Motivational strategies to improve self-management for rehabilitation of older adults

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Abstract: Self-management in older adults is of great significance since it can accelerate the rehabilitation process. However, many older adults do not take initiative in the rehabilitation process even though they are highly motivated to return to their normal life. Because of this problem, Ziekenhuis Groep Twente wants their patients to use a system/application that exploits motivational strategies for self-management during rehabilitation. Hence, the purpose of this research is to come up with a system that will support self-management of rehabilitating older adults in a motivational manner by means of creating a technology that changes the behaviour of older adults in such a way that they take more action on their own, ultimately increasing their activity adherence and autonomy. A functional prototype has been developed; a light and sound emitting photo frame that serves as a personalized trigger, and a cloud-based RFID architecture to back up the user's data and provide the user with the simplicity possible with this technology. Results from the usability tests have that the proposed system could provide the older adults with the support they need to be self-managing in their rehabilitation process. Hence, causing them to take more action on their own, increasing their activity adherence, and ultimately shorten their rehabilitation process.

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1| Introduction

A lot of older adults that must rehabilitate after hospitalization are motivated to go home early and return to their old lives. However, when it comes to older adults, the rehabilitation process doesn't always go as fast as the middle-aged person. Especially after a fall or fracture, they suddenly become less mobile and more dependent on caregivers. The main goal of the rehabilitation process is to grant the older adults their autonomy again, so they can return home and live their normal lives again. Rehabilitation for older adults normally takes place in nursing homes. During their stay, the older adults get half an hour physiotherapy every day according to specialists. To increase the progress of rehabilitation it is most of the time in their own hands to do activities that relate to their rehabilitation. Even though older adults are highly motivated during the rehabilitation process, self-management is difficult for them which leads to them taking no initiative in the rehabilitation process. The main reason for this is their lack of the components *competence*, *knowledge* and *skill* (Goolkate, 2018).

Among the older adults with a lower limb fracture, the problem of self-management during rehabilitation is of great importance since it lengthens the entire process. For this reason, the Ziekenhuisgroep Twente (ZGT) wants to develop an environment that can provide the missing components in such a way to stimulate the older adults after a lower limb fracture to take more initiative in the rehabilitation process and therefore to exercise more and rehabilitate more intensively. Because not every older adult has the same level of knowledge, competence, skills, or overall autonomy, the system must be personalized. There are already technological applications and systems that address this problem to a certain degree. However, in some of the systems, the initiative aspects are not addressed enough. On top of that, some of them cause barriers toward the used technology. Besides this, some technological applications still need guidance from caregivers.

The challenge is to come up with a solution that changes the behaviour of older adults in such a way that they take more action on their own, ultimately increasing their activity adherence and autonomy. Certain requirements must be met to achieve this and to reach this goal, the following questions will be answered: 1) Why is there no sufficient self-management in rehabilitating older adults? 2)How do current technologies provide self-management in (rehabilitating) older adults? 3)Given the existing applications, what would a suitable design for improving self-management in rehabilitating older adults? 4) Has the functional prototype, derived from the questions above, satisfied the requirements and therefore fulfilled the goal of creating a system that will change the behaviour of older adults, potentially resulting in an increase of activity adherence and autonomy?

The chapters of this research paper will be as follows: First, chapter 2 will provide a bit more information by answering question 1. It will briefly discuss the preliminary research done by Goolkate (2018), by explaining the components necessary for self-management in rehabilitating older adults. On top of that chapter 2 will go a bit more in-depth on the current situation at ZGT by means of describing a visit to the institution. After a clear context has been provided, chapter 3 will cover the ideation process. This chapter consists of requirements derived from chapter 1, a State Of The Art research (SOTA), requirements derived from the SOTA, and ideas generated both during and after the SOTA. After that, chapter 4 will establish the prototype specification by means of multiple evaluated paper prototypes. Chapter 5 will be about the realization of the functional prototype, followed by its evaluation in chapter 6. Finally, a conclusion will be drawn; answering the fourth question stated above. The research has been divided into three iteration phases, e.g. iteration I, iteration II and iteration III. Iteration I will start in chapter 3 and iteration III will start at the end of chapter 4.

2| Background

2.1 Preliminary Research

Currently, the population of older adults in the Netherlands is 3.2 million, which is 19 per cent of the total population in the Netherlands. In the future, this amount will be even more, e.g. 4.8 million in 2040 (Stoeldraijer, van Duin and Huisman, 2017). With this rapidly ageing population, the increasing demand for healthcare is undeniable. With it comes an increase in the number of people with a hip fracture. Only in 2012, this amount was already more than 20.000 in the Netherlands (Statline: Ziekenhuisopnamen; geslacht, leeftijd, regio en diagnose-indeling VTV, n.d.). With this amount, a long stay at the hospital must be prevented to reduce costs. However, as mentioned before, rehabilitating older adults only get 30 minutes of physical training per day, which doesn't really speed up the rehabilitation process. For this reason, Goolkate (2018) conducted a research for ZGT to find out how it is possible to support self-management in rehabilitating older adults, with the aid of technology. In this research Goolkate (2018) found that there are several components that support self-management in rehabilitating older adults, of which three of them are mentioned in the introduction. These components are *knowledge, competence, skills, activities that matter, autonomy, and motivation.* In addition to these, the components *social support* and *relatedness* also have influence on the degree of self-management. One of the findings of this research was that these components are all related to each other, as shown in figure 1**.**

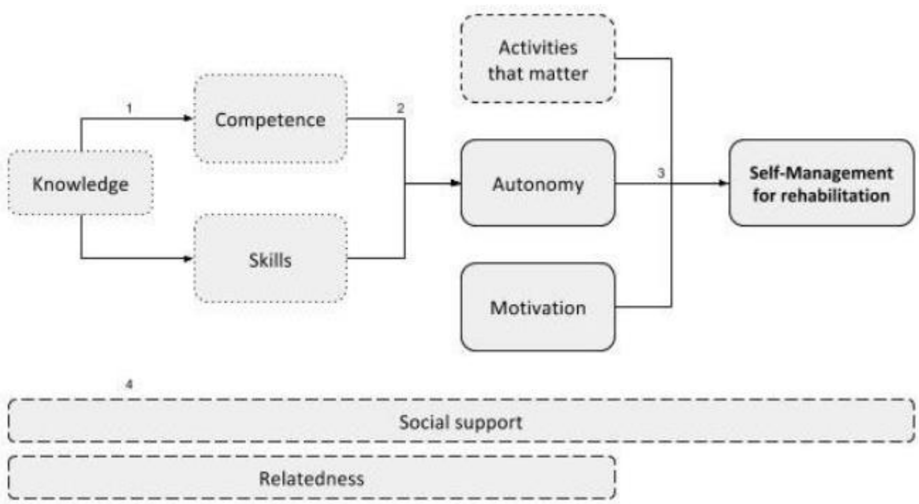

Figure 1: Components for self-management (Goolkate, 2018);

Interviews conducted in this research have shown that there exists a relation between the first three components; e.g., "when there is lack of knowledge, the older adults will not be able to obtain a degree of competence or skills" (p.18). Also, when one of the other components is missing, the older adults won't be able to obtain the other two.

The figure also shows that once all three components are available, the older adults could experience autonomy. However, Goolkate (2018) also found that, to reach self-management, autonomy must be complemented by the components *motivation* and *activities that matters*; motivation to rehabilitate as fast as possible and activities that the older adults are familiar with such as doing groceries ore householding.

In addition to all this, the components *social support* and *relatedness* have effect on all the components. Goolkate (2018) found out that many older adults value support from relatives; this motivates them and helps them increase their self-management in rehabilitation. Moreover, relatedness to the caregivers is also of great significance, since older adults are not always comfortable with just any caregiver. For example, when having a better relationship with their caregivers, it gives the older adults more confidence in asking questions, thus increasing knowledge, competence, and/or skills.

One of the main findings of this research was that the components *competence*, *knowledge* and *skill* are missing. Because of that, self-management in rehabilitation is not possible. Goolkate (2018) states that "their knowledge is very limited about the rehabilitation process, there is a between-patient variability in cognitive and physical skills and the level of confidence has decreased significantly after falling" (p.26). Due to this, autonomy is not possible. What these components exactly mean, will become clear in section 3.1.

2.2 Visits

During one of the visits paid at ZGT, situated in Almelo (Overijssel), a tour was given by two physiotherapists that are working at the institution. During this tour it came to the attention that many older adults were only sitting in their room all day, not performing much physical activity. On top of that, one of the physiotherapists emphasized that the older adults only get 30 minutes of physical training per day and that it was very common for the older adults to forget an appointment. This sometimes forced the physiotherapists to go pick up the patients themselves.

For training, there was one room available with different kinds of equipment for support and exercise. On the bottom floor, there was also the possibility to train with physiotherapists, but this was a bit further away. In addition to the conventional training equipment, there was also a virtual bike tour setup that rehabilitating older adults could use to bike through some of the villages and cities in the Netherlands. Paying this visit to ZGT also confirmed that many rehabilitating older adults are very dependent on their caregivers, as mentioned before. They had to be reminded how to do certain movements and tasks, and sometimes even had to be reminded that they had an appointment with their physiotherapist.

3| Ideation

Iteration I

To come up with a good design for improving self-management in rehabilitating older adults, it had to be established what the requirements and wishes are when designing a system for such a target population. Part of these requirements is found through conversations with experts in the fields such as physiotherapists, caregivers, and experts in the field of e-care. On top of that, the preliminary research conducted by Goolkate (2018) had brought up some requirements for the older adults by means of conducting qualitative interviews. This chapter will combine these requirements with the requirements set for a persuasive technology, as described in Fogg's Behaviour Model (FBM). In addition to these methods, a brainstorm session was held to find other potential requirements. Together with the other methods is has been converted into a mind map.

Section 3.2 will discuss potential design ideas of iteration I by first describing ideas that came up during a free brainstorm session in parallel with the SOTA research and then assessing the mind maps made earlier. After that, current technologies are explored in the SOTA, followed by the second design iteration. From the second iteration the best design idea had been chosen and a paper prototype was had been developed and tested to address possible design flaws. The results from this first test were taken to the next iteration that will be covered in the next chapter.

3.1 System Requirements

As mentioned already in chapter 1 and 2, there are components missing that prohibit the older rehabilitating adult to perform self-management. Based on these missing components, Goolkate (2018) set up a list of requirements the technology should fulfil. This list is split up into three categories: *Requirements based on supporting the missing components, general requirements for the rehabilitation process,* and *technology-related requirements.*

Within the first category, requirements are set that help in supporting knowledge, competence, and skills. Firstly, Goolkate (2018) states that "the technology should cover the knowledge gap of the older adults. It should provide the right information at the right time" (p. 20). This is mainly because their cognitive skills are lacking most of the time and because of this, the technology should be an extension of the user's cognition. Secondly, according to Goolkate (2018), the lack of confidence in performing certain tasks and activities should be bridged by the technology by means of providing self-esteem through coaching. The technology must be safe to use so they can gain the user's trust. Finally, the lack of skills must be tackled by providing the opportunity to set more personal goals, since there is a lot of variation between each patient's physical and cognitive skills. This could be done by including the ADL.

The second category covers two requirements that could provide general support in the rehabilitation process. One of the requirements stated by Goolkate (2018), is that the technology should create a sense of competition that suits the user. According to Goolkate (2018), this could stimulate the rehabilitation process. This could, for example, be achieved by implementing a scoring system in the exercising execution. Besides this, the technology should give older adults the feeling that what they are doing (together or alone), is useful. This could be achieved by letting them do activities that matter.

Finally, there are some requirements that are related to the technology itself. Goolkate (2018) states that the technology should start the interaction and respond to the individual by approaching the user personally. In addition to this, the older adult should be able to see their rehabilitation progress in a clear and understandable way. Also, according to Goolkate (2018), the technology should be as simple as possible and familiar to the older adult, such as a TV for example. By doing this, the technology is no longer seen as an abstract concept by the user. At last, the technology must encourage the user by means of motivational feedback, compliments, and supportive advice. These requirements will make it easier and more attractive for the older adult to use the technology, thus increasing activity adherence.

