Towards a mobile exercise application to prevent falls: a participatory design process

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ABSTRACT

In this cross-disciplinary project senior citizens and researchers participated in the collaborative design and development of a mobile exercise application to prevent falls. The methods Form-IT and Participatory and Appreciative Action and Reflection were applied in a series of workshops, facilitating the creation of new knowledge and a socio-technical platform for an end-user development process. The participation of the older adults was key to understanding the broad range of preferences and motivational aspects. The outcomes emerged into prototypes, which were composed using the ACKTUS platform for end-user development, resulting in a dynamic application, easily adaptable to future needs and studies.

1. INTRODUCTION

Falls represent the most common cause of injury in old age. At least one third of community-dwelling people aged 65+ fall each year, half of them more than once (Campbell et al, 1989), and the incidence increases with advancing age (Stevens et al, 2006). Falls are declared to induce the most costly consequences among older people, and these costs are expected to increase rapidly if the development continues (Davis et al, 2010). Not only the fall-related physical injuries have devastating consequences for older persons, but fear of falling and decreased balance confidence have major implications for quality of life and health, including loss of functional independence and participation in society. Fear of falling is particularly common among older women (Scheffer et al, 2008). Falls are often a result of the existence of multiple risk factors, such as impaired balance, gait, vision, and drug side effects. Therefore, it has been assumed that interventions that address several of these risk factors, i.e. multifactorial falls prevention, will be most effective. However, according to recent systematic reviews, exercise programmes that focus on balance combined with muscle strength in the lower limbs are as effective in reducing both the number of falls and fallers among community-dwelling older people (Gillespie et al, 2012; Sherrington et al, 2008).

The positive effects of exercise in old age to prevent falls are generally not known by older people (Yardley et al, 2006). There is a lack of guidance on how they can counteract or decrease their fall risk by regaining or maintaining balance capacity and physical strength. Furthermore, for those who are offered fall preventive exercises, low adherence has been reported as a major concern (Fortinsky et al, 2004). Even though evidence consistently suggests that balance and strength exercises are effective in reducing falls and fall related injuries, these kind of interventions are still only effective if the older persons at risk actually adhere to the training and continue to exercise. Average adherence rates to group based exercise programmes as low as 50% to 75% are not uncommon (McPhate et al, 2013; Clemson et al, 2012).

Through innovative technology, preventive interventions like balance and strength exercises for the avoidance of falls can be made available to large populations in both rural and urban areas. A number of reasons for introducing these kinds of welfare technology have been mentioned, but the two most important are: 1) to help in the implementation and adaptation of preventive actions to reduce the effects of chronic diseases and age-related complaints (Mörk and Vidje, 2010), and 2) to empower people and enable them to do things themselves, which they would previously needed help with (Melander-Wikman, 2008). In addition, interactive welfare technology does also have the potential to provide meaningful and motivating exercises, if strategically applied.

Building on existing evidence-based knowledge within the field of falls prevention the aim of the project presented in this paper is to develop, evaluate and implement a best practice fall preventive programme in the shape of an application for smartphones and tablets to be used in people's own homes and surroundings. The

goal is to implement the programme on a broad base, equally accessible in urban and rural areas, with the long term ambition to provide effective and empowering prevention methods for healthy ageing and the maintenance of body functions, activity and participation throughout the life span. This project consists of two phases: 1) design phase (design and develop the mobile application for falls prevention together with older women and men; 2) evaluation of implementation and effects phase (pilot study, implementation study, randomized controlled trial).

The aim of the present article is to present the methodology used and resulting experiences from the design phase. Section 2 describes the setup and theoretical background, and Section 3 describes how the theoretical and methodological underpinning was applied in the development process.

2. DESIGNING THE DESIGN PROCESS

A cross-disciplinary research group consisting of researchers in physiotherapy, informatics and knowledge engineering, including experts in falls prevention, e-health, and gender research, planned and carried out a series of workshops for community-dwelling older persons. The purpose of the workshops was twofold: 1) to gain knowledge about older women's and men's understanding of fall risk and falls prevention and their views and preferences regarding fall preventive exercises; 2) to together with potential users, design a mobile application that facilitate the creation of individualized balance and strength exercise programmes that inspire adherence. In addition to the workshops, sessions of design and knowledge engineering were conducted. In these sessions the physiotherapists developed testable prototypes based on their professional knowledge and the results from the workshops. The theories and methodologies applied in the project are described in the following section.

