Multimodal Interactive Assistance for the Digital Collection of Patient-Reported Outcome Measures

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Introduction

The advancing digitalization in healthcare aims to improve the quality and efficiency of medical care. A significant potential lies in the digital collection of patient-reported outcome measures (PROMs). PROMs are a fundamental component and the most important tool towards patient-centered and value-based healthcare, oriented toward maximizing patient benefits (Dean et al. 2021). On an individual level, their usefulness is discussed for doctor-patient communication, monitoring, or in the context of personalized medicine and shared decision-making.

They are particularly suitable for quality assurance and development. In Germany, PROMs have been firmly established in the area of rehabilitation for many years (Kawski/Koch 2002, Farin/Jäckel 2011). However in other countries, the use of PROMs in clinical practice is already more advanced (Steinbeck et al. 2021).

However, both the technical and organizational implementation and the routine collection of PROMs are fraught with numerous hurdles: inadequate integration into clinical workflows and lack of motivation and resistance on the part of clinical staff on the one hand, and insufficient education, motivation to participate, and health-related or cognitive burden on the part of the patients on the other hand. Practice shows that increased assistance by clinical staff would be necessary to maintain a high response rate and data quality (Köhn et al. 2022).

Within the scope of MIA-PROM (Multimodal Interactive Assistance for the Digital Collection of Patient-Reported Outcome Measures) project[1], we aim to investigate whether a multimodal assistance system, developed using AI methods, can reduce these implementation and application barriers on both the clinic and patient sides. In our envisioned baseline scenario, the collection situation is accompanied and supported by an assistance system, which is either physically present next to the collection device or virtually embodied on the same display, providing need-based and barrier-free support to the patient in completing the PROMs questionnaire (an overview on the supported modalities and the interaction concept is described in the following section). The system should focus not only on improving the collection itself, but also on fitting the technical interfaces and the organizational implementation, thus ensuring the potential dissemination of the product.

On the user side, MIA-PROM aims to make the PROMs collection more accessible through additional modalities. The assistance system informs about itself and the potentials of PROMs collection. Additionally, there is a special focus on the patient side to reduce cognitive load, for example, by

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adapting the speaking speed or offering breaks. All this is intended to improve the response rate and thus the quality of the collected data. On an organizational level, the focus is on easy implementation as well as everyday usability and operability by clinic staff. Moreover, the system should be as flexible as possible to integrate into existing work processes and organizational cultures. Here, the protection of patient data and the interoperability of the system architecture are of particular importance.

MIA-PROM System

The MIA-PROM assistance system comprises a mobile PROM app running on a tablet and a *physically* embodied agent – the system is designed to be spatially mobile. Together with the patient, the assistance system forms an interaction triad. Additionally, a pure *virtually* embodied avatar as a second variant is implemented, to investigate whether the *physically* embodied agent offers a measurable advantage over a *virtually* embodied avatar for the assistant. The agent acts as a visible and tangible embodiment of the AI-based spoken dialog system. Overall, the system allows interaction with the user by touch or natural voice for user input and vision (graphical user interface) or synthetic voice for system output. The patient can use either only one modality for input and output or change the modality in each interaction step. The general concept is to allow operating each system functionality by each provided modality.

To ensure interoperability, MIA-PROM utilizes the platform-independent FHIR data standard developed for data exchange in medicine, enabling easy integration into existing clinical systems (hospital information systems, archives).

Assistance Services: The system's assistance services focus on the multimodal design of the PROMs collection process and adaptation to users. The additional offering of voice-based operating options particularly represents a more accessible alternative for those with motor or visual impairments. The adaptation to the patient can further involve aspects of the speech signal (e.g., speaking speed, fundamental frequency), linguistic content (syntax and lexicon), meta-communication (e.g., confirmation strategy, help with dialogue), or the mood of the users.

In addition to the multimodal questionnaire filling options, the assistance system should also be able to provide information about itself and the purpose of the PROMs collection, as well as keep the patient engaged through motivating interjections in the interaction. In cases of detected cognitive overload, the system should offer breaks. To this end, a domain-specific Natural Language Understanding (NLU) will be retrained, along with the implementation of a dialog manager and as generic a response generation as possible.