3.1.1 The Fogg Behaviour Model

For this design project, it is important to establish a system that triggers the desired behaviour; older adults taking more initiative in the rehabilitation process to increase their autonomy. The goal of such a design is in line with the definition of a persuasive technology as stated by Fogg (2009); "learning to automate behaviour change" (p. 1). Fogg states that in order to make a technology persuasive, it needs the factors *motivation*, *simplicity/ability* and *triggers*, each again consisting of several elements. According to Fogg (2009), these factors are key components for making a technology persuasive, thus changing some user's behaviour. First of all, the factor *motivation* simply measures to what extent a technology motivates the user to do something. Secondly, *simplicity/ability* covers the amount of effort, either physically or mentally, it costs to do something. Humans are lazy by nature (Selinger et al. 2015) and because of that, products that require users to learn new things often tend to fail (Fogg, 2009). Finally, a *trigger* is key when making a technology persuasive. Fogg (2009) states that without a trigger, the desired behaviour won't occur even with the presence of motivation and simplicity. In the section 3.3.6 Fogg's Behaviour Model (FBM) was brought up by looking at each element of every factor, as listed below, to get a better idea of which of these elements are not addressed enough in the current technologies. After that, the factors that belong to the missing elements were picked out and possible solutions to fill the gap, caused by the missing elements, were generated. Below is a list of elements grouped per factor.

- **Motivation:**
    - *Pleasure/Pain*
    - *Hope/Fear*
    - *Social Acceptance/Rejection*
- **Simplicity/Ability:**
    - *Time*
    - *Money*
    - *Physical Effort*
    - *Mental Effort*
    - *Social Deviance*
    - *Non-Routine*
- **Triggers:**
    - *Sparks*
    - *Facilitators*
    - *Signals*

3.1.2 Overview of Requirements

To get a better idea of what requirements must be fulfilled, a mind map has been made, which is shown in figure 2. This mind map was also part of a free brainstorm session and therefore includes additional ideas and requirements. For better understanding, the requirements are categorized in intrinsic values such as persuasion, non-intrusiveness, reliability, and sustainability; with each of these values containing a set of extrinsic values; making these subset values more functional.

The definition of an intrinsic and extrinsic value stated by Zimmerman (2015) is as follows: “A non-derivative value of a certain, perhaps moral kind” while an extrinsic value is more particularly the derivative value of the intrinsic value, e.g. an instrumental value to reach the intrinsic value. Although Zimmerman’s definition of intrinsic and extrinsic values is not entirely in line with the usage in this mind map, the intrinsic values in this mind map still consist of ‘instrumental’ values to achieve them. For this reason, they will be called intrinsic and extrinsic values. The requirement “persuasion” follows from the FBM mentioned in section 3.1.1. In addition to all this, possible requirements that could answer the missing components *knowledge*, *competence*, and *skill* are also integrated; Like ADL’s to create activities that matter, providing knowledge by giving them feedback, or offering them confidence by providing personal advice and checking the correctness of exercises.

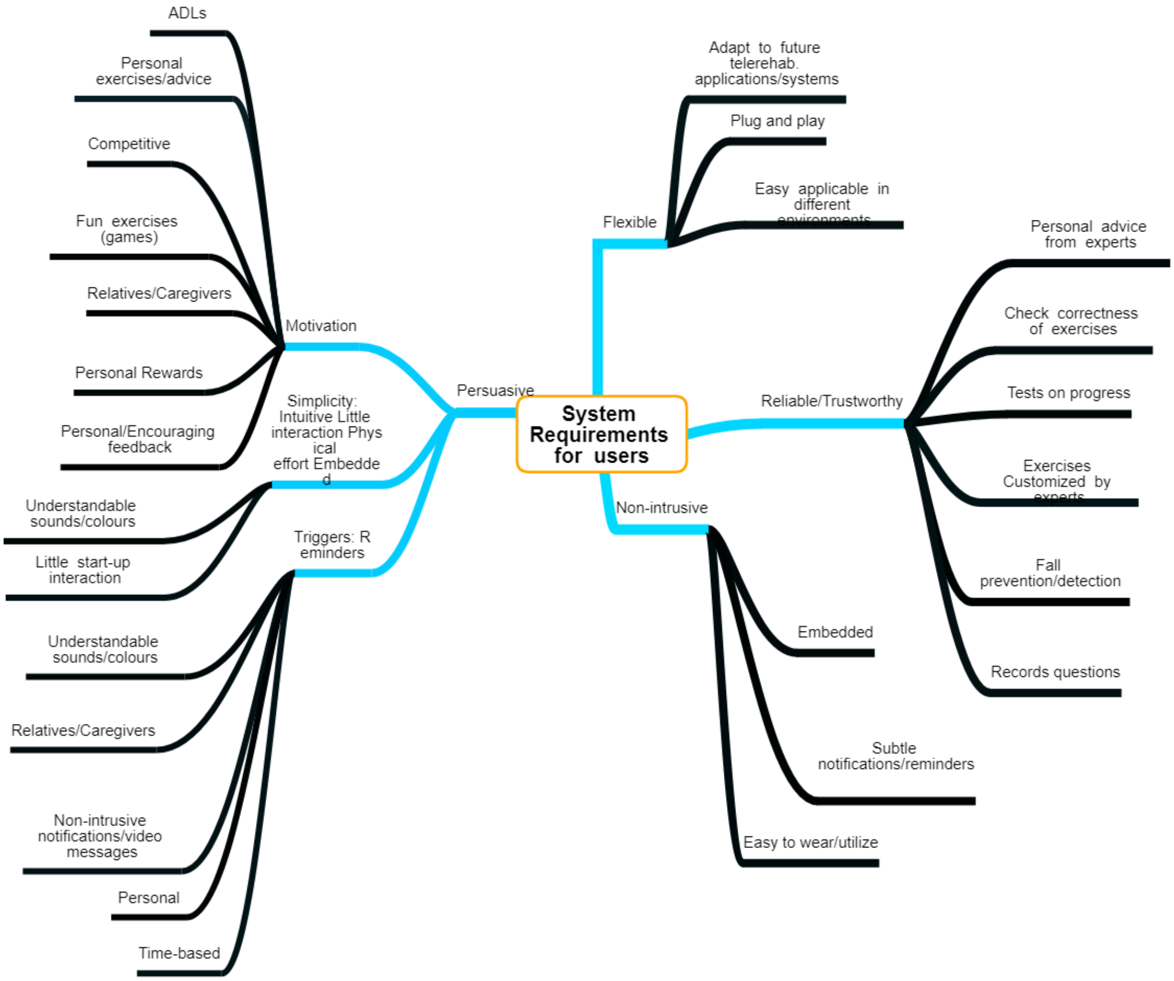

Figure 2: Requirements for users mind map

In addition to the mind map above, another mind map has been created for the secondary users, e.g. caregivers, simply because they might also have to use the system to a certain extent; for example, accessing some user data to evaluate progress, or to remotely prepare a training for the patient. Just like the previous mind map, this one is categorized in intrinsic values, each again consisting of supporting extrinsic values. This mind map will be taken into consideration during the design process. However, priority will go to the primary usage, the usage by rehabilitating older adults.

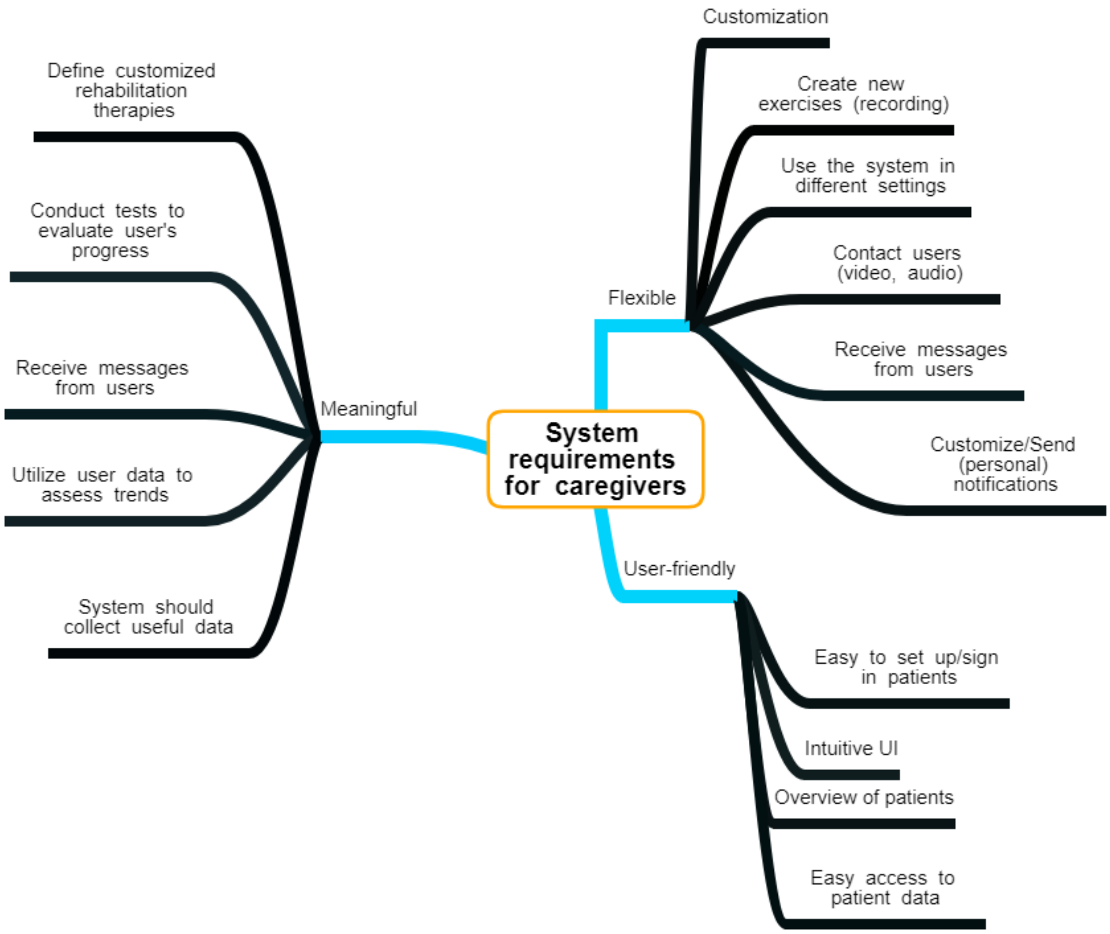

Figure 3:Requirements for caregivers

3.2 Product Ideation: Iteration I

During the SOTA a lot of design ideas were created that will be discussed in this section. This was partly because of the inspirational nature of that research, but ideas also came from external sources such as experiences, meetings with professionals and informal publications like videos and other media. Some of these sources will be discussed during iteration II. The design ideas that were made during the first phase, exists of both complete systems and useful application features that came up. All of these design ideas were created prior to the end of the SOTA research and some have been discarded due to a variety of reasons that will be mentioned later.

During iteration II a design idea has been made, resulting from the SOTA. This part will once again discuss FBM and shows how free brainstorm sessions and inspiration from informal sources resulted in the final design. The list below shows the results of the first brainstorm session during the first iteration. Majority of the list consists of some application features that might be useful for the final design.

- Using smart wristband for scanning patients to acquire patient data
- Scan token to activate exercise systems (e.g. exergames on tv, virtual home trainer, smart environments)
- Sensors and UI integrated in a walker
- Use tablet for notifications (e.g. reminders, encouraging messages etc.)
- Users should receive video feedback to make it more personal
- Whenever a user has a question he/she should be able to record that question to automatically send it to their caregiver
- Emergency button for device or application
- ADLs
- Virtual personal buddy
- Pendant or wristband for tracking activity adherence

In addition to this list, there are two system architectures that came up while doing the SOTA research. These ideas have been evaluated together with an expert. Both the ideas and their evaluation will be briefly discussed in the upcoming paragraphs.