2.1 Theoretical Approaches and Methodologies

In order to design an application, with the main purpose to motivate older people to perform fall preventive exercises, it is of paramount importance to gain a thorough understanding of the views and values underpinning the needs of the future end-users, as well as perceived aspects important for the sustainment of motivation. A lack of such understanding may be one factor that explains the limited adoption of many aging-related technologies (Thielke et al, 2012). Therefore Needfinding and Incitement-finding activities in the form of focus group discussions were central in our methodology (Makosky Daley et al, 2010). In addition, the overall research methodological and philosophical principles underpinning this project has been Form-IT (Ståhlbröst and Bergvall-Kåreborn, 2007) and Participatory and Appreciative Action and Reflection (PAAR) (Ghaye et al, 2008)

Form-IT is a human centred methodology aiming to guide and facilitate the development of innovative services based on a holistic understanding of people's needs, behaviour and values. The approach is an iterative and interactive process inspired by three theoretical streams: Soft Systems Thinking, Appreciative Inquiry, and Needfinding. Soft Systems Thinking provides tools for understanding the worldview of involved stakeholders, including potential end-users, in order to understand their interpretations and understandings of different situations. Appreciative Inquiry provides a focus on opportunities by identifying the dreams and visions of the users. Instead of starting by searching for problems to be solved, positive examples that work well are used as a basis for the design process. The third stream, Needfinding highlights the importance of defining and understanding the long lasting needs of users throughout the development process, and to use these needs as the foundation for the requirement specifications (Ståhlbröst and Bergvall-Kåreborn, 2007). The methodology iterates between three activities: conceptualisation, realization and use of design scenarios, mock-ups, prototypes, and the finished system.

When engaging the participating older persons in giving their views upon how the design should be to fulfil their needs, we were inspired by the PAAR methodology, which can be regarded as a kind of 3rd generation action research. The PAAR methodology, like Appreciative Inquiry, focuses on accomplishments, strengths, successes and their root causes, so that success can be better understood and augmented. Using PAAR requires four strategic 'turns', meaning a change in direction from one way of thinking and practicing to another. The four turns are: 1) away from a preoccupation with changing behaviours and problem solving, towards the development of appreciative insights, understanding the causes of success in order to amplify those things that will help build a better future from the positive present; 2) away from self-learning (individualism and isolation) and towards collective learning, appreciative knowledge sharing and the use of new forms of communications technology; 3) away from one way of knowing and one perspective on truth to an acceptance of more pluralistic views of understanding human experience, and putting this knowing to good use; 4) away from reflective cycles and spirals and towards the use of a reflective learning (r-learning) framework, comprising four mutually supportive processes: developing an appreciative 'gaze'; reframing lived experience; building practical wisdom; and achieving and moving forward(Ghaye et al, 2008). This interaction between researchers and older persons is a prerequisite for developing the practical wisdom that will serve as a decision-aid to support self-management

in health (Alpay et al, 2011). Building a strong, ongoing relationship with the older users in this project was crucial, since their involvement required a considerable time commitment on their part, as well as both physical and mental involvement (Bergvall-Kåreborn et al, 2010).

For the purpose to facilitate the transformation of the knowledge and experiences, which are informal and not easily translated into formal models to be executed by a computerized system, we apply a Meta-design perspective on the process and provide end-user development tools for modelling knowledge and designing the content of the system (Fisher and Herrmann, 2011). A Meta-design process acknowledges that the outcome is not a static product, instead a living knowledge system, which will need to be further developed since a full understanding of the users' needs and tasks will not be created at design time, and an individual's needs change over time. Moreover, this development should be possible to be conducted by the end-users. We consider both the older participants and the physiotherapy researchers as being end-users, since the physiotherapists see the potentials in using the system as a tool for providing therapeutic guidance and intervention. Moreover, the physiotherapy researchers are stakeholders as well, since the system can be used as a tool for mediating up-to-date evidence-based research findings. In this sense, the participants become both co-creators and end-users of the future and emerging application. Meta-design consequently supplements PAAR and Form-IT with an empowering end-user development perspective, enabled through the three levels of a Meta-design process: Designing Design (the conditions for creating an enabling end-user development environment), Designing Together (which complies with the participatory action research streams of PAAR and Form-IT), and Designing the "in-between" (essentially defining how the co-creative and evolutionary behaviour patterns can be sustained, to which both Form-IT and PAAR contribute).

