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Augmented Smart Insoles – Prototyping a Mobile Application: Usage Preferences of Healthcare Professionals and People with Foot Deformities

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Abstract: The augmentation of smart insoles gained increased interest due to the possibilities in foot-related rehabilitation, medical treatment, and postural risk prevention. As shown by previous work, the technology offers a personalized solution for individual foot morphology and biomechanics, which can monitor the health status and healing process. However, the success of this mobile technology depends on its usability and acceptance by healthcare professionals and patients. Therefore, an exploratory qualitative user study was conducted to investigate the preferences of healthcare professionals and patients regarding augmented smart insoles (ASI) usage. In focus groups, experts and patients explored their needs and suggested potential design solutions. The thematic analysis of the participants' feedback revealed useful information regarding user interface (UI) designs for the development of a mobile application supporting smart insoles. We found that patients and experts share similar data preferences for a mobile application supporting ASI and that both user groups desired the presence of complete pressure point monitoring, active feedback for posture correction, and personalized training videos for postural risk prevention. However, healthcare professionals expressed concerns regarding the lack of scientific evidence validating the effectiveness of this technology and suggested further research.

Keywords: augmented smart insoles, gait monitoring, foot health, rehabilitation

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1 Introduction

People with diagnosed foot malposition or incorrect gait pattern are often recommended or even required to wear insoles to prevent postural risk. Through gait analyses under laboratory conditions, detailed statements can be made about the biomechanical movement sequence during a gait cycle. However, the data collection procedure can be complex and enables only a sequential recording of gait patterns.

The development of a smart insole with integrated sensor technology allows recording and analyzing the movement in everyday life [1]. Experimental tests have shown the suitability of a prototype insole with integrated sensor technology for real-time analysis of static and dynamic measurements [2, 3]. And the use of this technology offers the possibility of continuously recording the wearer's movement data and providing the user as well as health professionals with data in real-time via a mobile application. Continuous data acquisition in real-time via a mobile application offers a benefit for many application purposes. Wearable technology and physiological sensors are already being combined in the field of sports applications, health monitoring for rehabilitation, and medical treatment [4–6]. For example, Zaufenberger et al. utilized the design thinking method to develop a mobile app for the identification of pressure ulcers for the clinical picture of diabetic foot syndrome [7]. As a result, a prototype UI was designed and presented, which enables continuous monitoring of plantar pressure distribution.

However, the success of the healthcare intervention and using a mobile application tracking one's own physiological state depends on the usability, acceptance, and effectiveness of healthcare professionals as well as patients. This leads to the research question asking for the requirements, needs, and preferences of patients and experts regarding a mobile application for people with foot deformities and wearing smart insoles. Therefore, we conducted an exploratory, qualitative user study with healthcare professionals and potential users of smart insoles.

2 Methods

The aim of this study was to investigate the perception of healthcare professionals and patients regarding the use of ASI. Using a human-centered design approach, we conducted a qualitative study with experts (N=2) and patients (N=10) to explore the preferences of both groups regarding the type of data and the UI design in a mobile application.

Ten patients (4 female, 6 male) and two experts (2 female) were recruited as participants of the study. The mean age was 26.75 years (*SD* = 6.15) and ranged from 21 to 42 years. The inclusion criterion for patient selection was any chronic foot complaints requiring the wearing of shoe insoles. Five participants suffer from flat feet (pes planus), two from knee osteoarthritis, two from ankle pain and one person from heel pain.

The focus groups were conducted in-person as workshops, utilizing four creativity techniques (questionnaires, mind mapping, proto-personas, and wireframing) as part of the methodology. After informed consent was obtained, participants were introduced to the topic of smart insoles with an introductory video. To illustrate the concept of smart insoles, a physical demonstration model called "ARIONCOACH" was used, which consists of a running shoe insole designed for athletes and an accompanying smartphone app [8].

After recording the demographic data, the initial survey method included a two-part questionnaire, consisting of open-ended and closed-ended questions. The first part of the questionnaire involved a critical analysis of previous health apps, in which participants were asked to assess their strengths, weaknesses, and potential for improvement through open-ended questions. The second part of the questionnaire consisted of closed-ended questions (multiple choice), which were intended to gather insights into user acceptance and the importance of design and functional preferences.

