MyHealthFrame
Design and Evaluation of a Minimally Invasive Communication Platform for Telemedicine Services Aimed at Older Adults

Mohammad Hossein Nassabi[1], Harm op den Akker[1,2], Marian Bittner[1], Coen Kemerink[2], Bert-Jan van Beijnum[1], Hermie Hermens[1,2] and Miriam Vollenbroek[1,2]

[1]*Telemedicine Group, University of Twente, Enschede, The Netherlands*

[2]*Telemedicine Group, Roessingh Research and Development, Enschede, The Netherlands*

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Abstract: MyHealthFrame is a communication platform that telemedicine (and well-being) services can leverage to deliver motivational messages and notifications to their end-users. Instead of being a telemedicine service in itself, MyHealthFrame is a channel through which external services can reach their users to provide reminders or deliver simple information such as number of steps. To its end-users, MyHealthFrame is a tablet device which is designed to be perceived as a photoframe and can be immersed in the users' living environment. In this paper, we describe the design and the preliminary assessment of the platform. The results of the feasibility study with five older adults (65+) are promising.

1 INTRODUCTION

Patient participation is essential to successfully move care from hospitals to homes. However, the uptake and adherence to telemedicine systems targeting the home environment remains poor (McGee-Lennon and Brewster, 2011). To address this gap, special attention must be paid to the characteristics of the end-users. Especially in the case of older adults, not only should researchers consider the cognitive and physical impairments, but technological literacy and ease of use also play significant roles in accepting a home-based system.

Some telemedicine systems support the elderly in establishing a healthy behavior in order to reduce future health complications. Researchers have been using persuasive technology to promote such changes to daily living. Virtual activity coaches are the prime example of systems in which techniques such as goal-setting, increasing self-awareness and reinforcing proper attitudes are used to increase levels of physical activity. Although the older adults' attitude towards technology is not uniform, it has been reported that they have greater fear and anxiety of using computers comparing to other age groups (Barnard et al., 2013). This can lead to the elderly not being keen on using technology. In addition, some barriers can further demotivate the older adult end-user from accessing the health service. Consider the example of a web-based rehabilitation service: The elderly has to turn on his computer, log into the Operating System (OS), open up the browser and log into the website to access the rehabilitation service. In a more dramatic scenario, changes to the elderly's computer setting (e.g., software updates) can result in the user becoming discouraged and not using the service at all. This example can become more complicated if the elderly has to use more telemedicine systems (and well-being services) to address the health needs in different domains. Each of these services may also use persuasive technology to motivate their end-users. However, the end-users will never receive the persuasive elements if they stop referring to the corresponding websites or devices.

The MyHealthFrame platform is designed to facilitate long-term communication between telemedicine systems and end-users who will benefit from the services offered by such systems. Therefore, MyHealthFrame in itself is not a telemedicine system. However, it is an always-available communication channel through which a simplified subset of functionality from a telemedicine system is delivered in the home environment. As such, it can be viewed as a proxy to the older adults' daily living. Moreover,

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the platform can be employed as a hub for collecting sensor data and passing this data to suitable external services. MyHealthFrame, with its ubiquitous front-end, attempts to overcome barriers to initiating service use by: (1) Reminding the user about the existence of the external services by delivering the persuasive elements generated by them and (2) Presenting simple information originating from the external services. Consequently, MyHealthFrame has the potential to yield higher user engagement and possibly long-term adherence to the offered services.

In this paper, we discuss the design, development and preliminary assessment of MyHealthFrame. The assessment will be done for services targeting the physical domain with which the older adults can achieve a physically active lifestyle.

2 BACKGROUND

To the best knowledge of the authors, no ICT system similar to MyHealthFrame—as a channel to deliver persuasive elements from external health services to older adult end-users—exists. The type of information delivered via MyHealthFrame is mainly related to health persuasion. Therefore, in this section, we briefly describe persuasive technology and subsequently present several systems that promote self-management and harness persuasive elements to establish healthy behavior change. These systems have been evaluated by either patients or healthy subjects. Our main interest here is to explore the opportunities for the delivery of persuasive content to older-adult end-users.

2.1 Persuasive Technology

Persuasive technology is defined as the study of interactive systems designed to deliver attitude or behavior change. Studies regarding the technology have already been performed in various domains such as education, marketing, safety, entertainment and health, where the latter has attracted most contributions.