2.2 Older Participants

The older participants were recruited at meetings arranged by senior citizen associations. The seniors were informed that their views and experiences were important input for the design and development of a novel digital application aimed to prevent falls. They were also informed that participation in the project meant that they could borrow either a smartphone or a tablet device during the project in order to test the application in their home environment. All who expressed an interest to participate (n = 38) were contacted by telephone and interviewed. Based on these interviews ten women and eight men were carefully selected in order to obtain a heterogeneous group with different experiences of technology, falls etc. The majority of the selected participants were former skilled white-collar workers and were, in general, fairly physically active. One third of the participants had fallen within the previous year, which reflect the rate of falling among the overall community-dwelling population. Two married couples were included, and four people lived alone. The mean age was 74.6 ± 3.5 years. Prior to the workshops the participants were divided into two groups. All group members, expect one woman, participated throughout the project and the attendance rate at all workshops and meetings was very high in both groups, around 90%. The study was approved by the Regional Ethical Review Board (Dnr. 2012-170-31 M). All participants provided informed written consent.

3. THEMES IN FOCUS FOR THE STUDY

Five physiotherapy researchers in the field of falls prevention participated in the project. They contributed with their expertise and domain knowledge, e.g., earlier research and existing evidence-based falls preventive exercise programmes already proven effective (the Otago Exercise Programme (Otago Medical School, 2003) and the Falls Management Exercise (Skelton and Dinan, 1999). Based on this knowledge, suitable exercises for the application were suggested. However, the exercise programmes needed to be expanded to include additional levels of difficulty and several new exercises. Besides this, there was a need to investigate how to introduce and structure these exercises in order to make the application appealing and motivate the older participants to engage in the exercises. It was also important to understand the future user's current knowledge about, and understanding of, fall risk and falls prevention. According to these prerequisites the workshops were planned based on four themes, which were considered crucial for the design of the application.

These themes were:

- Investigate the participants' experience related to fall
- Design exercises together with the older participants
- Explore motivational factors that can improve exercise adherence
- Design and develop the application together with the older participants

The first three themes are related to the conceptualisation phase of Form-IT, and create the base for realizing and using both test exercises and the application prototype. The design process was not linear, but rather iterative moving back and forth between conceptualisation, realization and use. During this process the application

gradually developed through interactions between all participants. The older participants in this study were very engaged and expressed that they learned a lot during the meetings, and that the workshops inspired them to start doing fall preventive exercises themselves. The content of the workshops and the progress of the design phase are presented in table 1. In the subsequent sections, the workshops are described following the themes in focus. Finally, the resulting design of the application, and the design and formalisation process are described.

Table 1. *The main themes and activities of the first ten workshops, as well as activities carried out by the older participants between meetings.*

Workshop date and main themes	Activities at workshop	Activities between workshops
1. Oct. 2012 ***Experiences, Motivation***	Presentation of the project and participants. Focus group discussions: "Personal meaning of 'joy of movement' and balance."	Take photographs or collect pictures from papers of situations representing balance and joy of movement.
2. Nov. 2012 ***Experiences, Motivation***	Focus group discussions: "Personal meaning of 'joy of movement' and balance." Inspired by the photographs and pictures collected. Focus group discussion "Falls and consequences – what do you do to avoid them?"	Think about what motivates you to be physically active. How may an application for exercises look like?
3. Dec. 2012 ***Exercises, Motivation***	Lecture on balance and practical testing of balance exercises. Focus group discussion: "How can new technology inspire you to physical activity?"	Think about specific every day activities that you have changed your way of doing recently. Start using tablet or smartphone.
4. Jan 2013 ***Experiences***	Discussions in small gender divided groups: "Identify altered strategies in everyday activities, and how they are perceived."	Try out a free exercise application, and watch specified web links.
5. Feb. 2013 ***Motivation, Design and Development***	Activity: Take position in the room. Discussions in small gender divided groups. "Reflections on web links and applications tested. What would we like our app to be like?"	Use your smartphone or tablet
6. Mar. 2013 ***Motivation***	Working with personas.	Activity calendar. Suggestions for stealth exercises. Write your own persona description.
7. May 2013 ***Experiences, Motivation, Exercises***	Feedback and discussions on activity calendars and personas. Activity: Balance and strength exercises in groups.	
8. Jun. 2013 ***Exercises, Design and Development***	Test and feedback of the first prototype and exercises.	Use the prototype
9 Oct. 2013 ***Exercises, Design and Development***	Test and feedback of the second prototype and exercises. Visit a research lab for inspiration to start thinking about possibilities for feedback in the application.	Use the prototype
10. Nov. 2013 ***Design and Development***	Test and feedback of the third prototype with a new interface.	Use the prototype