The next step was to collect requirements regarding the concept of a mobile health app. For this purpose, a mind map was clustered into three categories (design wishes, function wishes, goals of the app) in order to document the ideas of the participants in it.

In order to identify key characteristics, preferences and needs of the largest possible intersection of "foot patients", a target group analysis with proto-personas was used as third method. This approach is intended to derive possible insights into the structure of the app, regardless of the user's age and media usage knowledge. For this purpose, four fictitious people were created as user profiles to represent a cross-section of the target group of people with foot disorders. The user profiles describe the type of foot disease, as well as sociodemographic, media-oriented, and psychological characteristics. User-specific requirement criteria were recorded in form of brainwriting. Finally, interactive wireframes were created to visually integrate all desired features.

For evaluation, an inductive thematic analysis was conducted based on the feedback from four focus groups [9]. The transcribed data were coded sentence by sentence to elaborate and analyze the categories of the data set. The analysis of the data set was performed in a team of three persons.

3 Results

In this section, the results of the study were presented, which aimed to identify new insights into needs and user preferences for a mobile app in relation to ASI. To achieve this, questionnaires, mind mapping, and proto-personas were applied to identify key features and design elements. As a result, it was shown that patients and experts share similar data preferences for an application to support ASI. Based on these findings, six wireframes were interactively designed by experts and patients with all basic functions.

3.1 Questionnaires

The patient surveys have shown that the current biggest weaknesses in existing applications are "not for medical purposes" (P6), "too expensive" (P4), "not intuitive" (P7), and "too few relevant functions"(P9). However, patients consider the use of ASI as a "suitable and useful tool" (P3) to monitor their health status. The most important preferences mentioned by patients were the monitoring of pressure points in a clear false color display (N=8), personalized exercise plans with instructions and videos for prevention or rehabilitation (N=10), active feedback on gait pattern with indications of malposition's/incorrect use (N=7) and tracking of steps and movement activities as a diary with trends over time (N=6).

According to the experts, the current problem is that the success of therapy often depends on observations and subjective patient perceptions. In short time intervals, it is difficult to detect progress because measurable data are rarely available and reliance is placed solely on patient testimonials. The experts, therefore, describe the continuous tracking of measured variables, such as the pressure distribution of the foot, as a "helpful point of reference" (P1) in order to be able to better assess the long-term developmental progress. For better comparability of data, a digital diary will help to document daily pain levels and track walking activities. The realization of an expert and user mode is "strongly recommended" (P2) in order to reduce the complexity of the recorded data during the illustration. The experts emphasized that they would currently describe user acceptance among older people as "low" (P2) and "hardly existent"(P1), which is why "simple and intuitive APP" (P1), as well as "content customizable for the user group" (P2) are essential to increase user acceptance. However, healthcare professionals expressed concerns regarding the lack of scientific evidence validating the effectiveness of this technology and suggested further research. The user behavior of smart insoles with mobile application should be tested over a long-term period of time.

3.2 Mind-Mapping

The evaluation of mind mapping shows, the recommendation of specific footwear or a contact function to local experts were named as desirable functions. During the discourse among the participants, the idea emerged that it would be useful to establish several modes to change the load depending on physical exertion (e.g., sports activities) or wearing a backpack. The following aspects were mentioned as possible key target aspects for prevention and rehabilitation: “more awareness of health status”, “pain monitoring”, “healing process monitoring” and “posture correction”.

Regarding design aspects, all participants preferred a minimalist and simple design with only a few information on the main screen. In addition, there was a desire to be able to customize the dashboard itself to display user-specific content.

3.3 Proto-Personas

The evaluation of the proto-personas shows that a lack of understanding of the impact of foot problems on the entire musculoskeletal system often makes successful treatment difficult. For this reason, an overview of relevant foot complaints with additional information and visual sample images should be provided in the app to give patients quick access to further information.

The experts also recommend including video sequences in the APP to facilitate repetition and recall of exercises, which can "prevent incorrect performance" (P2). To increase user acceptance, data should also be available offline.