(Oinas-Kukkonen and Harjumaa, 2009) present a Persuasive System Design (PSD) model in which persuasive techniques are classified into four categories: (1) Primary Task Support, which are techniques that help users perform the main activity and achieve their goals; examples include personalization and self-monitoring; (2) Dialogue Support, addressing computer-human interaction bearing in mind similarities to human interactions such as reminders, praise, feedback and rewards; (3) Credibility Support to promote the user's trust in the system for example, verifiability and trustworthiness; and finally (4) Social Support Techniques, leveraging the social factors to increase system's persuasiveness by competition, recognition and normative influence (namely, peer pressure).

2.2 Self-management Promoting Systems

A well-known category of persuasive systems are virtual activity coaches in which a pedometer or an accelerometer sensor is used to measure physical activity so that the intervention can be adjusted accordingly. For example, in Fish'n'steps (Lin et al., 2006), a virtual pet is presented on a fixed LCD display whose life state is dependent on the user's activity. In Ubifit Garden (Consolvo et al., 2008), the authors use a PDA mobile device to depict a garden metaphor in which the number of flowers increases as a result of achieving activity goals. In Flowie (Albaina et al., 2009), a flower metaphor representing the end-user's physical performance is provided through a photoframe device. Extra user interfaces have also been introduced for goal-setting. The authors evaluated the prototype in a panel consisting of two older adults (aged 65+). The results showed that the panel had a positive attitude toward adopting the system.

Some systems have used the TV as their service delivery medium. In (Giordano et al., 2009), the Philips Motiva system was connected to patients' TV through which the educational videos were shown. The authors in (Stojmenova et al., 2013) used an interactive TV to increase adherence to medication by sending reminders. However, an intrinsic problem with systems employing TV as their medium is the communication loss when the TV is off.

Beside the more conventional modalities, researchers have also used robots to provide health services. For example, in (Johnson et al., 2014), a socially assistive robot was integrated into a smart home to support the elderly's independent living. However, the long-term acceptance of such robots has scarcely been studied (de Graaf et al., 2015).

The above-mentioned studies show the range of different options that can be chosen as delivery device in telemedicine systems. We can consider multiple criteria to compare various options and choose the most suitable device for a given application. *Portability*, *Affordability*, *Availability*, *Information Richness* (op den Akker et al., 2014), *Computation Power*, *Required Infrastructure*, *Learning Curve* and *Interaction Type* can be named as some criteria for consideration.

3 CONCEPT OVERVIEW

Our aim in this research was to design an affordable interaction device that could be immersed in the home. This led on from previous research indicating that the homes of the elderly can be an ideal location for providing persuasive elements (Cabrita et al., 2015). We ruled out mobile devices as we could not find strong evidence of elderly preference for such devices in home-based systems (McGee-Lennon et al., 2012). Moreover, we selected a photoframe representation for the end-user device as it seems to easily become a natural part of the existing living environment. This kind of end-user device has already been investigated with older adults (or with their caregivers) in (Mynatt et al., 2001), (Dadlani et al., 2010) and (Albaina et al., 2009).

MyHealthFrame provides a single point of reference for the older adult end-users via which motivational messages, reminders and feedback are communicated.

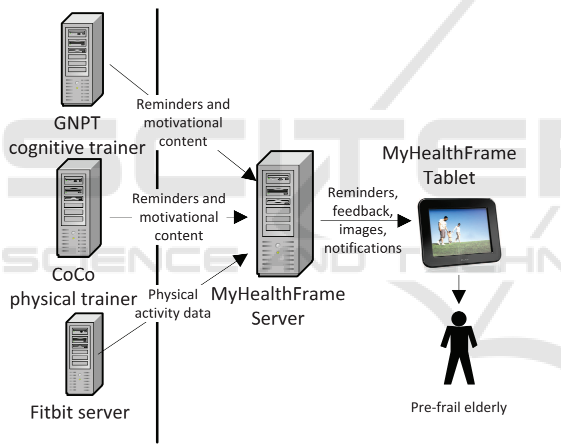

Figure 1: MyHealthFrame presents the motivational messages to the older adult end-user.