3.2.1 Cloud-based AR Walker

The Cloud-based AR Walker consists of integrated sensors and a HoloLens UI. When using the walker, the older adult gets real-time feedback on their performance by means of a holographic physiotherapist. Moreover, while walking, they have the option to play minigames that make walking/exercising more interesting and fun by adding virtual components to the real environment. One could think of collecting coins by following a virtual trail or looking for hidden items in the environment. Once their exercise or daily activity is done, the results get uploaded to a cloud-based server that can be accessed by both the older adults and their caregivers. Figure 4 describes the system architecture.

A problem with this design idea is that, despite the fact that a holographic personal coach sounds like the optimal solution, the actual implementation might exclude many older adults from using it, due to the fact that many older adults have decreased vision; which makes the usage of the HoloLens impractical. A second argument is that most of the older adults don’t even use a walker during rehabilitation, and if so, only for a short period. Despite this downside, the element of real-time feedback is something that’s desired when building a system for rehabilitating older adults. Hence, this element should be included in future designs.

3.2.2 RFID Station Scoring System

Another system idea that was made up, is an RFID architecture where the user would wear a pendant or bracelet that consists of an activity tracker, an RFID chip, and pre-scheduled physical activity reminders. Whenever the older adult has to go for a walk or do some other physical activity, he/she will get a notification through their wearable, reminding them to perform that task. When starting the task, the user passively scans the wearable at point A, then walks to point B, C, or D, and finally goes back to point A. Every time the individual reaches one of the points their RFID tags will be scanned. The final results will be displayed on a scoreboard in a common area, where they can see the distance they've walked (from point A to B, C or D etc.) and the time it took them to walk such a distance. Using a scoreboard adds a competitive element to their daily activity adherence and therefore potentially motivates them to outperform fellow rehabilitating older adult.

Be that as it may, there are several reasons why this design might not create the desired impact. There exists a high chance that older adults either do not want to wear a sensing device (e.g. smartwatch or smart pendant) or simply just forget to wear the sensing device. Moreover, to make an activity only competitive is not enough since some users might attach less value to their score and therefore not making it more attractive for them to perform physical activity. Besides that, they won't know whether they are walking properly or not because there is no real-time feedback. Implementing it as a personal progress overview, where only the user can see his/her progress, might be more attractive. Using RFID in the system should still be considered as a possibility since it offers great flexibility and almost always requires little interaction. Also, the reminders could perhaps be implemented in a different way to still provide the user with triggers and cognitive support.

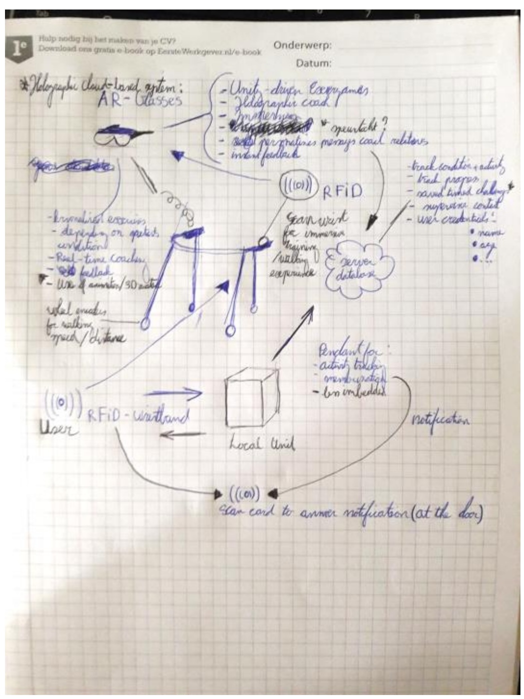

Figure 4:Cloud-based AR walker

3.3 State of the Art Research

3.3.1 Current technologies for rehabilitation/support in older adults

In the past few years, many new technologies have emerged, which in return create new opportunities when it comes to telerehabilitation. However, most of these applications are either only proofs of concepts or still in the experimental phase. Antón, Goñi, Illarramendi, Torres-Unda, Seco (2013) and Gschwind et al. (2015) describe Microsoft Kinect based systems suited for telerehabilitation, prediction, and prevention. In a similar way, Ortiz-Guttirez et al. (2013) state the use of exergames for patients with MS. Feedback in these kinds of systems is normally provided by including avatars in the UI (User Interface) that mimic the users. In contrast to this, there are research groups that have developed wearables that use real-time force-feedback to guide people's movement (Bao et al. 2018). Other technologies described and tested are elder-care environments that use a TV-channel based applications that monitor users' wellbeing and home-based self-management systems that aim to support the user's autonomy (Amaxilatis et al. 2017; Doyle et al. 2014; Cesta et al. 2011). Because telerehabilitation is a topic which is rather new, relatively few applications have emerged as potential products. Later sections of this paper will go more in-depth on how these systems and applications work, and how they are used.

3.3.2 Categorization

The technologies described in the previous section could be grouped into different categories. For the sake of this paper's structure, and for convenience, the technologies will be placed into three categories; Exergaming, smart environments, and wearable technology.

The first category can be considered as any exercise method that makes use of full-body interaction to play computer games. According to Skjæret-Maroni et al. (2016) and Klompstra, Jaarsma, and Strömberg (2014), the general goal of exergames is to improve physical exercise. For clarity, one could think of Microsoft Kinect based systems as exergames. The category smart environments cover environments usually consisting of embedded sensors and actuators as extensions of cognition. Since this paper focusses on older adults as user group for the technologies, the definition of a "smart home", described by Cesta et al. (2011), will be used to define a smart environment; A system which is responsive to people's needs and actions, a pervasive accessory to human cognitive and physical capabilities. The last category, "wearable technology", will consist of devices that can be worn by older adults to help them with self-management of rehabilitation or support them in daily life activity (Bao et al. 2018; Gschwind et al. 2015). Categorization of some technologies can be argued since there will be some overlap between certain categories and their technologies. Due to this, some systems will be mentioned in more than one section.

The following sections will cover current applications in each of the categories. This will be done by assessing the technology and architecture they exploit, followed by a critical look at the overall feasibility. Since these sections are more about understanding how technologies within these categories are generally applied, some of the paragraphs only cover one product and its corresponding paper(s) at a time. In some cases, I will compare multiple applications in one paragraph to point out similarities, weaknesses, or strengths.

3.3.3 Exergames

Within the category of exergaming, there are a lot of applications that make use of camera-based technology such as Microsoft Kinect, or balance boards and accelerometer-based controllers. Antón et al. (2015) describe in their paper a system named KiReS [1]which is a telerehabilitation system that uses video tracking technology that allows patients to interact with the system through an interface that recognizes movements, objects and speech. A natural form of interaction is possible due to the use of two 3D characters shown in figure 5**.** One of the avatars shows the exercise to be executed, while the other represents the user by following their movement through motion tracking, thus providing useful feedback. Besides that, the user can consult the information list at the top which shows exercises to be done in the session (Antón et al. 2015). Although this system seems to successfully implement exercise training and flexibility for its users, it forgets to cover things like UI simplicity and triggers, which could be key components in making a persuasive design.

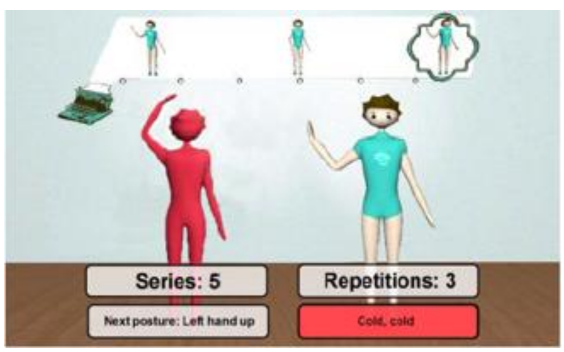

Figure 5:UI of exercise screen (Antón et al. 2015)

The following system uses similar components such as a 3D camera and avatars for feedback. Gschwind et al. (2015) describe an ICT-based system called IstopFalls[2], which uses Microsoft Kinect. However, IstopFalls is primarily focused on fall prevention of independently living older adults. To achieve this, they extend their system with a wearable Senior Mobility Monitor (SMM) which continuously monitors fall risk and more. This sensor will be further described in a later section. Just like KiRes, IstopFalls provides exergames like balance games and strength games, the possibility to review performance during exercises, and the ability to change level difficulty. In addition to that the system offers automatic

[1] KiRes refers to Kinect Rehabilitation System

[2] IstopFalls: http://www.istoppfalls.eu/

reminders to exercise, cognitive games that target semantic and working memory, a social platform, and more advanced information for the user based on the data extracted from the wearable sensor and the finished exercises (Gschwind et al. 2015; http://www.istoppfalls.eu). Compared to KiRes, the IStopFalls system seems to put more focus on the older adult's autonomy.

Besides covering the development and design of exergames, there are research teams that examine the feasibility of exergaming, by evaluating already existing applications. Skjæret-Maroni et al. (2016) mention two exergames which both utilize camera-based technology such as Kinect; SilverFit[3] and YourShape: Fitness Evolved[4]. While the latter is merely a game designed for commercial purposes, the other is designed for older adults that require exercise or are rehabilitating. SilverFit is an exergame company that develops exergame applications, consisting of multiple minigames that are customized to the user's needs, for older adults in exercise and rehabilitation settings. While SilverFit also exploits camera-based technologies similar to the ones previously described, it puts more focus on the personalization of the exergame. Although Antón et al. (2015) mention the possibility to apply KiRes in multiple fields of rehabilitation, SilverFit already allows multiple applications for their system, and within those applications, it is possible to set up an exercise program which fits the patient's diagnosis[5] (http://silverfit.com/nl/). Just like KiRes, SilverFit seems to put more focus on the exercise programs rather than the menu's UI[6] simplicity. Moreover, the menu's UI looks like it is designed for the caregivers. In addition to that, there seems to be no feature that reminds the older adult to exercise. On the other hand, these assumptions are based on video sources and limited content from the website. No scientific literature has been consulted for constructing these statements. The validity of these statements is therefore questionable.

Exergames have the potential to offer rehabilitation aid to a variety of patients. A study conducted by Ortiz-Gutiérrez et al. (2013) describes a similar rehabilitation approach as SilverFit. However, in this study they test existing Xbox 360 Kinect exergames, designed for commercial purposes, as a rehabilitation tool for MS patients; with the aim to improve balance and postural control (Ortiz-Gutiérrez et al. 2013). Similarly, Klompstra, Jaarsma, and Strömberg (2014) assessed the influence of the Nintendo Wii on exercise capacity and adherence to daily physical activity of elderly heart patients. The Nintendo Wii uses wireless accelerometer-powered controllers that enable the patient to interact with the console through movement (Klompstra et al. 2014). While looking at these two systems, it might be worth to consider designing a system/application that is applicable to a broad variety of rehabilitating older adults, or at least a system that could be easily adapted to other types of patients in the future.

Majority of the applications described in this paragraph allow user flexibility for both patients and caregivers and don't require additional handheld controller devices or body sensors for interaction. However, additional body sensors could be implemented to get better and/or more insight into the patient's performance, activity and condition. Finally, many of the systems described in this section emphasize how their technological application could motivate users to exercise more regularly, thus developing a greater adherence to daily physical activity. However, almost no focus was put on making the users take initiative in attending daily physical activity.

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[3] SilverFit: http://silverfit.com/nl/

[4] https://www.youtube.com/watch?v=-MDq694ltSY

[5] Currently possible for amputee patients, COPD, CVA, hip arthrosis, knee arthrosis, total hip arthroplasty, total knee arthroplasty (http://silverfit.com/nl/)

[6] https://www.youtube.com/watch?v=Txs98oApJJU

3.3.4 Smart Environments

There are some parties that have been developing multi-agent, closed-loop architectures to provide ambient assisted living (AAL) environments for elder care; whether it is for support in personal wellness or the purpose of rehabilitation. Cesta et al. (2011) explain a proof of concept they developed, called RoboCare and describe the system as follows: “a multi-agent system with intelligent fixed and mobile robotic components”. More specifically, it is a prototype smart environment consisting of a robotic mobile platform that integrates the capabilities of a SLAM[7] algorithm and a path planner, and intelligent stereo cameras for localization and tracking of people. The robotic architecture consists of a robotic mediator, interaction manager, and a daily activity monitor. Schematics for both RDE and service cycle can be seen below. As shown in figure 6, the daily activity monitor utilizes constraint-based temporal knowledge to deal with changes, hence judging states (defined by caregivers) based on its reasoning capabilities. The goal of the system, as stated by Cesta et al. (2011), is “to ensure, through daily activity monitoring, the adherence of the assisted person’s behaviours to “good living” behavioural patterns”. However, it could be questioned to what extent such a robot is not intrusive, or whether it is efficient and acceptable.

