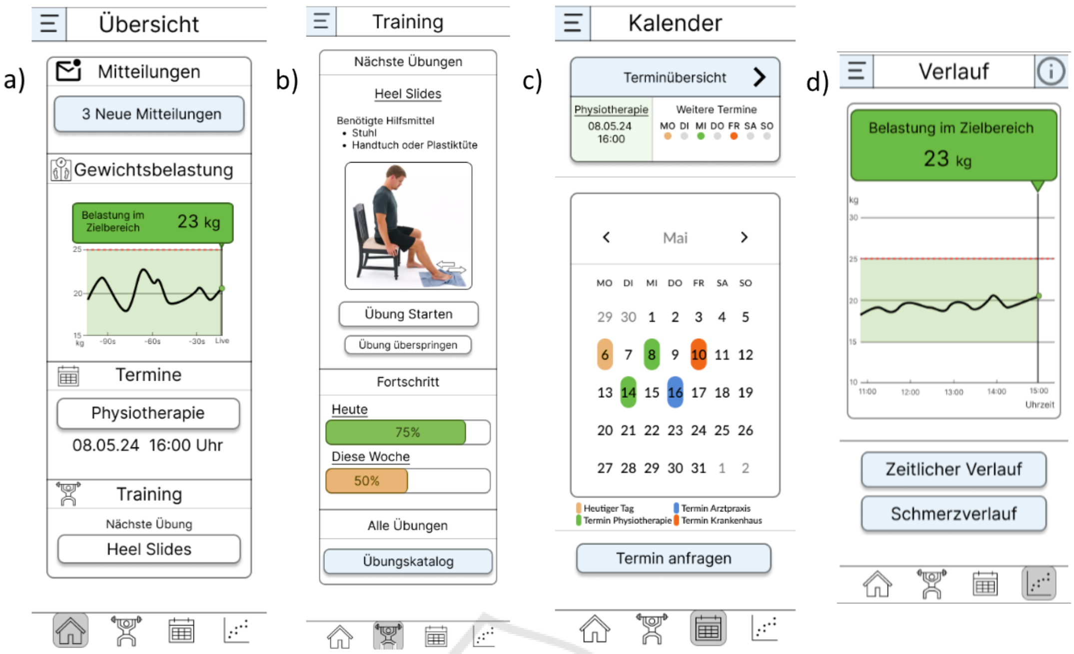

Figure 2: The figure shows the four main views in the prototype: a) The main screen when starting the app shows new notifications as well as a history of the physical load at the fracture, the next physiotherapy assessment and the next training exercise. b) The training overview shows a more detailed explanation of the next exercise along with the material needed and a progress bar to track how many exercises should still be done. c) The calendar shows the next physiotherapy session or the next clinical monitoring. It also contains a function to request assessments with the clinic or physiotherapy. d) The history gives a more detailed look at the current and past physical load compared to the felt pain that can be recorded by the patient.

patient-focused solutions tailored to addressing complex healthcare challenges.

The proposed system aims to integrate features such as exercise assistance, load monitoring, collaborative documentation, progress tracking, and educational content into a single app that supports patients throughout the therapy process while remaining intuitive and user-friendly. It prioritizes ease of use to accommodate patients with varying levels of technological proficiency, reducing the risk of frustration or disengagement. By maintaining simplicity and focusing on essential functions, the system seeks to empower users without overwhelming them, ensuring they can navigate the app confidently and stay engaged throughout their rehabilitation journey. While several rehabilitation mobile apps have been developed, many of which incorporate user-centered approaches, a comprehensive system integrating all necessary features for effective postoperative care following a fracture is still not widely available. This work aims to explore and address this potential gap. A Human-Centered Design approach helps to ensure that the app effectively addresses the real needs of its users.

3 CONTRIBUTION

In a previous work, we proposed a comprehensive mobile application to connect healthcare professionals and patients. (Maszuhn et al., 2024) This system included three main features:

1. A recording and assessment system for performing at-home physiotherapy exercises
2. A load measurement system that can monitor the weight-bearing and warn patients if they exceed their current limit. For example, this could be achieved by integrating sensory insole data into our app.
3. A shared documentation tool where all stakeholders involved in the aftercare process can collaborate to access and update treatment-related data

In this work we want to focus more on the patient side of our app. Our goal is to identify the key features for an aftercare app that would benefit the recovery process the most. Another incentive is to find additional useful features that we didn't think of yet. For this we conduct a usability study where we present a simple prototype of the patient app with basic navigation and functionality to the participants. It also contains placeholders for the aforementioned features, i.e., the training assistance system and the load measurement system to give participants a basic idea of how they work. The participants are then asked to share their thoughts while navigating through the app using the Think-Aloud method and complete the user experience questionnaire (UEQ).