3.4 Wireframing

The wireframes created by patients and experts can be summarized by six base screens (see Figure 1).

The "pressure monitoring" screen includes the visualization of the recorded pressure distribution for each foot. Specific load values for the three-foot zones (forefoot, midfoot and heel) can be displayed here. This screen will show warning messages with additional information on the current health status.

The screen "technical data" includes a detailed view of the user’s desired gait parameters (e.g. stability in X and Y direction, stride/step length and gait speed). On this screen, users have the ability to personalize their selection of tiles.

An overview of daily walking performance is implemented on the "walking diary" display. Patients can document their pain behavior here on a daily basis. In addition, users can also display statistics for various time periods.

The "training mode" contains a personalized training program adapted to the specific pain problem. Visualized step-by-step instructions can be displayed and training reminders activated.

In the "knowledge database" section, users can also access information offline for acute question about health problems. All basic settings can be made in the "personalized data" area. There is also a contact function to local experts and an overview of shoe recommendations.

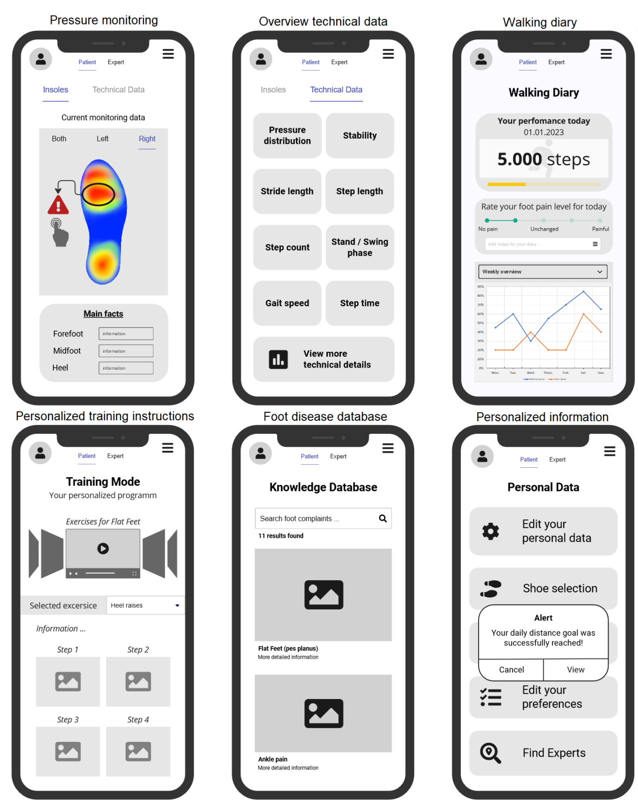

Fig. 1: Overview of six prototyped app wireframes (pressure monitoring, overview technical data, walking diary, training instructions, foot disease database, personalized information) with the desired functions of patients and experts

4 Conclusion

The qualitative study conducted in focus groups showed that experts and patients with foot diseases have fundamentally similar expectations and requirements regarding the usage preferences of a mobile application.

However, there was varying feedback regarding the visual presentation and level of detail of the displayed data. As a result, an application with expert and patient modes tailored to the respective user seems to be sensible. A limitation of our study is the small sample size and the participants did not cover all types of foot-related diseases or disorders. Due to the limitation of a small number of participants, a larger group of participants should be included in another follow-up study. Based on the determined preferences and elaborated wireframes, the next step is to develop a digital UI design prototype in order to test it in a follow-up study.

Overall, the study highlights the need for further research to validate the effectiveness of ASI, and for enhanced collaboration between healthcare professionals and patients to ensure the development of a technology that meets the needs and expectations of both groups. In addition, further research should be conducted on the feasibility and a business model, because previous approaches have not yet been able to establish themselves on the market. A well-functioning business model is essential to simplify entry and positioning into the healthcare market. Furthermore, it seems reasonable to consider the group of athletes in addition to the target group "foot patients", because the implementation in hobby sports seems to be low-threshold. With regard to user acceptance, willingness to pay should also be investigated in order to better assess the application potential.

Author Statement

Informed consent: Informed consent has been obtained from all individuals included in this study.

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