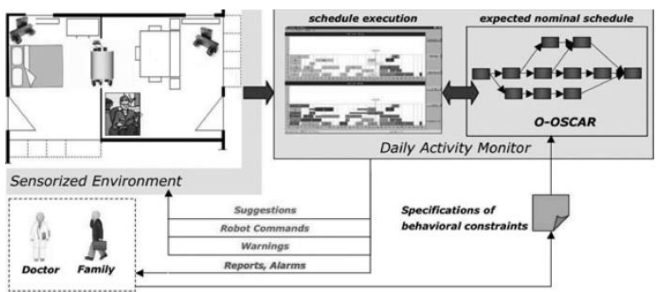


Figure 6: The complete service cycle in the RDE (Cesta et al. 2011)

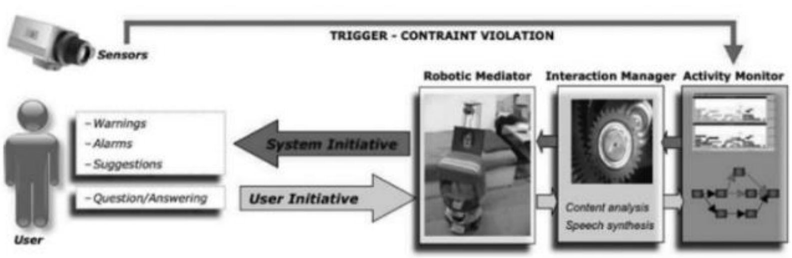


Figure 7: The general schema for mixed-initiative interaction generation in ROBOCARE (Cesta et al. 2011).

In contrast to RoboCare, there are also AAL architectures that use different mediators. An AAL architecture developed by Amaxilatis et al. (2017) uses a TV to access services such as communication platforms, informative pages displaying health feedback, Google Calendar, and Flickr Photo Gallery.

[7] SLAM refers to Simultaneous Localization And Mapping

Also, it deploys sensor units throughout the living environment, which measure activity and other biometric data; thus, creating a multi-agent architecture similar to the previous one. Amaxilatis et al.

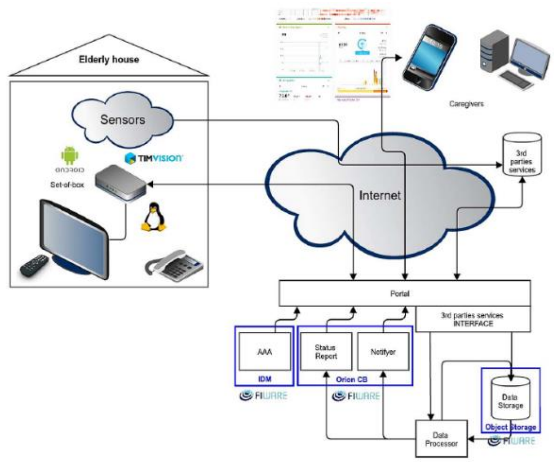


Figure 8: System's architecture (Amaxilatis et al. 2017)

(2017) state that the system uses cloud-based services for most of its features. For example, biometric data sent to the cloud base is used to identify significant events related to the elder's well-being, then locally stored and eventually used to trigger notifications, inform relatives or caregivers, or produce a periodic report (figure 8). In addition to that, caregivers and relatives can access the cloud base services through a web portal via PC or smartphone at any time Amaxilatis et al. (2017). Yet it solely serves as a communication platform that monitors the user's wellness, instead of motivating them to attend daily physical activity or to increase physical autonomy.

The system described below, using a likewise approach, additionally includes a tablet app. Doyle et al. (2014) designed, deployed, and tested a closed-loop AAL environment that also consults multiple sensor units to recognise behaviour and uses an iPad application named YourWellness to provide informational feedback and interventions. Around 100 sensors are placed in each home that, in combination with ground truth data and behavioural recognition data, establish an intervention approach that will be used to send feedback and interventions to the resident (Doyle et al. 2014). A system overview is shown in figure 9. Doyle et al. (2014) also explain how automation for tasks like turning on/off lights and open/close doors/windows/blinders, using a controller, is deployed and shows that the system is also capable of monitoring home security and energy consumption. The relevance of such extensions for rehabilitating older adults is questionable.

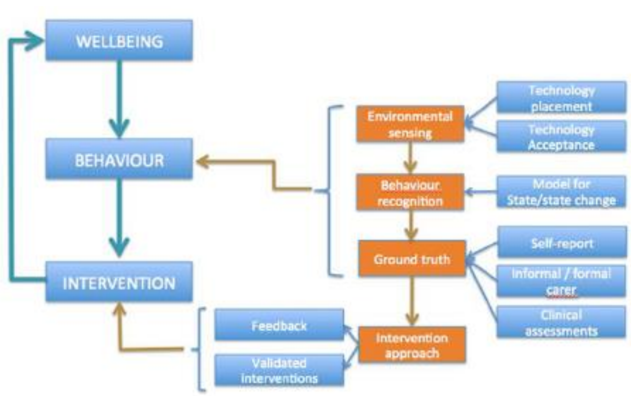


Figure 9: SE system overview (Doyle et al. 2014).

Although the systems described in this section show very similar architectures, each of them has a different approach resulting in different usability of each system. While one system focuses more on monitoring of elderly people, another system puts more focus on elderly people developing a healthier lifestyle or making them more independent. Even though these systems don't necessarily cover rehabilitation, it is not impossible to integrate them in rehabilitation settings.

3.3.5 Wearable Technology

Sometimes wearable technology is used to get additional information, as mentioned in the section "Exergames and their methods", by monitoring daily activity or to enhance movement performance and adherence. The IstopFalls system previously described also exploits an additional sensor unit in the form of a pendant. The SMM consist of an accelerometer and a barometer which are used to monitor the older adult's activity. More specifically, the purpose of the SMM is described as follows: "to detect walking distances and sit-to-stand transfers during daily life activities" (Gschwind et al. 2015). Similarly, the wearable application developed and described by Boateng, Batsis, Proctor, Halter, and Kotz (2018) is worn on the older adult's wrist to monitor in real time their daily activity levels with the help of similar sensors. Boateng et al. (2018) state that the wearable application consists of four components. The data collector that samples data from the sensors, an activity-level detector that computes the activity level of the older adult, the activity-level monitor that tracks and logs the minutes spent per day, and the display which shows information related to progress and presents daily encouraging reminders based on the progress made. Like the authors state: "Our system, unlike Fitbit[8] and other commercial devices, is open-source and could be modified to compute other statistics for exploring activity patterns of older adults and include in-app messaging to facilitate engagement by the research/clinical team". On top of that, the application is user-friendly because the app doesn't require any interactivity and frequent charging due to the long battery life (Boateng et al. 2018). A point to consider for both wearables is the likability that older adults, especially the cognitive impaired, keep wearing them or remember to put them on.

In contrast to these two sensory devices, there is one more wearable system that is more elaborate and contains more components. This is the balance trainer covered by Bao et al. (2018). This wearable requires more interactivity in terms of that its user needs to select the exercises and use the smartphone for configuration. Besides that, the system is larger in scale because it consists of an elastic belt, which is to be worn by the user, that carries more sensors used for detailed measuring and actuators used for real-time force feedback. When a certain threshold is exceeded during exercise (due to postural change), a signal from the sensing unit is sent to the tactor bud accessory which analyses the signal and activates the right tactor to offer vibrotactile cues (force feedback). In a like manner to the other wearable sensor devices, it sends some data to a server which can be assessed by caregivers who in return can send a customized exercise program to the user by email (Bao et al. 2018). A disadvantage of this wearable could be that it is more intrusive (due to its size) and therefore less appealing to the older rehabilitating adults.

Despite the similarities between the three sensor applications described in this section, a trade-off must be made between whether one would desire a more detailed architecture including physical feedback and detailed measurements, but also more interactivity; or a less detailed architecture which allows more

[8] https://www.fitbit.com/home

flexibility and less components, but also less detailed measurements and minimal immersion. In the last case, it could be beneficial to integrate this as a system extension rather than using it as a system on its own. The next section addresses the shortcoming of the state-of-the-art applications, their usability, and the improvements that must be done to solve the problem mentioned in the introduction.

3.3.6 Improvements on the state-of-the-art

To tackle the problem stated in the introduction, a system must be designed that triggers the desired behaviour; older adults taking more initiative in the rehabilitation process to increase their autonomy. In the previous chapter, FBM made its introduction by explaining the factors and how it should be used. In this section, it will become clear whether the factors from FBM are present in the current technologies or to what degree they are lacking. The reason for using FBM is because it offers a systematic approach to evaluate factors that influence behaviour change. In addition to FBM, we'll assess the presence of the components *competence*, *knowledge,* and *skill* are addressed. Continuing from this point onward, the strongest points per category will be fully addressed, eventually leading to the conclusion stated in 3.3.7.

Exergaming

All applications described in the previous sections provide support when it comes to rehabilitation, wellness, or self-management. The exergames mentioned in this paper managed to increase physical activity and physical performance to some degree. The KiRes system, for example, increased user performance-accuracy and created a high level of interest among older adults. However, they seem to focus more on the game performance, rather than usability. Extensions like exercise reminders are still missing. Also, according to Antón, Nelson, Russell, Goñi, and Illarramendi (2016), system usage still requires physiotherapists to set up exercise routines. This contradicts the idea of older adults having more autonomy.

Just like KiRes, SilverFit manages to increase general physical activity by making exercising more interesting. However, they do not address any UI components that make it easy for older adults to navigate through the menu or to start up the system. Furthermore, there seems to be no feature that reminds the older adult to exercise. Nonetheless, it is important to know that these remarks are based on video sources and limited sources from the webpage.

In addition to these two systems, IstopFalls 'does' provide signalling triggers in the form of reminders through a tablet app. Nevertheless, according to Gschwind et al. (2015), they still encountered a relatively low adherence, possibly due to older adults having difficulties with adapting to the new technology.

When consulting the FBM, it can be concluded that the factors ability and triggers are still lacking in some of these applications. To achieve the desired behaviour, it is important to fully deploy these factors. When assessing the three requirements stated by Goolkate (2018), it can be concluded that all three are addressed to a certain degree. Firstly, the majority of these exergames is designed to provide the user with knowledge about their rehabilitation process. Some transfer knowledge by means of feedback or minigames constructed according to ADLs (Activities of Daily Living). Secondly, skill is provided in a way such that the level difficulty is adapted to the patient's condition/progress. Finally, competence is partially accounted for by providing the user with immediate feedback on their exercise performance. However, operating an exergame from beginning to end (start up, execute, close down) might not support the user's feeling of competence, as suggested by Gschwind et al. (2015).

Smart Environments

The smart environments covered in this paper have the potential to deliver non-intrusive daily support to older adults. The RoboCare environment mentioned by Cesta et al. (2011) got positive outcomes regarding its acceptability, especially in emergency situations. Research shows that users consider the RoboCare system rather useful and that they see the practical advantage of such a system (Cesta et al. 2011). The authors state that there exists no intrusion due to low familiarity, among the older adults, with its technology. Furthermore, they state that this system can maintain both competence and self-efficacy, which in the paper by Goolkate (2018) refers to the same definition. Even though RoboCare tries to guide the use towards "good living" behaviour patterns, the system doesn't monitor the user's exercise performance and rehabilitation progress. Also, It must be made clear that usability and acceptability have been evaluated by following a video-based methodology for user testing. No actual physical system has been used during the evaluation process.