In summary, this work aims to answer the following questions regarding the app:

1. How well do the provided functions align with the users' expectations? (In this work we do explicitly not cover the app's design)
2. In what ways do the functions and content available in the mock-up support therapy in physiotherapy care, and what additional features could be beneficial?
3. What are users' intentions and motivations regarding the use of the app for therapeutic purposes?

4 METHODS

In this work, we applied the Human-Centered Design (HCD) approach to guide the development process of our prototype, adhering to the 'Human-centred design for interactive systems' standard in ISO 9241-210. (International Organization for Standardization, 2019). HCD is a design methodology that focuses on understanding the needs, preferences, and limitations of end-users at every stage of the design process, ensuring that the final product is intuitive, effective, and tailored to the user's experience. This methodology is structured into four iterative phases as shown in Figure 1: understanding and specifying the context of use, specifying user requirements, creating a design solution, and evaluating the design.

The foundation for the prototype's core functions was established in an earlier study, in which initial features were explored and outlined. Additionally, an extensive review of current developments in exercise assistance and weight-bearing was conducted. In the second phase, we gathered requirements by creating personas representing typical patient groups using the app and use case scenarios. We also conducted semi-structured interviews with the project's physiotherapists and clinical staff to further refine these requirements.

The requirements were then implemented in a mock-up using the design software "Figma". During development, the design was guided by Nielsen's heuristics, Apple's 'Human Interface Guidelines,' and comparable existing applications. The prototype was developed across two iterations. In the first evaluation, an expert review was conducted using selected Nielsen heuristics. The feedback from the expert evaluation informed revisions for the second iteration, leading to an updated design. The second version of the mock-up underwent a final evaluation with potential users, which is described in more detail in section 5. This assessment employed the Think-Aloud method alongside the User Experience Questionnaire (UEQ) to collect both qualitative and quantitative insights.

5 USER STUDY PROCEDURE

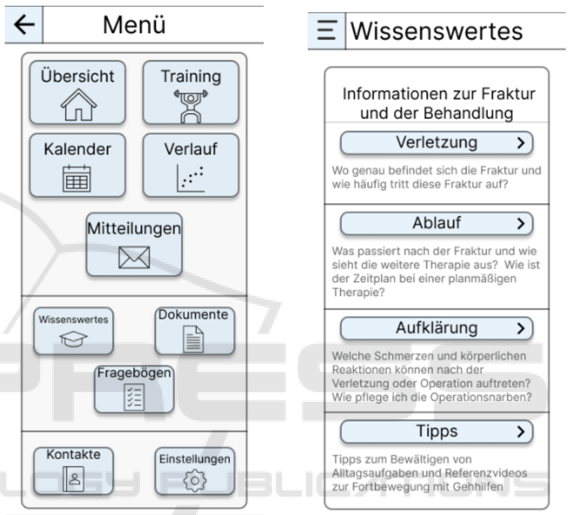

Figure 3: Left side: From the menu, patients can access features such as educational content, shared documents, and questionnaires. Right side: The education view, which received the most positive feedback, provides information about fractures and tips for aftercare.

We recruited a total of 16 participants for our study - 8 males and 8 females, with an average age of 27 years ($\sigma \pm 8$). We recognize that the average age of patients tends to be higher. However, patient demographics are generally divided into two groups: fractures in older individuals, often caused by falls, and fractures in younger individuals, typically resulting from sports injuries. Our study thus focuses on sports-related injuries, anticipating that younger users are generally more comfortable using apps. The participants had to be at least 18 years of age, be fluent in German and experienced either a fracture or ligament tear followed by physiotherapy within the past ten years. To minimize potential bias, standardized information about the study and project was provided to the participants, with an option to answer specific questions verbally.

Each session was conducted individually in a controlled laboratory setting over a two-week period. The study moderator as well as a note-taker were present to observe and record findings. Participants were provided with a modern smartphone pre-installed with the prototype. The smartphone screen was mirrored to the moderator at all times and the screen was additionally recorded to allow an analysis afterwards.