Another possible assistance service in rehabilitative settings is the disorder-specific appropriate design of the PROMs collection. For example, patients with depression may have longer response latencies and may struggle more with reading concentration, while patients with personality disorders might react to the wording of questions with significant emotionality or rejection.

The effective added value of the assistance system, compared to conventional digital PROMs collection systems, lies in its multimodality and its adaptation to the user, focusing on accessibility and motivation. Language-based interaction offers have not been implemented in common PROMs collection systems so far.

Virtual and Physical Agent: A central scientific working goal is the comparison of the physically embodied and the virtually embodied agents regarding the success of the interaction in general and more specifically, the assistance. In the design of the *physically* embodied agent, we follow design paradigms from Human-Robot Interaction (HRI) such as triadic interaction and the matching hypothesis, and we have taken into account factors that would increase the acceptability and would lead to more trustworthiness and competence for an avatar. The *virtually* embodied agent is intended to resemble the physical one within the limits of media possibilities, thus being recognizable as the same character. Additionally, the agent should be capable of movement behaviors, facial expressions, gestures, and appropriate gazing behaviors (not constantly gazing at the user). While those preconditions were set from the beginning of the project, a lot of decisions on the agents had still to be taken.

Background

The digital collection of PROMs offers numerous advantages - including user-friendliness, data quality, and clinical usability – compared to analogously filled out questionnaires (Meirte et al. 2020). In the routine collection of PROMs in clinical settings, central hurdles that have emerged include lack of acceptance by clinical staff and IT infrastructure problems (Steinbeck et al. 2021a). From a quality assurance perspective, patient nonresponse to PROMs is another central hurdle, as certain patient groups are underrepresented in these surveys (Köhn et al. 2022). Risk-adjusted comparisons also show significant deviations in data quality between different clinics (Beierlein/Schulz 2020), indicating significant potential for process optimization. The innovation height in MIA-PROM addresses these findings by aiming for process optimization through an easy-to-implement, interoperable IT solution, focusing on multimodality, accessibility, motivation, and reduction of cognitive load for the user. A techno-sociologically informed perspective can guide the participatory development process, frame it theoretically, and reveal potentials for interaction design.

The fundamental idea of relief through an embodied agent is closely aligned with the description of a so-called triadic interaction, which has been shown to provide proven relief in Human-Robot Interaction (HRI) situations for users (Boumann et al. 2020; Krummheuer 2020). This concept, describing a situation where a two-sided interaction is expanded by a third actor, in this case the embodied agent, has been successfully implemented in works by Severinson-Eklundh et al. (2003) and theoretically described by Höflich (2003) and Krummheuer (2020). In the context of elderly care, the concept was applied in the ReThiCare project (Lefeuvre 2021). Additionally, experimental studies suggest that the social (Alač 2011) and material context of a situation (Young 2011), along with the specific appearance of a physical or virtually embodied agent, are crucial for a system's usefulness. In their exploratory study on PROMs collection using a humanoid robot, Boumann et al. (2020) demonstrated the basic suitability of robotic systems for such interactions, though improvements in dialogue capabilities were recommended.

For this reason, the focus of the technical implementation of the assistance system lies particularly in the adaptivity and dialogue capability of the AI-methods developed assistance system. Real-time end-to-end speech recognition algorithms are now state-of-the-art (Sainath et al. 2020), but without hardware and software adaptation to the conditions, they often do not function satisfactorily. The speech recognition and natural language understanding will be adapted and trained for the dialogue management of the PROM collection.

Conception and Development Process

The MIA-PROM system is user-centred and developed with a focus on usability. The project combines participatory design and co-creation approaches, which means that key and sensitive decisions in the development process of the assistance system are discussed and made in close consultation with a Patient Advisory Board (PAB) during workshops (Clemensen et al. 2007). The members of the PAB have been recruited with flyers at clinical partner sides, self-help groups, and ambulant services. However, most responses came from Charité studies participation email distribution list. The final PAB consists of two male and three female members, being between 42 and 76 years old with an average age of 61 years. They fulfill our inclusion criteria of people with patient and rehabilitation experience like psychosomatic rehabilitation (one board member), rehabilitation with somatic focus (three members), chronic patient with rare diseases (one) and dual role as health professionals (three). By the end of 2023, after about one year project time, we had three in present workshops and one online meeting. Two more workshops are planned for 2024.