The other home-based self-management environment seemed to be effective in providing feedback to support the well-being of the older adult. One of the participants in the research (Doyle et al. 2014) even stated the following about feedback messages: they "reinforced my confidence in what I was already doing" (p. 372). Just like the previous system, it puts more focus on the general well-being of the older adult. For it to work in a rehabilitation setting, a lot more must be done to for example make it recognize the correctness of exercises or rehabilitation progress. This might make the use of such a system less obvious.

Similar to the smart environments, the TV-channel based system solely serves as a platform that monitors the user's wellness, instead of motivating them to attend daily physical activity or to increase physical autonomy. Arguments mentioned in the previous two systems, are to a certain degree applicable to this system. In addition to that, Amaxilatis et al. (2017) state that no immediate drastic change of behaviour should be expected. On the other hand, the author also points out the simplicity of using this system because it is an extension of something already familiar to the older adult, e.g. a TV. Other applications could take over this approach to lower the barrier towards new technology.

Although these systems (could) provide good, non-intrusive general support in the older adult's daily life, they might not be suitable enough (yet) for rehabilitation settings unless they would be able to evaluate the user's physical performance and make users effectively motivated and confident in doing exercises correctly. When assessing the FBM again, it becomes clear that most of the factors are addressed to some extent. In terms of knowledge and skills, there is still some work to do. Firstly, Knowledge is provided by use of a mediator like an app, robot, or TV like in exergames, just like RoboCare. However, these measurements should be available on a clear UI, and more focussed on physical performance rather than wellbeing. Secondly, cognitive skills are addressed by means of reminding users of their tasks, but these systems do not train physical skills. finally, competence is provided in terms of helping users in the management of daily activities or other difficulties related to age. This could be very beneficial in rehabilitation settings since it will stimulate the user's confidence in certain tasks.

A major drawback of smart environments is that there is less flexibility in implementing them. When using such a system in a rehabilitation setting, lots of sensors would have to be implemented in the environment which puts a major constraint on the mobility of such a system. Moreover, it might also make the sustainability of such a system more difficult.

Wearables

The wearables covered in this paper are possible alternative/extensions to/for exergames or smart environments, but there are some trade-offs to be considered. Even though research conducted by Boateng et al. (2018) suggested that the wearable application can be used by older adults with sensory impairments, there exist the possibility that older adults, especially the cognitive impaired, forget to wear them again after taking them off when they go to sleep. As pointed out by Gschwind et al. (2015), the mean wearing time of the SMM was approximately 580 hours during a 16-week test period. This implies that participants didn’t wear the sensor every day, or at least not the requested amount of time per day.

In contrast to the above-mentioned wearables, the vibrotactile sensory augmentation device managed to achieve improvements in more specific clinical outcome measures related to balance (Bao et al. 2018). This could be considered an advantage over the other two applications since it involves more specific user-tailored training. Moreover, the inclusion of real-time force-feedback makes the usage more immersive, which encourages better results. Consequently, the system involves a lot more sensors and actuators, hence increasing the possibility of making it more intrusive (due to its size) and therefore less appealing to the older rehabilitating adult. The paper does not address this, even though it could have a significant impact on its use.

For all three of these wearables the number of factors that is lacking according to the FBM, differs. All three of these sensory devices provide triggers in the form of encouraging reminders. When looking at simplicity, only SMM and the wearable wrist application fulfil this requirement, the vibrotactile sensory device requires users to wear a lot more instead of one simple and small device. Also, it requires much more interactivity whilst the others require almost none. The factor motivation, on the contrary, seems to be more present in the latter in terms of that it includes immersion, which might make the exercises more interesting. However, the fact that one would have to wear such a large unit, could perhaps take away that motivation. When looking at all three sensory devices as stand-alone systems, the components knowledge, skill, and competence are not/little addressed. First, skill is addressed by only two of the devices in a way that it extends the cognitive skills (reminders etc.). Secondly, little to no knowledge is transferred to the older adults. Only the vibrotactile sensory device includes knowledge transfer by giving exercise guidelines. Lastly, the component competence only exists to a certain degree in the vibrotactile sensory device.

It has become apparent that a wearable device as a stand-alone system, is not sufficient enough. As already mentioned by Bao et al. (2018), they do require less expert engagement. Nevertheless, too many factors are not sufficiently addressed for it to be a stand-alone system. Using it as an extension, like IstopFalls, might be more effective.

It must be made clear that this section’s purpose was more that of a critical view on the state-of-the-art, and that some of the statements made are based on thought-processes rather than scientific literature. Therefore, some of the statements made in this section could be argued.

3.3.7 Conclusion

Encountering different shortcomings does make it apparent that there is a need for a re-design. However, designing an entirely new system that provides motivational exercises, personal feedback, communication platforms, and detailed daily activity data seems unnecessary since solutions for that exist, such as KiRes or Silverfit, and have mostly been evaluated in detail. Taking this into account, it is more efficient to use the existing ideas, address their shortcomings, and build something on top of that to reach the desired system. Moreover, extending the current applications which are similar in approach, creates the opportunity to develop something flexible which could form a common ground for rehabilitation systems and home-based systems that support older adults. When comparing the different application categories, that of exergaming seems the most solid given the fact that it already fulfils many requirements for rehabilitation in older adults, and because there are already some evaluated fully working systems deployed for usage by rehabilitating older adults. Many of the exergames mentioned in the SOTA, support the components *competence*, *knowledge,* and *skill* to some extent. On top of that, the factor motivation seems to be addressed well enough given the fact that the aim of these exergames is to motivate their users to adhere more to physical activity. Even though some components and factors are still under-addressed, exergames seem to be most promising for now when it comes to rehabilitation of older adults. For these reasons, exergames will be used as a basis to an extent from to answer for the deficiency in some of the components and factors.

Iteration II

Lots of different ideas were generated during phase I of the ideation, but the majority has been discarded during the research process. The last section showed that most of the telerehabilitation technologies developed so far fulfilled the requirements from 3.1 to a certain extent. This is especially the case for exercise games and because of this, it has been decided that the aim of the design project is to extend the existing exergames applications to meet the missing requirements. The end of the last section explained with the aid of FBM what requirements are still unanswered in many exergame systems. This process will be further explained below. After this, the results of another free brainstorm session will be described. As mentioned earlier, this brainstorm session supported with the help of informal sources.

3.4 Product Ideation: Iteration II

3.4.1 FBM

After assessing the three factors of the Fogg Behaviour Model in exergames, it has become apparent that two of the three factors show neglection, e.g. simplicity and triggers. One of the aims of exergames is to motivate older adults in doing exercises; doing so by gamifying the rehabilitation process, thus making it more intuitive and fun (http://silverfit.com/nl/; Gschwind et al. 2015; Antón et al. 2013). SilverFit states that research in "motivation in connection to SilverFit" showed that patients achieved the highest scores in intrinsic motivation[9] ("Therapy adherence can be increased by the use of computer games", 2017). Besides that, Goolkate (2018) showed that motivation is not the primary problem with older adults. Given these facts, it will be considered unnecessary to further assess the elements of "motivation". While assessing the elements of simplicity (ability) and research studies, it came to the attention that the element 'mental effort' needs more attention. Gschwind et al. (2015) explain that, although the iStopFalls system resulted in bigger adherence and improved skills like stepping reaction, regular exercising wasn't always achieved probably due to the pioneering use of a new technology, resulting in technical difficulties. Especially for older adults that are cognitive less capable, it seems reasonable to believe it takes more time to understand and accept new technologies in their life. In addition to that, most other studies mention that use of these applications requires supervision or guidance (Ortiz-Gutiérrez et al. 2013; Gschwind et al. 2015; Skjæret-Maroni et al. 2016).

The other factor that needs some design attention is "triggers". Many of the discussed articles mention how "good" their system or application is in motivating their users to exercise more regularly, which results in higher physical activity adherence. However, some of them do forget to mention the fact that elderly people, especially the cognitive impaired, tent to forget training sessions, to go for a walk, or to do some exercises; as mentioned by Goolkate (2018) and physiotherapists at ZGT. Systems like SilverFit should extend the elderly user's cognition in such a way so they don't forget these things, causing neglection of their rehabilitation process. Fogg (2009) mentions that triggers are vital design components when it comes to designing persuasive products. Fogg (2009) also states that "without an appropriate trigger, the desired behaviour will not occur even if both motivation and ability are high" (p. 3). Fogg (2009) describes three types of triggers: sparks, facilitators, and signals. There's no lack of motivational factors in the majority of exergames, so sparks will be ignored. A facilitator can also be considered

[9] Intrinsic motivation describes the 'will' to take action ("Therapietrouw kan verhoogd worden door computerspellen", 2017)

irrelevant since this will mainly be covered by the design pattern proposed earlier, e.g. simplicity. Implementing a trigger in the form of a “signal” is probably most suiting.

3.4.2 Design of Simplicity

Decreasing the amount of required mental effort caused by technological barriers can be done by making it easier to start up an exergame without any help of caregivers. After conducting another free brainstorm session, a possible solution for this requirement that came up was the use of an embedded cloud-based RFID architecture. More specifically, utilizing this RFID architecture with RFID wristbands[10] which allow the patients to store their credentials and other relevant patient information. This could be done with the use of a laptop and the help of a caregiver. To prevent the older adults from not wearing these wristbands, it should be considered to integrate the RFID tags in the already used hospital tags that patients have to wear. This makes it less apparent, unlike the already mentioned wearables. Besides the wristbands, the exergame system on the TV should be extended with a unit that consists of an RFID reader and a transmitter of some sort. This will allow the user to scan their wristband, containing their data, at any given time, resulting in the system to start up and displaying their profile with the saved progress from previous training sessions. After the patients are done with their exercises they would only have to scan thein their wristband again to save the progress made within that session and to turn off the device.

There have been multiple applications where RFID has been utilized to simplify the life of an older adult. Joshi (2015) for example describes a system where older adults can unlock their doors through RFID authentication. Furthermore, Huang et al. (2008) talk about a system that also utilizes RFID to assist independently living older adults. Both systems are totally different from each other; while the first one requires more interaction, e.g. unlocking the door, the other one doesn’t require any interaction since it is only passively tracking the user’s activity. Despite their different implementation and flaws that sometimes occur, like not being able to properly open/lock the door (Joshi, 2015), it could be considered reasonable to assume that RFID offers the simplicity that is needed.

Extending systems like SilverFit with the proposed RFID architecture, potentially makes it easier for the patient to start an exercise by themselves and ultimately giving them more confidence in using novel technologies, resulting in more initiative from the patient’s side. Nonetheless, it must be pointed out that this a strong presumption based on the research done in the SOTA and the above two mentioned sources. It must, therefore, be tested to prove the effectiveness.

A big inspiration for this idea is the RFID architecture used during the event ‘*Star Wars Identity’* [11] where they used a flawless RFID system that would store user data with the help of RFID wristbands that were handed out when entering the event. Every time when scanning the wristband, it would either retrieve one’s data from a cloud server and show it to that person or update their profile with new data. The event succeeded in showing the simplicity of RFID and has therefore contributed to the design process of *simplicity* for this rehabilitation system.