3.1 Investigate Participants' Experience Related to Falls

During the first workshops the objective was to understand how the older participants conceptualized falls and fall risk and their strategies for avoiding falls in their every-day life. For these purposes the participants were encouraged to reflect on the concepts *balance* and *joy of movement* and what they meant for them. They were also asked to search for and select figures and photographs representing their perspective of these concepts. During the workshop the participants presented their different pictures followed by an open discussion. The discussion was led by an experienced researcher in an encouraging and positive atmosphere according to PAAR. The additional participating researchers took part in the discussions by adding questions and remarks, but were careful not to dominate or take focus from the participants' stories. One of the researchers had a specific

responsibility to observe the participants from a gender perspective during the discussions and to take notes. All focus group discussions were recorded and transcribed verbatim and the content was analysed with a content analysis approach (Lundman and Graneheim Hällgren, 2008). Among many other insights, these discussions brought an understanding of the many needs; practical, mental, emotional, and social that may be involved in the process of developing fall risk awareness. (Pohl et al, 2014). This knowledge was above all important in order to understand how to give information to new users and market the application.

3.2 Design Exercises Together with the Older Participants

During the workshops related to developing exercises, practical sessions were conducted where participants could try out different exercises for balance and strength. In this way, they expressed how the exercises were experienced; which they liked and disliked, and why; how the exercises might be modified to be easier or more difficult; and what they judged as appropriate levels of difficulty. During these activities the older participants emphasized the importance of knowing why and how a particular exercise was beneficial. The older participants did also express preferences regarding details as the age, sex and clothing of the instructor and they all agreed that an inspiring and joyful instructor was important. Between meetings the participants were encouraged to carry on with the exercises and give feedback on how they managed. They were also asked to consider how the exercises could be woven into their daily activities, as well as to provide suggestions for new exercises.

3.3 Explore Motivational Factors that can Improve Exercise Adherence

The motivational aspects were central to the aim of this project, and as such they were part of nearly all the workshops. A range of different methods were used to elicit knowledge of what motivates older people to start and continue to exercise. The discussions in the focus groups were inspired by photographs that the participants brought, web links provided by the researchers, and try-outs of existing exercise applications as RunKeeper (FitnessKeeper Inc.), Moves (ProtoGeo Oy) and Workout Trainer (Skimble Inc.). In addition, more practical activities were conducted in which questions regarding exercise preferences were explored and discussed. Examples of questions could be: *Would you like to exercise alone or in a group? Would you like to exercise outdoors or indoors? Would you like to have your exercise calm or intense? Would you like to exercise with a scheduled programme or vowed in to your daily activities?* In these actives the answer alternatives were marked as areas in the physical room, and the participants were asked to go and stand in the area of their preferred view. Later they were encouraged to explain and argue for their choices.

Data from the first workshops were analysed with the help of content analysis and formed the basis for the construction of five fictional characters created to represent the different user types, i.e. personas. These personas were then presented to the participants, who rated how well the descriptions defined themselves and the way they preferred to do exercises. The participants did also write their own personas. These descriptions provided knowledge on how a falls preventive application may be designed to attract users with different characteristics and preferences. From this work it became clear that the participants had many diverse preferences but it was evident that many preferred to workout outdoors and to weave in exercises into their normal daily activities. Therefore, the resulting application contains both exercises for outdoor use, and so-called stealth exercises (that can be performed everywhere as part of everyday activities) and the possibility to create a personalized exercise programme.

The knowledge retrieved was used to develop a questionnaire on motivating factors in falls preventive programmes. This questionnaire was distributed to participants in our group present at workshop 9 (n. 16) and to a larger sample (n. 42) of potential users of the future application recruited at a "culture café meeting" at a local church. The questionnaire showed no major differences between preferences of the participants in our research group and the larger sample. In addition this questionnaire showed no particular differences in what men compared to women perceived as motivating factors.