Using the simultaneous Think-aloud method, participants were encouraged to share both positive and negative feedback about the mock-up at any point. This method also helped us to understand the interaction with the prototype better and to prevent interpretation errors. At the beginning of each session, participants had five minutes to freely explore the prototype and familiarize themselves with its interface and features. Following this, the participants were asked to navigate through the prototype to simulate the completion of ten typical tasks within our app. The specific tasks, listed in 6.2, were designed to cover all major areas of the prototype, ensuring comprehensive feedback on each feature and section of the interface. During the tasks we did not interact with the participants other than telling them when they finished a task.

After completing the tasks, participants provided overall feedback on the prototype, reflecting on which app views and features they found most beneficial for their therapy experience. They also suggested additional functionalities that could enhance rehabilitation. To conclude the session, participants filled out the User Experience Questionnaire (UEQ). The UEQ comprises 26 bipolar items, grouped into six factors: Attractiveness, Clarity, Efficiency, Controllability, Stimulation, and Novelty (Laugwitz et al., 2008). Attractiveness comprises six items, while the remaining factors each include four items, collectively assessing various aspects of user experience.

6 RESULTS

6.1 Think-Aloud Method

The Think-aloud method was evaluated using ”summarizing qualitative content analysis” (Mayring and Fenzl, 2019), which is a systematic approach used to condense and analyze textual data by focusing on the core content while reducing redundant information. The categories were defined deductively from the research questions and the participants’ statements were assigned to the relevant research questions where possible. The categories included statements related to:

- specific views of the prototype
- missing functions
- the overall structure of the prototype
- the participants’ intention to use the app in case of future therapy

In the overall evaluation, statements were grouped that rated one or more functions, or the entire project, as positive, effective, or useful. This was the case for all 16 participants; however, some limitations regarding the intent to use were also noted. None of the participants made negative comments about the fundamental system or its functions; only limitations regarding intended use were noted. Not all participants commented on each individual function or view in the prototype when evaluating specific features, but each participant could comment on multiple features.

6.1.1 Evaluation of Specific Views

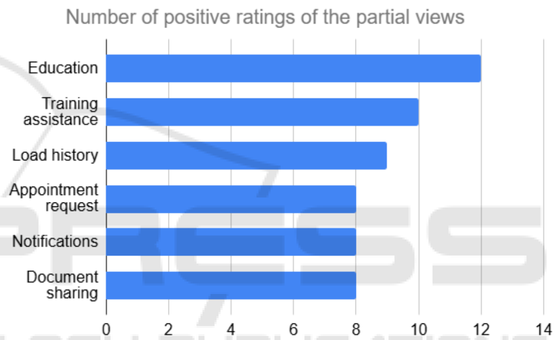

Figure 4: The graphic shows the six most positively rated views in the app. All comments gathered with the Think-aloud method regarding a view being ”good” or ”useful” were grouped here.

Positive statements that were mentioned multiple times and could be attributed to specific functions are shown in Figure 4. Only statements that explicitly describe one of the functions are included and only functions evaluated by more than seven participants are presented in the figure. The information section (Figure 3) received the most positive feedback (N=12). According to the participants, the key reason for the positive evaluation was the availability of reliable and verified information within the app, reducing the need for time-consuming and potentially error-prone online research. The second most frequently mentioned positive feedback was that the exercise assistance feature (Figure 2b) was highly practical (N=10). Additionally, participants noted that the exercise catalog provided a good overview of additional exercises and the included progress bar was seen as useful. However, they felt that more information than necessary was displayed alongside the progress bar.

A total of N=9 participants specifically commented on the physical load history feature (Figure 2d). They noted that the timeline was considered easy to follow, and the pain tracking feature was appreciated for promoting transparency among stakeholders. This was followed by the function to request appointments (N=8) (Figure 2c), notifications regarding the recovery status (N=8) and the document-sharing (N=8). Especially for the latter, the traditional method of transferring documents via paper or CDs was perceived as cumbersome, making this in-app feature a positive advancement. Other sub-functions, such as the schedule (N=5) and scar care (N=3), were also positively mentioned multiple times.

6.1.2 Missing Functions

Following the Think-aloud method, participants were asked if there were any features they felt were missing thus should be added. The most frequently requested function was the ability to export the calendar to a smartphone's system calendar (N=5). Four participants expressed the desire to add notes on pain assessments and pain progression to potentially link changes in their pain perception to specific events. Additional features and requests were mentioned by individual participants, but these were not included in the further analysis due to their singularity.