[10] https://www.wristbands.com/blogs/blog/how-rfid-wristbands-work
[11] http://nl.starwarsidentites.com/#!/

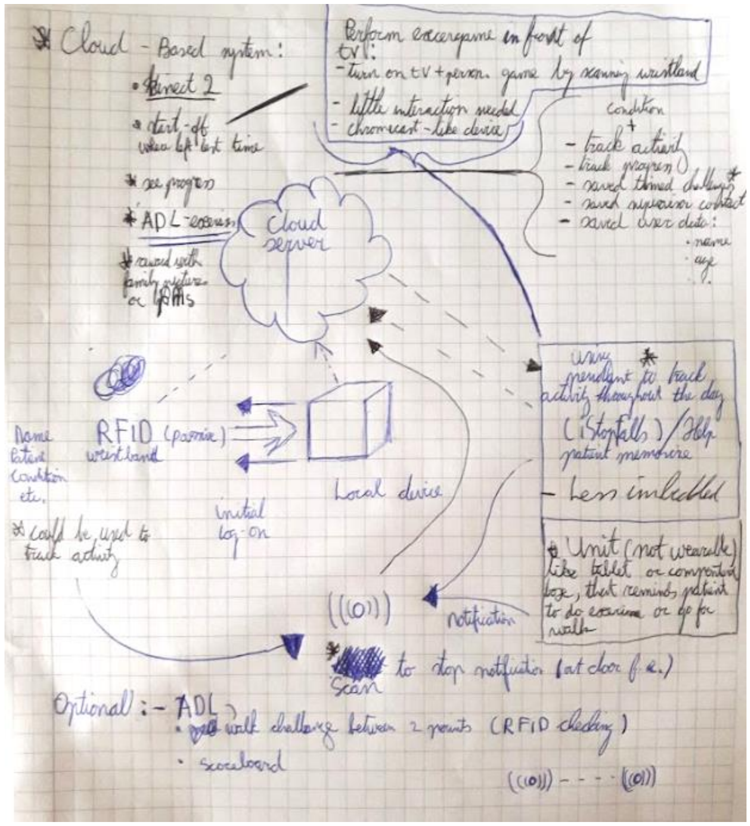


Figure 10: Cloud-based RFID system

3.4.3 Design of Triggers

It has been pointed out already that a persuasive technology cannot exist without an appropriate trigger, even with the presence of motivation and simplicity. In the case of this design project, the signalling trigger should act as a reminder. Gschwind et al. 2015 mention the use of reminders via a tablet to tell users they should do their exercises. Several studies (Kobayashi et al. 2011; Page, 2014; Voumvakis, 2014) show that users are perfectly able to use devices like smart tablets, as long as the interface is user-friendly. The use of a tablet as a system extension, solely for the use of reminders and maybe family related messages, is a convenient design option. However, another option is the use of a wearable app such as previously mentioned GeriActive (Boateng et al. 2018), specially designed for older adults. On the other hand, it has already been pointed out that there exists the possibility that older adults easily forget to wear such a unit. Moreover, a reasonable assumption, also pointed out by an expert at ZGT, is that such notable wearing units might not appeal to the patients and therefore might not be worn at all.

An idea that was generated while thinking of a possible encouraging trigger, is the use of an interactive photo frame that uses sound and light to notify its users. To make it more personal, the photo frame will display photos of the user's interest, such as family pictures or landscapes. A couple of times a day, the photo frame will emit sound and light when a reminder is received. The reason for using light is not only to potentially increase the attention drawn from users but also as a back-up since many older adults have decreased hearing abilities. When opening the reminder, it shows an instructive video from the patient's caregiver, telling them to attend some physical by means of playing the exergame. This is also where the usage of the RFID comes in.

Several studies have indicated the psychological effects of colours on human behaviour. In a recent study review, Elliot (2015) stated that colours can have effectiveness in different areas, such as attention, performance, or eating and drinking. This categorization of colours and their psychological effects come from the findings that have emerged from several studies about the different areas in which colour can work. For example, Elliot (2015) states that "blue light has been shown to increase subjective alertness and performance on attention-based tasks" which is backed up by multiple sources (Lockey et al. 2006; Lehr et al. 2007; Viola et al. 2008; Cajochen et al. 2011 and Taillard et al. 2012). Similarly, the author states that "red stimuli have been shown to receive an attentional advantage" (Lindsay et al 2010; Tchernikov and Fallah. 2010; Buechner et al. 2014; Pomerleau et al. 2014; Sokolik et al. 2014). Yet, Elliot (2015) together with sources, show that the same colours can also have different psychological effects (Cherry and Gans, 2018; Nunes, 2018). Nonetheless, Elliot (2015) does emphasize that "the existing and theoretical and empirical work is at an early stage of development" and that it is therefore "premature to offer any bold theoretical statements, definitive empirical pronouncements, or impassioned calls for application". For these reasons, the influence of light on older adults must eventually be evaluated besides the photo frame, to measure its effectiveness in this design project.

3.4.4 Final Design Idea

Using RFID to start and shutdown exergames significantly decreases the required interaction and hence, lowers the barriers to using and adapting to technology. Together with the interactive photo frame that supplies the user with encouraging reminders through video messages, it will address the shortcomings of current applications and steer the user's behaviour towards the desired behaviour (taking initiative in the rehabilitation process), therefore reaching greater autonomy in rehabilitating older adults. By implementing the potential simplicity of RFID and the potential effectiveness of encouraging reminders this system design is taking care of both *simplicity/ability* and *triggers* in addition to the factor *motivation*, and therefore could be considered a persuasive technology. Caregivers could benefit from using the system since they will have access to data (obtained from measurements in exergames) regarding the user's condition and progress, they can monitor the user's activity adherence with the aid of the RFID architecture, and because they can work from a remote distance. Besides that, it might even help them with better understanding the patient's recovery although this is just a presumption and should therefore eventually be proved. Nevertheless, it will be designed with the goal to acquire the behaviour not fully achieved by the existing applications; doing so by primarily putting the older adults at the centre of the design process, for now.

4| Specification

To get a better idea of how the proposed system should work and should be used, two paper prototypes have been made, of which one has been tested with the target group. With the help of these paper prototypes, possible flaws and errors will be tackled and the general usage of this system will be established. This chapter will cover both iterations of the paper prototype by means of describing their functionality and their evaluation.

4.1 Paper Prototyping I

The reason for building the first paper prototype was primarily for defining the user flow of the interactive photo frame and the RFID architecture and trying out different UIs that could possibly work for older adults. This is a significant part of building a successful working prototype since it puts the user at the heart of the design process and therefore creates a better user experience. The paper prototype begins at the initial sign up of the rehabilitating patient and goes all the way through the process of getting a reminder, starting up and playing the exergame, and shutting down the system. Part of this paper prototype can be seen the Appendix A.

4.1.1 Paper prototype testing I

Testing of this paper prototype has been done without any test subjects because it has solely been used as tinkering tool for defining the UI and user flow. While playing around with the different steps that had been made, many questions arose that were tried to be answered by means of altering the paper prototype a little every time a question came up. The most relevant questions that came up are listed below.

1. How will users register when using the photo frame app for the first time?
2. How is the authentication part of registration going to be done? Will there be password and email usage? What user information is relevant for setting up their profile?
3. When does the user data transfer to the RFID tag take place; e.g. when do the users scan their wristbands for the first time to complete registration?
4. How does point 3 take place; e.g. will the photo frame be RFID compatible so that they just can hold their tag against the photo frame, will the scanning station wired to the TV be used, or will there be a separate station just for the purpose of initial authentication?
5. How will the reminder coming from their caregiver be received? What will be the interaction with the popup notification? How will the user open the message?
6. Will the video message automatically start playing?
7. Will the users have the possibility to replay the message?
8. How will they return to the home screen?
9. What to do when they miss a reminder? Will an extra notification follow? How many extra reminders will the users get?
10. How will the exergame system shut down when training with an exergame is completed?
11. How to prevent other users from accidentally interrupting another user by scanning their tag when they want to train, while someone's training session is still in progress?
12. Would the possibility of sending recorded questions to the user's caregiver be of interest to the user? How would this be done?

Many of these questions have been answered during this tinkering process. Nonetheless, the outcomes of this tinkering session still had to be evaluated by testing on the actual target population. This process will be described in the next section.

4.2 Paper Prototyping II

4.2.1 User scenario and System overview

The paper prototype discussed in the previous section has led to the establishment of a potential user flow of this rehabilitation system. To get a better idea of how this system should work, a script has been made to describe a typical user session with the photo frame and the RFID architecture.

1. Once a patient gets into the rehabilitation phase he/she will set up their user profile together with the caregivers. This is done on the interactive photo frame. During registration, they are asked to scan their RFID tag (which will be implemented in the standard hospital tag) to complete authentication. Also scanning the RFID tag will be done by simply holding the tag close to the photo frame when asked.
2. After user registration the application will start up, simply showing some of their favourite pictures or some default pictures of beautiful scenery. The picture displayed on the photo frame will change to a different picture over time to create some diversity.
3. When the moment is there, the photo frame will emit a sound, e.g. a voice or a gentle tone, and show a pop up that tells the user that they have received a message from their caregiver and how to open the message. After opening the message, it shows an instructive video from their caregivers, reminding them to do an exergame.
4. After the reminder, the user will go to the designated location of the exergame, either their room or outside their room, and hold his/her wrist tag in front of the RFID unit connected to the television.
5. By doing so, the television will automatically turn on, the application will start, and their user profile with the suiting exergames will appear. This allows them not to worry about figuring out how to start the application and what exercise to do. Parallel to this, their profile in the cloud database will be updated with a timestamp and remark that they have done their training.
6. When the user is not training but has some questions regarding their rehabilitation, they can go to the information menu in their photo frame and record a voice message by first choosing “vraag opnemen”, which automatically causes the device to start recording audio, and then press “verzenden”. By doing this, the message will automatically be forwarded to their caregiver.

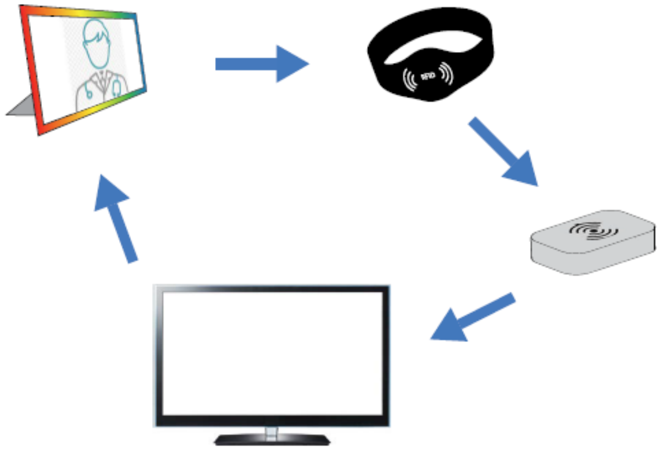


Figure 11: User flow 1

The following is a system overview that illustrates the previously described steps.

Figure 12: User flow 2

4.2.2 Paper prototype testing II

Similar to the first paper prototype, this one also had to be tested. Because the usability of the photo frame has been assumed to be the most difficult to design into a user-friendly product, this usability test mainly focuses on the user interaction with this photo frame. The initial RFID tag registration is still included to see if the test subjects understand how to interact with them. However, a more elaborate evaluation of the RFID interaction will be conducted in chapter 6.

Method

Before performing the usability test, a test plan had to be made. The complete test plan for this usability test can be found in the Appendix B. The prototype in this usability test has been made with a web tool called Marvel[12]. This web application allows one to create interactive designs and wireframes without any coding involved so that the user flow an UI can be properly tested before building a working prototype. The images below give an indication what the Marvel prototype looks like.