3.4 Design and Develop the Application Together with the Older Participants

The participating older persons contributed significantly to the design of the application, especially regarding how the exercises are presented and to the user interface. Although there is currently no similar product with the same aim and target group available on the market, we could use other applications to inspire the older participants to get ideas. By trying out suggested existing physical training applications and exercise programmes in the form of web links, and later discussing their design, the participants expressed how they preferred to get their own exercises presented and organized. A very clear and simple layout of the interface was desirable, and the participants jointly decided to design the application based on short film clips in which the exercises are shown by an older person while verbal instructions are given. If the user wish to have more information about each exercise (e.g. more about why the particular exercise is important; how it can be adapted, for instance, in case of pain; or what to consider regarding safety issues) the information is easy accessible via

buttons. All film clips are sorted into the categories “strength exercises”, “balance exercises” and “gait exercises”, and each category have a number of subgroups with exercises of varying difficulty. Users can easily find preferred and appropriate exercises and choose the ones to include in their own programme. The older participants did also contribute with concrete tips, which were integrated, about how to make exercises safer, and how to increase safety in everyday life. The researchers in physiotherapy contributed with new knowledge from research studies.

As a range of information and ideas were identified, discussed and prioritized, the researchers and participants created a perception of how a system supporting fall preventive strength and balance exercises might be designed and function. This informal knowledge, expertise and experience were transformed by the physiotherapists into formal information and process models using the ACKTUS platform (Lindgren and Nilsson, 2013; Lindgren et al, 2011). ACKTUS integrates a generic semantic model, based on models of human activity, the International Classification of Functioning, Ability and Health (ICF) and other medical terminologies, and can be expanded into higher granularity specific for a knowledge domain. None of the physiotherapists had prior experience in knowledge engineering, but were guided by a knowledge engineer in the process. As a starting point the physiotherapists researchers had a meeting with the knowledge engineer and began to structure the content and the flow of interaction, and a map with key concepts and their relations were drawn. Once the overall structure was created, the ACKTUS functioned as a tool for achieving the goal of developing a working prototype and the physiotherapy researchers themselves managed to model the content and design the interaction using the ACKTUS tool (figure 1), which allowed the participants to test hands-on.