To its end-users, MyHealthFrame is a tablet device, designed to be perceived as a digital photoframe. The tablet requires minimal explicit user interaction and is placed at a location that is easily accessible by the elderly end-user. When idle, it can show images of family members or delightful scenery to improve the the elderly's mood and mental state. External telemedicine systems can trigger the tablet to convey persuasive elements to the elderly. In addition, the tablet can transmit sensor data to the relevant external systems.

The first major exploitation of the platform will be in the PERSSILAA project in which multiple electronic health services in the domains of physical, cognitive and healthy nutrition are offered to pre-frail community dwelling older adults. Participants in PERSSILAA use their personal computers to access electronic health services (some of which are shown in Figure 1) to train and thereby improve their health. For example, PERSSILAA users follow a 12-week physical exercise program on the Condition Coach (CoCo) system: a web-based physical trainer allowing the elderly to perform exercises in their home setting (Tabak et al., 2014). Moreover, cognitive exercises are provided through the Guttmann Neuropersonal Trainer (GNPT) which is a Java-based desktop application (Solana et al., 2015). The users are also provided with Fitbit sensors to track their physical activity.

4 REQUIREMENT ELICITATION

The main functional requirements considered for the MyHealthFrame platform are listed below. Not all the functional requirements have been implemented in the first prototype.

1. An external telemedicine (or well-being) service can register itself with the platform.
2. The end-users can register themselves with the platform by providing the credentials for the external services.
3. An external service can send motivational items via the platform to registered end-users.
4. The platform queues messages based on their priority.
5. The end-user tablet filters the received messages based on their validity period.
6. The platform collects sensor data and sends it to the corresponding services.
7. The platform can update parts of the user interface in the tablet to present simple information such as step count originating from the external services.

We took a user-centered approach while designing the first prototype of the system for requirements related to end-users. Initially, we presented the concept and ideas regarding to MyHealthFrame to a focus group consisting of four older adults aged between 65 and 75. Subsequently, the participants were asked several questions about the concept and the features they would like to see included in the prototype. All participants mentioned that they would place such a solution in the living room for example, next to the TV, and some mentioned that they would favor the inclusion of a clock and an overview of their physical activity. The focus group was also asked to give their preferences for the activity sensor and all stated that they would like to use it to record their daily movement level.

5 PROTOTYPE DESIGN AND IMPLEMENTATION

The first prototype was built to assess the feasibility and potential uptake of the solution by older adults.

5.1 System Architecture

The architecture used in the prototype is shown in Figure 2. The user can interact with external services via their proprietary browser-based applications. The Java programming language is used to develop the required JSON-RPC 2.0 web-services exposed by MyHealthFrame server. Since the CoCo physical trainer's functionality to generate motivational messages is under development, we created a back-end control panel (i.e., caregiver user interface) that allows an experiment conductor to inject motivational items into the system.

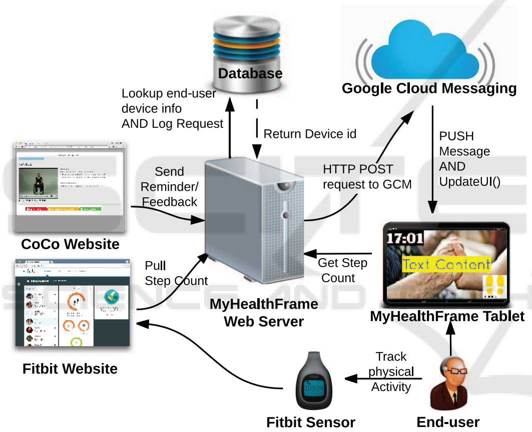

Figure 2: The push mechanism is used to communicate persuasive elements to the MyHealthFrame tablet.

In the prototype implementation, we have used the Google Cloud Messaging (GCM) service to push items to the tablet. The decision was made to accelerate the development process. Moreover, the tablet is set to pull sensor data (i.e., step count) every 15 minutes using the Bluetooth protocol. However, the successful synchronization of the accelerometer data depends on: (1) the proximity of the sensor and the tablet; and (2) the sensor not being idle. The classes in the back-end that are defined for communicating with the tablet are shown in Figure 3. Despite considering a single device per user for our first prototype, the software architecture allows for multiple user devices.

Each message sent to the tablet is defined as an *ActionMessage* object containing a pair of action type (e.g., image) and content (i.e.,parameters). After verifying that the end-user's device is capable of executing the requested *ActionMessage*, the message is transmitted via the GCM service.