By having the PAB, we aim to partially open up the process: The PAB, in collaboration with the development team, makes necessary decisions consensually. To do so comes with the advantage of negotiating with each other on a trustworthy basis and within a transparent process (von Unger 2012).

As the first step in this process, a needs assessment, incorporating personas and user stories, was collected by iteration with clinical experts and the PAB. Secondary, we iteratively discussed the choice of PROMs that shall be collected and administered by the assistance system – hereby we focussed on a set of questions that is relevant to a broad range of patients as well as considering a holistic perspective of different aspects of experiencing health. As a result, a generic questionnaire focusing on different dimensions of health-related quality of life and work-related aspects emerged, integrating resource-oriented and not just deficit-oriented subscales. Most of the scales stem from the PROMIS (patient-reported outcome measurement information system) initiative (Cella et al. 2019). In a third step, we worked together with the PAB on an identity and a social role of the assistance system – what it should look like and what kind of behavior and background it could have. In addition, a particular robotic device for the physical avatar was selected by the PAB from a range of products available on the market. As next steps – based on a first prototype of the assistance system – aspects of dialogue behavior and multimodal interaction will be iterated with the PAB in order to adapt it as much as possible to real user needs.

In the frame of the participatory design process, we decided on several aspects of the agent's design, such as its identity, form and social role, in discussion with the PAB. As researchers with a sociological background and experience with critical design perspectives on HRI, we had a strong opinion on these issues, preferring not to inscribe human categories into a non-human artificial entity, which might otherwise allow for ethically questionable references or provoke disconcerting experiences in users. This includes, in particular, the avoidance of stereotypical representations associated with gender, ethnicity or social background. Instead, the design should aim to present the agent as an artificial being with its own ontological status, never negating its inherent artificiality. However, this academic argument aside, the PAB could not be persuaded to use an abstract form for the assisting entity, so we decided to use an anthropomorphic form for the agent's character. While the PAB agreed on the overall anthropomorphic form, they were not in agreement on the gender assigned to it, with the male participants arguing for a female character and the female participants opposing this idea. Still in discussion, we favor the possibility of making this aspect of the agent chooseable for the user. Regarding the physical agent, we presented the PAB with robotic devices that could be purchased and that met our requirements. Again, the PAB chose one of the two anthropomorphic options – the Furhat (https://furhatrobotics.com), which is a robotic head with a projected face. A specific argument for the PAB to use a Furhat was the ability to change the gender and appearance of the robot as well, so it better suits the needs of the users.

Multiple iterations of testing versions will be performed during the development to ensure usability and user experience. An iterative usability evaluation accompanies the project, and technical implementations are evaluated directly. Laboratory studies with test participants have been and will be performed to test the physically and virtually embodied agents, and the developed sets of indicators to record satisfaction with the interaction. After completion of the development work, a final summative evaluation will be carried out. The assistance system is evaluated using a mixed methods approach at two clinical rehabilitation locations.

Conclusion

The MIA-PROM project's approach and developments offer significant insights and methodologies which can be transferred to the digitalization of healthcare for people of advanced age. The intuitive and adaptive interaction concepts are also relevant for older adults, who may face unique challenges in using digital healthcare solutions. By prioritizing ease of use and accessibility, MIA-PROM showcases how digital tools can be designed to accommodate the varying physical and cognitive abilities of people in rehabilitation and also for the elderly population.

Furthermore, the participatory development process used in MIA-PROM, involving a patient advisory board, serves as a model for inclusive and empathetic design in digital healthcare. This method ensures that the developed solutions are not only technically efficient but also deeply resonant with the specific needs and preferences of the respective target group. The insights gained from the MIA-PROM project (until now and in the future) can guide in creating more inclusive and effective digital health solutions for the aging population.

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