6.1.3 Structure of the App

To assess the app's structure, statements were grouped into categories related to sorting and usability. Ten participants responded positively to the app's overall structure, describing it as intuitive and aligned with their expectations, whereas six made no remarks on the structure. Few comments were repeated across participants; individual opinions mostly concerned internal links between views or specific design suggestions. Four participants commented on the overview (Figure 2a), critiquing it as cluttered and overly complex. For the home screen structure, participants noted that appointments should take prominence, followed by notifications and progress tracking. Two participants suggested that new notifications should be more clearly highlighted within their respective views. Regarding the load history view (Figure 2d), four participants mentioned that a zoom function, perhaps via a pinch gesture, would be useful.

6.1.4 Intention of Use

Participant statements regarding their intention to use the app were also considered. comments on the app's usefulness for managing their own or similar injuries were interpreted as an intention to use. Ten participants made statements reflecting an intent to use a fully developed app with the demonstrated features. Additionally, six participants commented on the prioritization of certain features, with some mentioning multiple functions. Four identified training support as the most important feature, three prioritized document sharing and informational content, and two valued the contacts feature.

6.2 Task Evaluation

All sixteen participants completed all ten tasks. Below are the tasks along with the number of participants who encountered difficulties with each. This includes all instances where participants mistakenly navigated to another view in the app first The tasks were designed to cover each area of the mock-up and required extensive navigation.

1. Request an appointment for a check-up at the joint practice! (N=6)
2. Look for information on possible swelling after the operation! (N=6)
3. Turn off the notifications! (N=2)
4. Find and start the questionnaire on your general condition! (N=1)
5. Check with whom the medical history form from the clinic was shared! (N=1)
6. Find out the business email address of your doctor! (N=0)
7. Find out what the physiotherapy schedule is for the 3rd-6th week after the operation! (N=13)
8. Find the overview of the exercises that are already stored in the prototype! (N=3)
9. Find the information on the care of the surgical scar! (N=2)
10. What was the approximate weight bearing 60 days after the operation? (N=1)

Most tasks were completed by participants within seconds. We attribute the higher error rate on the first two tasks to participants still familiarizing themselves with sections of the prototype that they hadn't yet explored during the initial orientation phase of the study.

The highest number of issues occurred with Task 7, with thirteen participants experiencing difficulties. Participants reported that the high error rate for Task 7 was mainly due to the wording of the task and the terminology used within the prototype. In the Education section, there is a subsection labeled "After the Surgery", which participants mistakenly referenced to complete the task.

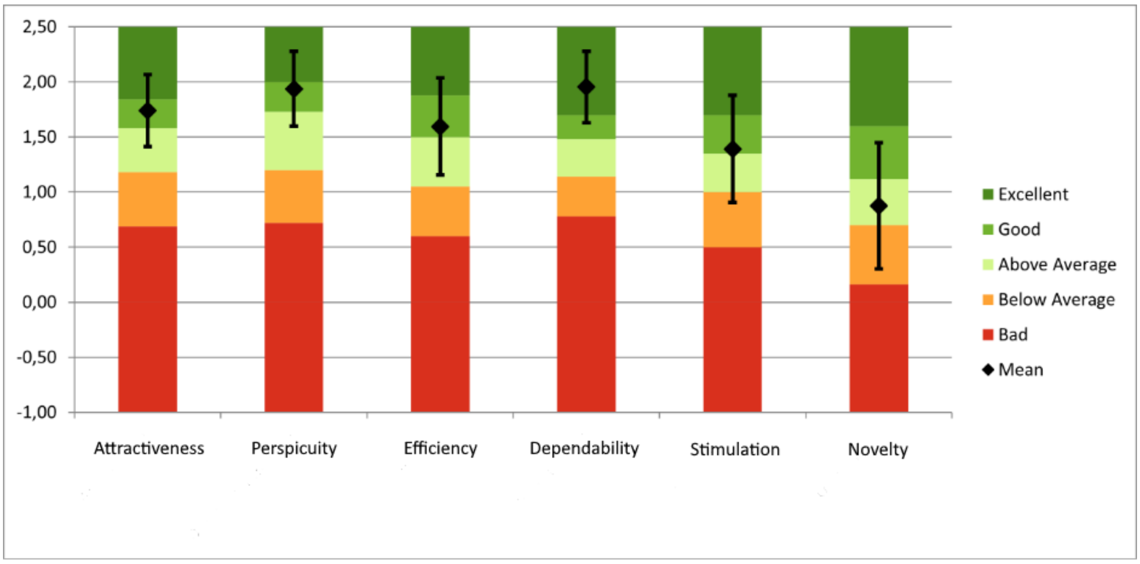

Figure 5: The results were compared to a dataset released by the UEQ authors with 468 other prototypes that were evaluated with the UEQ. An "excellent" score implies a score in the top 10% of evaluated studies. a "good" rating is within the top 25%, an "above average" rating within the top 50%.