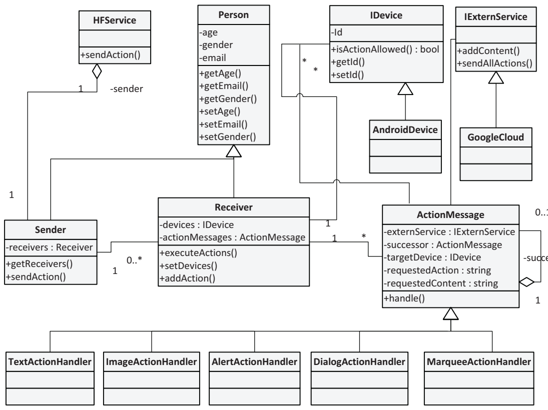

Figure 3: Extensibility and multiple end-user devices were considered when designing the system.

Table 1: The various types of messages that can be sent to the MyHealthFrame tablet.

Type	Parameters
Image	imageAddress, playMusic?
Text	messageText, position
	fontSize, fontType
	fore/background colour
MarqueeText	Same as a text message plus
	numberOfRepititions
Dialog	messageText, dialogDuration
Voice	messageText, voiceGender
	voiceSpeed
GetDisplayedData	No Parameters
ResetFrame	No Parameters

5.2 Communicated Items

A communicated item can be an *image*, a *textual* item, a *marquee* text, a *voice* message and a *dialog* item. In case of the later, a user dialog is shown on the tablet that requires the user to press a button.

Each item can be parametrized according to its type, thereby allowing for some levels of customization. For example, if a text message is sent, beside the content, the text location, size and color can be adjusted. As another example, each image can be accompanied by a random music sample 10 seconds long.

Table 1 lists the message types implemented in the first prototype. The last two types were added to help the experiment conductor to verify that the tablet is always in a consistent state.

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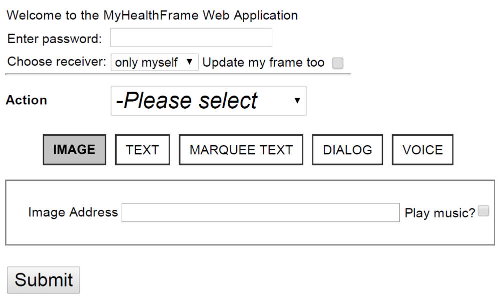

Figure 4: Message parameters can be set via the caregiver user interface.

5.3 User Interfaces

Two user interfaces (UI) were designed for the first prototype. The caregiver UI shown in Figure 4 is a secure website that the authenticated study conductor can use to send items to the elderly's tablet. Following the successful transmission, a notification is provided.

The care receiver UI is the interface designed for older adults. This interface is integrated in an Android application. The application cannot be closed unless the tablet is out of power.

Figure 5: The implemented Android app on MyHealth-Frame tablet is always running and cannot be closed.

Textual messages can be rendered in either of the four boxes shown in Figure 5. The strong contrast between the white number and the black background makes it easy to read the time. The step counter in the lower right corner shows the latest received number of steps for the Fitbit sensor. The shoe color changes from yellow to green if the step count is higher than a pre-defined threshold.

6 EVALUATION

We investigated the feasibility of MyHealthFrame in a small exploratory study. The only external telemedicine system based on which motivational content was communicated was the browser-based CoCo physical exercise trainer. This system provides a set of exercises in the form of narrated videos accompanied by textual descriptions. Each exercise set consists of a warm-up, main phase and cool-down stage containing four, nine and four exercises respectively. The participants had to use their own computers to access the physical trainer. Step counts were collected using the Fitbit Zip sensor given to each participant.

CoCo's motivational message-generator service is currently under development. Therefore, this study was done as a Wizard of Oz experiment: the participants were told that an intelligent system communicates with them through the tablet, although in reality, a nursing student was sending messages based on participant's activity levels and their progress in the physical trainer.