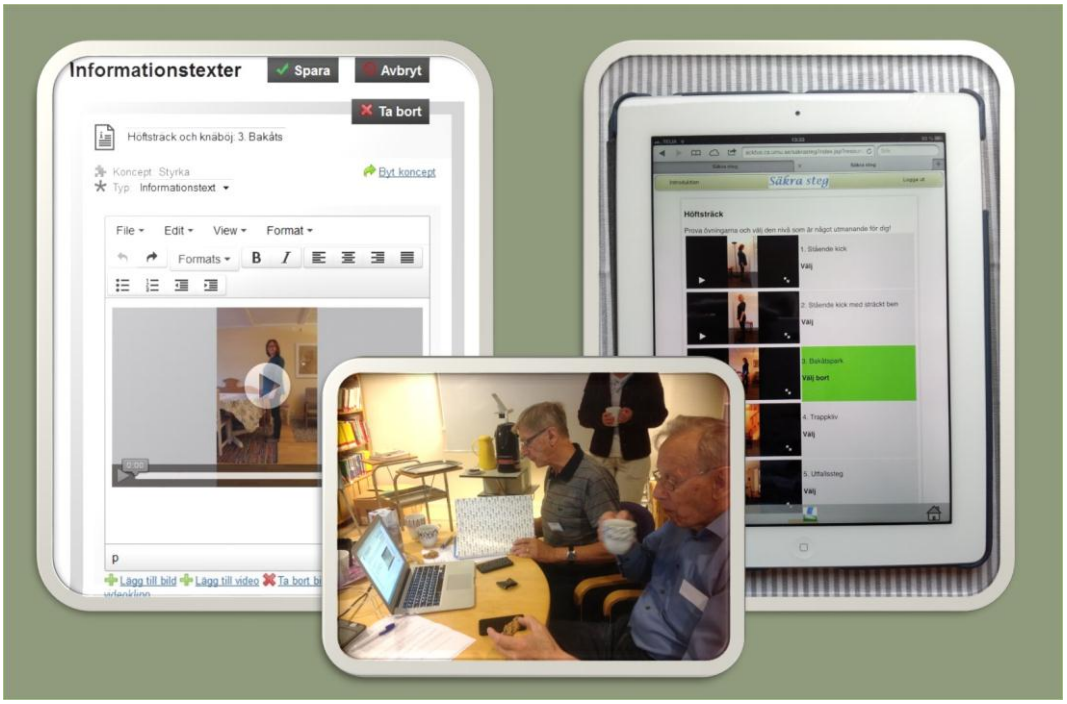

Figure 1. *The ACKTUS platform was used to model the content and design the interaction in the prototypes, which allowed the participants to test hands-on. Through ACKTUS the responsible physiotherapist researchers are able to modify and further develop the application.*

A first simple prototype of the future application, based on the ideas conformed during the workshops, was presented to the participants at the eighth workshop. The participants worked in groups exploring the prototype, while observed by the researchers, and shared their opinions and suggestions for improvements. The following workshops were dedicated to the refinement of the prototype in an iterative process. Between each workshop, changes were made to the interface based on the observed difficulties of the older participants to navigate in the programme. New exercises were gradually added for evaluation. An observation made during these workshop sessions was the wide variety of opinions and suggestions for change, where the participants often had contradictory opinions. As a consequence, a large degree of flexibility in the application was strived for.

The iterative procedure of prototype evaluation resulted in a process where both ACKTUS and the prototype were refined according to the requirements made by the users. This lead to a redesign of the user interface and the implementation of additional functionality in ACKTUS as well. By the use of ACKTUS the resulting

application is modular, extendable, flexible and adaptable to the individual end-user. Moreover, the responsible physiotherapist researchers are able to modify the information and process models, and in this way further develop the application.

4. CONCLUSIONS AND FUTURE WORK

The combination of Form-IT and PAAR methodologies helped to create a positive atmosphere during the workshops, which greatly facilitated the interaction and likely contributed to the high engagement and attendance rate by the older participants. The methodologies encouraged the acceptance of pluralistic opinions, which was important because the participants had many diverse preferences. As a result the prototypes were designed with a high degree of flexibility. The participants expressed that they learned a lot during the meetings, and were inspired to start doing fall preventive exercises themselves. At the same time, the researchers felt that they learned a lot from the older participants as well. They got a deeper understanding of the older persons' understanding of fall risk and their views on falls prevention. The older participants also contributed to a greater understanding of exercise preferences and factors that might enhance motivation. Many of the things that emerged and later on was implemented in the application (e.g. outdoor exercises), was such that the scientists, despite their expertise, would never had thought of without the interaction with the older people. Consequently, the involvement of older persons was crucial in order to develop a falls prevention programme with the ability to attract older users.

The application of a Meta-design perspective resulted in an end-user development environment, which allows the end-users to continue to take an active part in further hands-on development of the prototype. The ACKTUS platform functions as a tool for this, by enabling the physiotherapist researchers to model and re-model both content and interaction. The older users can modify the content of their application by creating tailored exercise programmes, using the building blocks included by the physiotherapists. The resulting application is a dynamic application, easily adaptable to future needs and knowledge evolvement.

For future development of the application, the need for inclusion of motivating personalized feedback about progress over time, was discussed during the workshops. To achieve this, the user interfaces need to be enhanced with sensor information, carefully analysed and calibrated to the individual and the context, as a supplement to subjective evaluations. We have recently started work on including options for movement analysis, through the accelerometers already available in the phone or tablet, for these purposes. Another line of development is to transform the exercises developed for the application into an interactive video game using intelligent interface technology based on 3D sensors. In such a game the users would be able to see themselves doing the exercises as an integrated part of a game narrative, if desired, in a social context, and get both instant and summarized feedback. The application will be evaluated in future randomized controlled trials in order to study both method of implementation, user experiences, and the effect of the balance and strength exercises provided.

To summarise, the main contribution of this work is the application of the described theories and methodologies for achieving a socio-technical platform for engaging all stakeholders, both older adults and physiotherapists as domain experts and researchers, in a long-term collaborative "hands-on" design and development process, which provides sustainable and evolving knowledge-based instruments for prevention and rehabilitation.

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