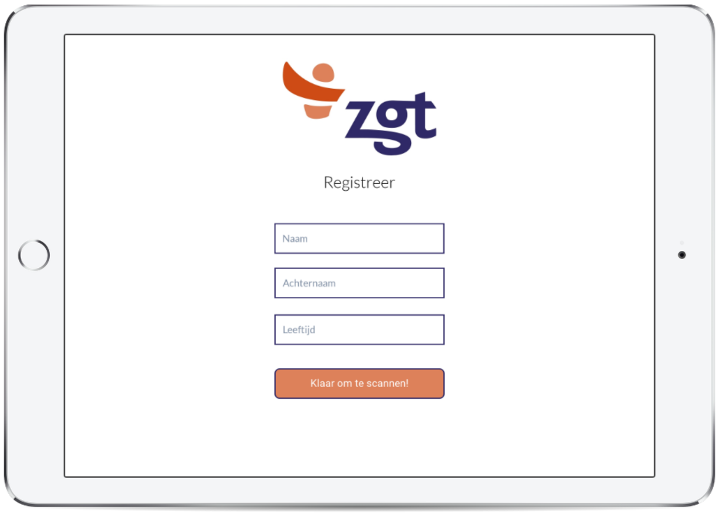


Figure 13: Paper prototype start screen

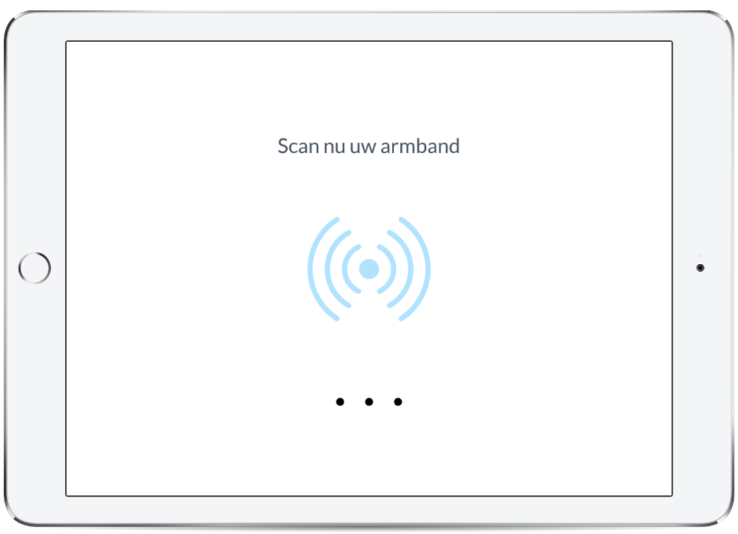


Figure 14: paper prototype RFID

[12] https://marvelapp.com/

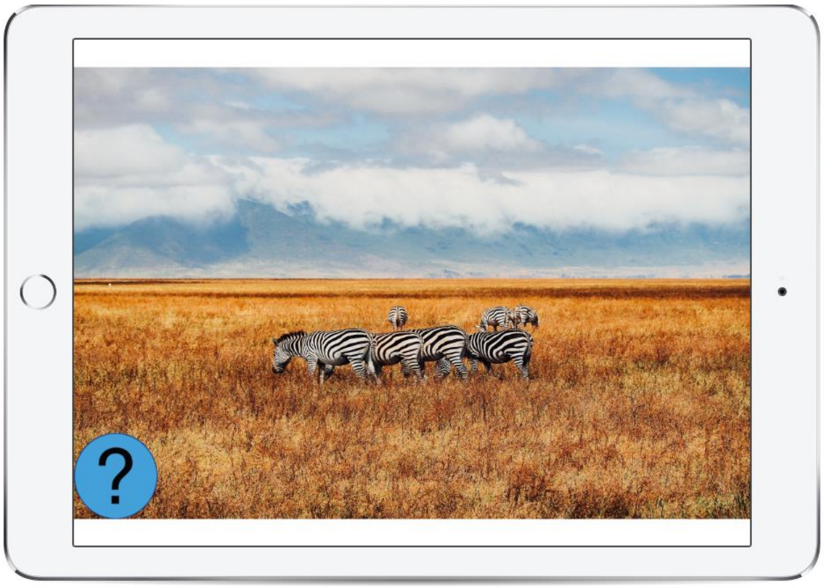


Figure 15: Paper prototype home screen

Prior to the usability test, the paper prototype has been tested utilizing Hallway usability testing (Hallway Usability Testing, n.d.). This method uses random individuals from every age to test prototypes and their interface. Several students have been asked to participate in this test to tackle potentials errors that should not be present during the actual usability test, but also to improve the prototype if needed prior to the usability test and thus ensuring a smooth usability test.

For the actual usability test, five random people have been asked to participate, varying between the age of 70 and 84. Three of the five patients were residents of the Humanitas[13] retirement home. All the participants had different backgrounds in education and different mental health. Before the test subjects participated in the usability test they were asked to sign the consent form in Appendix C.

The test has been done by means of an individual synchronized test with 'Thinking Aloud' method (Theelen, 2016). This means that the tester will be present in the same room as the test subject to guide them through the test at some set points, and the test subject will be asked to speak out their thoughts while interacting with the prototype. During the test, the user's thoughts and interaction will be recorded with the use of screen capture software (www.nchsoftware.com). On top of that observations will also be noted down on paper. Afterwards, the test subjects are asked to fill in the Likert scale questionnaire in Appendix D about the prototype usability. With the use of this questionnaire, one can compute the System Usability Score defined by Brooke (n.d.). The calculations for computing these

[13] https://www.humanitas.nl/

scores can also be found in Appendix D. www.usability.gov was a big source of inspiration for setting up the user test and contributed to the overall layout of this test.

During the usability test the participants had to complete two main tasks: 1) Record a question and send it to the caregiver. 2) When a message is received, open it and read the message sent by a caregiver. However, these two main tasks were split into smaller tasks to make it easier to complete them and to get the test subject acquainted with the UI. The complete set of tasks is listed in table 1.

Table 1: Tasks

1	create a user account together with the test supervisor
2	go to the question menu and record a question
3	send the question
4	open the notification when you receive it and read the message from your physiotherapist
5	return to the home screen or read the message again when you are not done yet

For convenience, each of these steps was individually printed on an A4 size paper with big letters. This made it better for the participants to understand.

Although the first test is more of a qualitative measurement, two types of data that have been collected during the test; these are qualitative and quantitative. The qualitative data consists of their thoughts, body language and emotions, and additional remarks. The quantitative data consists of the time spend to complete all tasks, a number of mistakes made, and the number of questions, related to the tasks, that have been asked during testing.

4.2.3 Results

The results varied a lot among the five participants. Only two of the five participants had some sort of experience with computers or tablets. However, this did not seem to have influence on their performance during the tests. Table 2 summarizes the quantitative results from the usability test.

Table 2: Results

PARTICIPANT	TIME (MINUTES)	MISTAKES MADE	QUESTIONS ASKED
1	07:50	7	4
2	05:00	2	5
3	05:10	4	5
4	02:45	1	1
5	03:40	3	5

Two of the test subjects, aged 78 and 84, had difficulties with understanding the context of the design project and had no clue what they were doing and why; even though they were informed prior to the test. One of them only understood the photo frame functionality and purpose after explaining it again when the test was done. Also, when performing the second task, three of the participants had difficulties going to the question menu because they were tapping on buttons outside of the prototype display frame even when explaining to them they must only look within the marked frame. Also, four of the five participants did not notice the question menu button to begin with. The first participant (76) seemed to have the same problem initially and therefore made quite some mistakes, but after explaining it for the first time this participant perfectly understood. Participant 4 and 5 had similar problems with task 2, but not as big as the other participants. Besides that, no major issues were observed with these two participants when using the prototype. Even more surprisingly, one of them (70) had no prior experience with computers or tablets but was very comfortable with using the prototype and even found the prototype very intuitive nonetheless.

All participants, except for the two that had difficulties understanding the prototype, were very positive about the prototype and definitely saw opportunity in using such a system during rehabilitation. However, all participants also either got stuck or made a mistake during step 5. For example, after reading the message from the caregiver the participants had to go back to the home screen by tapping the 'return to home' button, but all of them found the 'playback', which was next to it, and 'return to home' buttons very confusing and seemed to mix them up. Also, all of them didn't see the point of step 2 and 3 simply because they didn't have a real question; some of them didn't want to ask a question, which caused confusion. One of the participants even started an entire conversation because this person had a question about a procedure he had in the past. Besides that, two participants started asking a question about the people in one of the pictures when asking them to perform task 2; instead of going to the question menu and recording the question. This clearly indicated that some participants had little idea of the meaning of this prototype question menu. On the other hand, most of them found the idea of having the possibility of sending questions by speech, very convenient. Another design flaw that came up during the test, was the popup message. Only two of the five participants instantly noticed when they received the message. The others only found out after about a minute. Also, four out of five participants made the mistake of tapping the question button after receiving the popup notification. This could be an indication that the design of the popup notification is not clear enough, hence failing to trigger the right user behaviour.

Computing the SUS score of this usability test leads to an average of 64. According to Sauro (2011), a SUS score above 68 would be considered above average and a score below 68 would be considered below average. Multiple sources refer to this interpretation as common ground for the SUS (Thomas, 2015; System Usability Scale (SUS), 2018). Nonetheless, there still is the question of how to interpret the score of 64. Sauro (2011) states that converting the score to a percentile rank by normalizing it, is the best approach to interpret a score. Sauro (2011) created guideline which takes in the SUS scores, generates the percentile ranks and grades from A to F. Moreover, he provides a graph that shows how the percentile ranks are associated with the SUS scores and letter grades. This graph can be seen in figure 16.

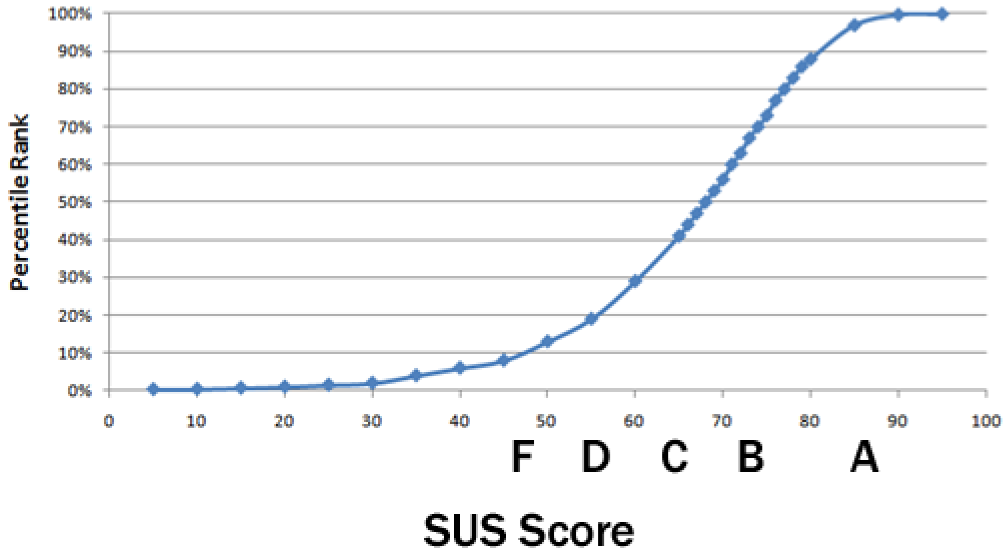


Figure 16: SUS graph (Sauro, 2011)

A score of 51 or lower would mean an F, showing that the system has very poor usability. A score of 68 gives the system a C, meaning that its usability is okay, but there is still room for improvement. Anything above 80.3 would mean that the system gets the grade A, implying that it has a very good usability and people would recommend it to others (Thomas, 2015). In general, a score of 64 is not too bad. However, this also means that things should be improved to get a more convincing result. On top of that, while testing the photo frame prototype, it came to the attention that there are still some important design issues that need to be addressed.

Even though some participants had difficulties with completing the tasks, especially the two that had a lot of trouble with understanding the general purpose of the prototype, it must be pointed out that it is very likely that the usability test was biased from the beginning. This speculation is based on the fact that the prototype that was made with Marvel (www.marvelapp.com) was displayed and tested on a web browser opened on a laptop. The prototype, as seen in figures 13 to 15, was a tablet with the corresponding UI, displayed on the laptop. The test involved tapping the buttons on this prototype, just like a real tablet, and not clicking by using the laptop's mouse. This caused confusion even among the ones that perfectly completed the tasks. This could also be the reason for why participants 2 and 3 had more difficulties in grasping the prototype. On top of that, some of the participants even had difficulties grasping the concept of a "prototype" because even after explaining they thought it was real. Both these observations played a role in the performance of the participants and should, therefore, be taken into consideration for future tests.

Feedback on the UI and the user flow will be processed in the next iteration that will be discussed in chapter 5. Also, the experience obtained from this user test will be used to do further improvements on the next user test to prevent possible biases.

Iteration III

4.3 Functional Specification

With the results obtained from both paper prototype test, new and more requirements have been added regarding the UI and user flow of the photo frame. These updated requirements together with the specification of the new prototype will be discussed in this section.

4.3.1 Requirements

The added requirements stated in this paragraph will mostly define the functionality of the photo frame application since the RFID structure has not changed much. Since the new requirements are quite specific and more focused on functionality, the mind map made earlier won't alter and these requirements will be treated separately. The new requirements are categorized into segments that each describe a specific part of the photo frame app.