Table 1: The 26 bipolar items of the UEQ were assigned to six factors on a scale from -3 to 3.

Factor	Mean (M)	Standard Deviation	Confidence intervals (p=0.05) per factor
Attractiveness	1.740	0.667	1.413 to 2.066
Perspicuity	1.938	0.692	1.598 to 2.277
Efficiency	1.594	0.898	1.153 to 2.034
Dependability	1.953	0.660	1.630 to 2.276
Stimulation	1.391	0.992	0.905 to 1.876
Novelty	0.875	1.165	0.304 to 1.446

6.3 User Experience Questionnaire

For the analysis of the User Experience Questionnaire (UEQ), the items' seven-point scale was converted to values ranging from -3 (extremely poor) to +3 (extremely good). Mean values were calculated, and the standard deviation was determined. Mean values from -0.8 to 0.8 indicate a neutral assessment of an item or factor, values below -0.8 are considered negative, and values above 0.8 as positive. The results of the UEQ are presented in Figure 6 and Table 1.

The prototype achieved an overall positive rating. The UEQ authors also provide a general benchmark for the questionnaire that allows to compare the results with 468 other software prototypes (Schrepp et al., 2017). Compared to this benchmark, the dependability factor was rated as excellent, placing it within the top 10% of comparative studies. Attractiveness, perspicuity, efficiency, and stimulation were rated as good (with 10% of comparative studies scoring better and 75% scoring worse). Only the novelty factor fell slightly short and was assessed as above average (25% of comparative studies scoring better and 50% scoring worse) (Figure 5). However, this is to be expected for a prototype in the medical context as the benchmark contains all types of software.

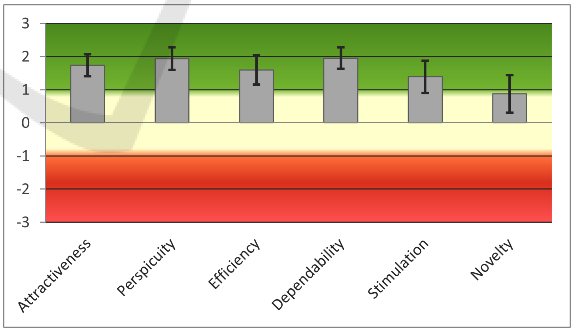

Figure 6: The six UEQ factors in comparison. The dependability received the highest rating while the novelty was rated slightly worse than the other factors.

7 CONCLUSION

In conclusion we presented the development of a prototype for the patient interface of a comprehensive mobile app designed for fracture aftercare. For this, we used a Human-Centered Design approach. The requirements for the app were gathered by developing personas and typical use case scenarios and conducting interviews with the stakeholders, i.e. physiotherapists, doctors and patients. The prototype was than evaluated by 16 study participants who had fractures or similar injuries requiring physiotherapy in the past.

The study highlights the significant potential of digital aftercare solutions to address challenges in physiotherapy care. The proposed mobile app prototype demonstrated promising features, including training assistance, load monitoring, and a shared documentation tool, which were positively received by the participants. These functions align with identified needs for enhancing therapy support and increasing accessibility, especially for patients with mobility issues or those in rural areas.

Feedback from participants emphasized the prototype's intuitive design and practical application. High levels of user satisfaction were reported in key areas such as attractiveness, clarity, and dependability. While some limitations were noted, particularly regarding specific functionalities and task terminology, these findings provide valuable insights for refining the app's features. Additionally, the ability to monitor recovery progress and offer real-time guidance fosters transparency, engagement, and confidence among patients, while also enabling timely clinical intervention when necessary.

The study underscores the importance of involving stakeholders, especially patients, in the development process to ensure that digital solutions meet real-world needs. By integrating Human-Centered Design principles and addressing identified gaps, the app has the potential to significantly improve aftercare experiences and outcomes. Future work will focus on implementing additional requested features and further validating the app with a broader patient demographic to optimize its usability and therapeutic impact.

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