6.1 Study Protocol

The goal of the study was to evaluate the feasibility of MyHealthframe with a group of older adults and to collect their feedback about the system. The study duration was three weeks and consisted of two phases. The data collected during the initial phase (first two-weeks) was used as a baseline for sending persuasive elements in the the second phase (last week) of the study. During the registration meeting, the research conductor explained the goal of the research and collected the signed informed consent form. Moreover, the participants filled in a short questionnaire about their physical activity levels and were given access to the CoCo physical trainer. The participants were asked to perform the exercises on the trainer three times per week using their notebook computers. The Fitbit sensors were given to participants in the same day. In the third week, the participants were provided with the tablets for a one week period.

At the end of the study, the nursing student held an interview with the participants asking them to fill in the Computer System Usability Questionnaire (CSUQ) (Lewis, 1995) containing 19 items on overall system usability (OVERALL), system usefulness (SYSUSE), information quality (INFOQUAL) and interface equality (INTERQUAL). The items can be answered using 7-point Likert scales, ranging from ”Strongly agree” with one point to ”Strongly disagree” with seven points, and an additional Not Applicable (N/A) point. Moreover, to collect further information regarding user acceptance, the six extra questions listed below were asked during the interview of which some focused on the feedback given and future potential improvements to the system.

1. How was your experience with the system and

the provided feedback?
2. What did you learn from the given feedback?
3. What could be improved when giving feedback?
4. Have you benefited from the feedback or reminders? Please elaborate on your answer.
5. What would you like to change in the system?
6. Would you recommend MyHealthFrame to a friend? Please elaborate on your answer.

6.2 Participants

Five participants aged between 65-68 were recruited for the pilot consisting of two couples (Subjects 1 & 2 and Subjects 3 & 4) and a single male subject (Subject 5). Only four tablets were distributed amongst the participants resulting in Subjects 1 & 2 receiving a single tablet.

All of the participants mentioned that they cycled every day. Three participants mentioned exercising at a gym or a sport center for a minimum of once per week e.g., playing tennis. All participants were able to do daily activities such as shopping and performing household tasks.

6.3 Communication Timing and Content

Motivational messages were sent to the tablet both at fixed and time-varying moments. Based on the time of the day (morning, noon, evening), three generic images accompanied by a text were communicated to the participants e.g., the *“Good Morning”* message was sent at 9:00 am. In addition, after performing six (out of nine) exercises on the CoCo system, positive feedback in the form of an image would be sent. Moreover, a motivational message was sent if the number of steps was more than the average step count for a specific person (based on two weeks collected data).

If the participant had not been exercising on the physical trainer and the step count was lower than 5000 steps on a given day, a reminder was sent to the user to perform physical activity e.g., a textual message containing *“It is a great day to exercise”*.

6.4 Results

The number of steps measured during the study is shown in Figure 6. The average number of steps in some cases (e.g., subject 1) is significantly higher than the recommended 7000-8000 steps for the 65+ age group. The step counts supports the finding that the studied participants, other than subject 5, are more active than the general population.

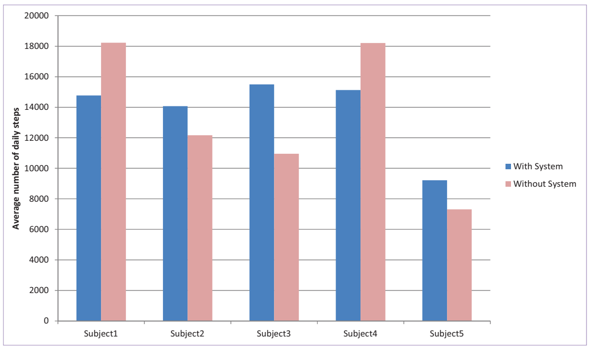

Figure 6: The average number of daily steps collected from participants in during the study.

Table 2: Four scores are calculated based on the answers to the CSUQ usability questionnaire.

Score	Based on questions	Average responses	Missing value ratio
OVERALL	1 to 19	3.04	0.31
SYSUSE	1 to 8	2.74	0.11
INFOQUAL	9 to 15	3.5	0.56
INTERQUAL	16 to 18	4	0.4

Only one couple (Subject 1 and Subject 2) regularly exercised using the CoCo physical trainer system. The other users stated that they were already physically active which was confirmed by sensor data.

The participants could not provide answers to all 19 questions of the CSUQ questionnaire. Following the guidelines of (Lewis, 1995), the questionnaire can be summarized into the four scores listed in Table 2. This table also contains the ratio for missing values per score defined using Equation 1:

$$\text{Missing value ratio}=\frac{\sum N/A \;\; Answers}{\#Questions \times \#Participants} \quad (1)$$

Unfortunately questions regarding information and interface quality seemed ambiguous or not applicable to most participants. However, the SYSUSE score suggested that the participants were satisfied with the system.

All participants were satisfied with using the Fitbit Zip sensor; indeed, Subject 5 mentioned that he became more active because of the sensor. Subjects 3 and 4 also stated that presenting the step counts on the tablet motivated them to compete with each other.

Subjects 1, 2 and 3 mentioned that they liked the received feedback shown on the tablet. The most active participant, Subject 4, did not notice any feedback as she was mainly outside doing voluntary work. Subject 5, the least active participant, could not understand how MyHealthFrame could help him.

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7 DISCUSSION AND FUTURE WORK

The acceptance of a computer system is influenced by multiple factors including user satisfaction, system usability, perceived ease of use and perceived usefulness (Acton et al., 2004). In this feasibility study, we attempted to collect subjective measurements related to the usability and usefulness of the MyHealthFrame platform with a limited number of participants. Even though the qualitative results regarding system usefulness are limited, still they indicate a positive attitude towards accepting the system.

The low value for information and interface quality and the corresponding high missing value ratios in Table 2 suggest that better explanations should be given about the system and its intended role. Although the participants were given a one-page description of the overall system at the beginning of the study, their answers to the extra questions about the system suggested some levels of confusion. For example, one participant suggested improvements to the CoCo physical trainer despite the fact that the question concerned MyHealthFrame. Another reason for such confusion can be the introduction of CoCo and Fitbit without taking into account the differences in the learning abilities of the participants. Therefore, one inclusion criteria for future studies can be the participant's prior acquaintance with web-based systems and his or her computer literacy.

The most important consideration for future studies is the inclusion of participants who benefit most from the platform. All participants in this study were moderately to highly active in comparison with people in the same age group. Consequently, there was no need for them to follow the online physical exercises. This inevitably led to fewer feedback moments related to their progress.

An interesting extension to the platform would be the addition of competition features for older adult couples. As stated by two participants, such functionality could have motivated them to become more physically active. However, the competition features would not need to be limited to physical activity and could be generalized to make use of any health/service information. For example, the user progress in GNPT cognitive trainer can also be considered as the competition information source. In this case, a total score could be aggregated based on scores in each health domain. Inclusion of such features in a future prototype would require implementing a light computation engine in the back-end. Moreover, the user interface would need to be modified to present the couple progress in a single tablet.

The calculated total scores can also be used to implement other game mechanics than (intra-couple) competition such as leaderboards, challenges, social networking and awarding points amongst all participants. For example, a reward scheme can be defined for end-users motivating them to become more engaged with the external telemedicine systems. The scheme can reward users in terms of prizes in the form of electronic badges as done in Fitocracy (Hamari and Koivisto, 2013) to promote individuals' achievements.

Our main focus for next prototypes will be on improving the user interface for participants belonging to the target group (pre-frail end-users). Specifically, we plan to perform a task-oriented user study. Participants will be asked to perform a pre-defined set of tasks using MyHealthFrame tablet and will be subsequently interviewed and asked to fill in the User Experience Questionnaire (Laugwitz et al., 2008). Setting up the study in this way will allow us to compare and improve various design elements in the system which can eventually lead to a more effective solution.

The architecture of the platform allows users to use multiple Android devices. Consequently, it is possible not only to send messages to the devices at home but also to communicate with the mobile devices that the user carries. Therefore, as a future extension, we would like to assess the effectiveness of cross-platform electronic health content delivery.

After analyzing the log files from the study, some end-user mistakes when sending messages based on time of the day were detected (made by the experiment conductor). Therefore, to minimize the human error in future studies, a scheduler component will be included in the platform that can be used for fixed time/rule-based messages.

8 CONCLUSION

In this paper, we have presented MyHealthFrame, a communication platform that third-party electronic health service providers can exploit to deliver persuasive elements such as motivational messages and reminders. The platform can also gather sensor data and send it to the relevant external services.

The preliminary results from the feasibility study yielded small yet positive indications. In addition, the study highlighted essential improvement points for future evaluations such as a more strict inclusion criteria for participants. The focus of the next study will be on improvements to usability and collecting more credible evidence about the platform's effectiveness.

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