Table 3: Functional requirements

Segments	*Requirements*
Registration	- registering a new user should be simple; e.g. no passwords or email addresses Instead, only the first name, last name, and age will be asked - after submission of credentials, the app will automatically forward the user to the RFID scan screen where they will complete the authentication by scanning their wristband; this will be done together with the caregiver - only when the scan is complete, the user will be forwarded to the home screen - audio and visual cues must be provided to give a clear indication of when a scan can be done and when a scan is succeeded - a link to login screen must be provided
home screen	- the home screen will have automatically changing pictures - the look will be as simplistic as possible - question menu will be left out for this prototype
Notification/ Popup	- the popup notification must be more apparent; e.g. bigger and more outstanding colours - the popup notification must guide the user to perform the according action; e.g. opening the message - sound and light must be emitted when the user gets a notification
Video message	- the users should have the possibility to play, pause, and replay the video message - the video message should start playing automatically - the window where the video message is being displayed should provide a clear indication of how to go back to the home screen

Login	-	when it is necessary to log in the user should only have to use its RFID tag to authenticate; this will be done by holding it near the photo frame
RFID exercise startup	-	when holding the tag near the RFID unit connected to the television, it must start up an exercise video for hip patients
	-	Parallel to this it must send a confirmation to the user's profile stored in the cloud database, indicating that they have completed the training

4.3.2 Functional Prototype

As a result of the updated requirements, a new prototype has emerged of which its functionality will be described with an updated user scenario. This user scenario defines the functionality of the final prototype and will, therefore, be realized during the realization phase discussed in the next chapter.

1. Once a patient gets into the rehabilitation phase he/she will set up their user profile together with the caregivers. This is done on the interactive photo frame. Registering the patient only requires them to fill in their name and age.
2. After the first step, they will complete authentication by either holding their wristband near the photo frame or near an extension plugged into the photo frame. This solely depends on the kind of tablet that will be used in the next prototype.
3. After user registration the application will start up, simply showing some of their favourite pictures or some default pictures of beautiful scenery. The picture displayed on the photo frame will change to a different picture over time to create some diversity.
4. When the moment is there, the photo frame will emit a sound, e.g. a voice or a gentle tone, and show a pop up that tells the user that they have received a message from their caregiver and how to open the message. After opening the message, it shows an instructive video from their caregivers, reminding them to do an exergame.
5. While watching the video, the user can pause it, play it, and restart it.
6. After watching the video, the user can press the button that says "hoofdmenu" to go back to the home screen.
7. After the reminder the user will go to the designated location of the exergame; in this case, a TV or computer screen that will show an instructive exercise video for hip patients.
8. By holding the tag against the unit connected to the TV or computer screen, it will start up the exercise video. This allows them not to worry about figuring out how to start the application and what exercise to do.
9. Parallel to this, their profile in the cloud database will be updated with a timestamp and remark that they have done their training.

5| Realization

In this part, the assembly of the functional prototype will be described. The content will be divided into the sections *System Components* and *Functional Architecture*; each will describe in detail the implementation solutions that have been chosen for this design project.

5.1 System Components

5.1.1 Photo Frame

For the assembly of the interactive photo frame, an Android touch tablet has been used. Preferences went out to a touch tablet that would support NFC for transferring to/reading data from an RFID tag. However, due to the lack of availability and price, an alternative had to be sought. Therefore, the Archos 90b Neon has been used for the photo frame. It is a relatively slow tablet, but sufficient enough for performing the tasks required nonetheless.

The software for writing the photo frame application is Android Studio™[14]. This software supports multiple programming languages, but for this application, only Java has been used. A downside of programming in Android is that it makes the application incompatible for IOs systems such as iPad or iPhone unless a converter is used.

The casing and stand of the photo frame have been made with laser cut triplex. Although wood might not be the user-friendliest material to use, it is sufficient enough for this functional prototype. A blueprint of the photo frame case and all other component casings can be found in Appendix E.

In addition to the casing, there is backlight made out of two RGB led strips. The led strip emits different colours of light and changes colour when a message is received; this is to notify the user.

Figure 17: Functional prototype; photo frame

[14] https://developer.android.com/studio/

5.1.2 RFID Writer

Specifications stated that the photo frame would either use an internal RFID unit or an external one for completing the registration. The ideal situation would be to use an internal one, but the Archos 90b Neon does not provide this. For this reason, an extra unit, connected through USB, has been built to be only used during registration. After completion of registration, it must be detached from the photo frame to proceed. This external RFID writer consists of an Arduino Uno, USB OTG cable, MFRC-522 RFID module, male-female wires, and a piezo buzzer.

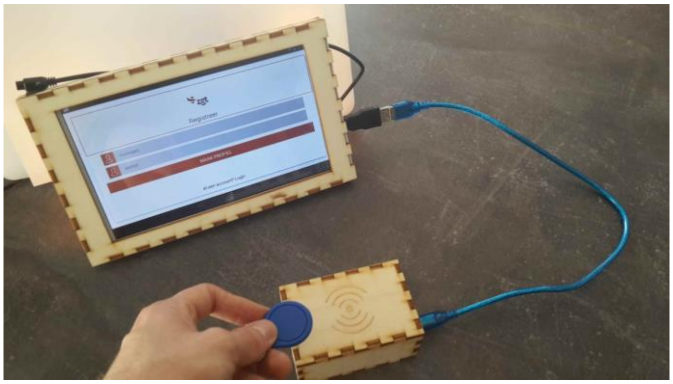


Figure 18: Functional prototype; RFID authentication

When inserting this unit in into the photo frame buzzer emits a signal when the RFID module is ready for reading/writing data. Once data writing to the RFID tag is succeeded, it emits another signal consisting of three tones to give the user an indication of success. Figure 19 shows the schematic of this unit's circuit.

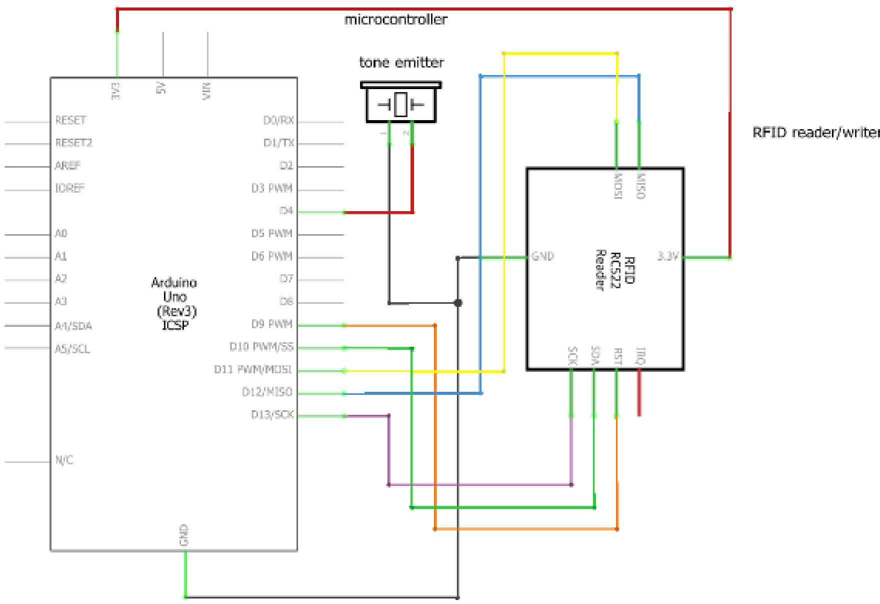


Figure 19: RFID writer scheme

5.1.3 RFID Reader

This RFID reader should ultimately be attached to a TV to start up the exergames and display the user's personal account. However, for this prototype the RFID reader will be attached to a laptop that runs Processing™[15] as a background program; showing an instructive exercise video once a user scans his/her tag. After the user has done their training, or in this case watched the video, their profile stored in the cloud database will be updated with a notification confirming they have done their training. Similar to the previously described RFID unit, it uses different tones to signal the user when a particular event has taken place such as scanning the tag for example. This unit consists of a NodeMCU v3 with integrated ESP8266 module, USB mini B cable, MFRC-522 RFID module, female-female wires, and a piezo buzzer. Figure 20 shows both writing and reading RFID units.

15 https://processing.org/

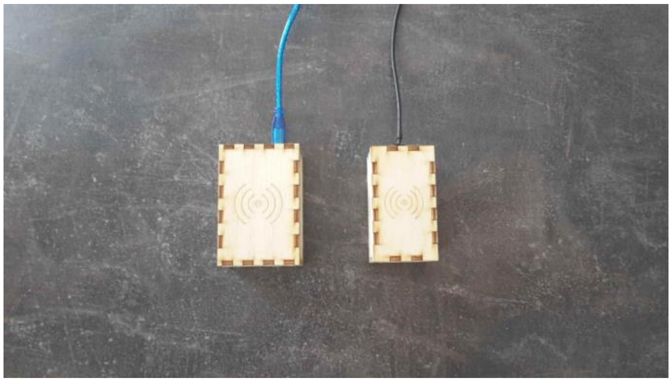


Figure 20: RFID units

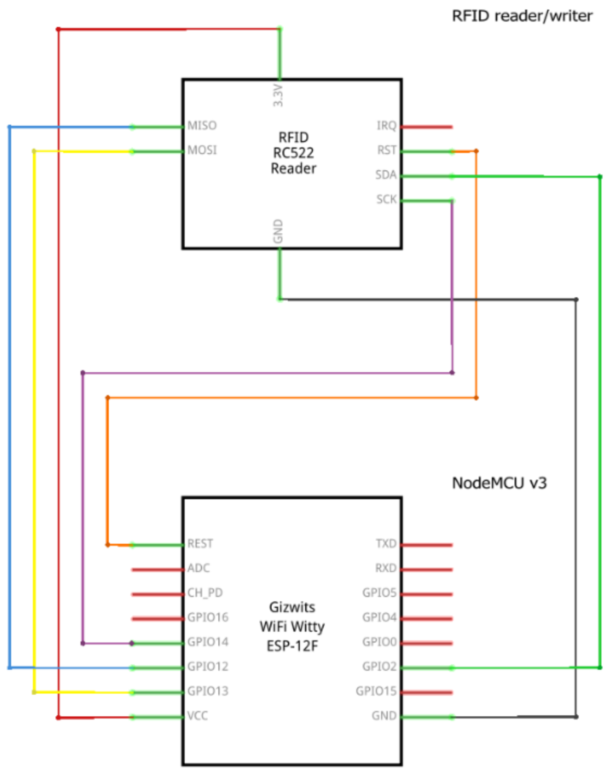


Figure 21: RFID reader scheme

5.1.4 Cloud Server

For this design project, Firebase™ has been used to integrate a real-time cloud database and user authentication methods with the photo frame application. Firebase provides functionality like analytics, messaging, crash reporting and databases which allows the user to put more focus on the development of a user-friendly application. Besides using Firebase as a database and authentication tool, it is also used as a messaging tool to provide the photo frame users with scheduled reminders. On top of that, it is also possible to send instant messages at any time.

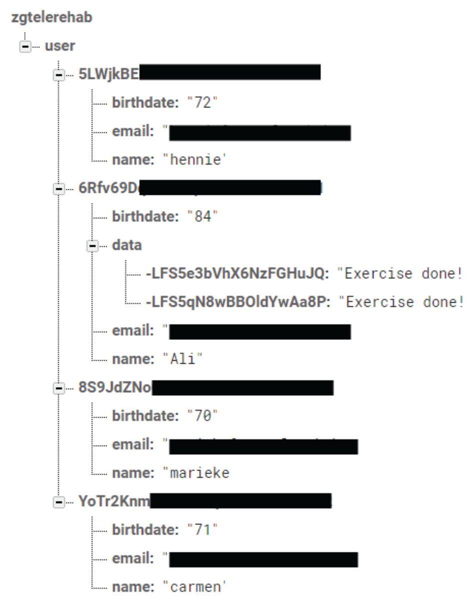


Figure 22: Cloud database

5.2 Functional Architecture

In chapter 4 the functional prototype has been described already. Figure 23 shows how this functional prototype description is implemented in the prototype made during the realization phase.

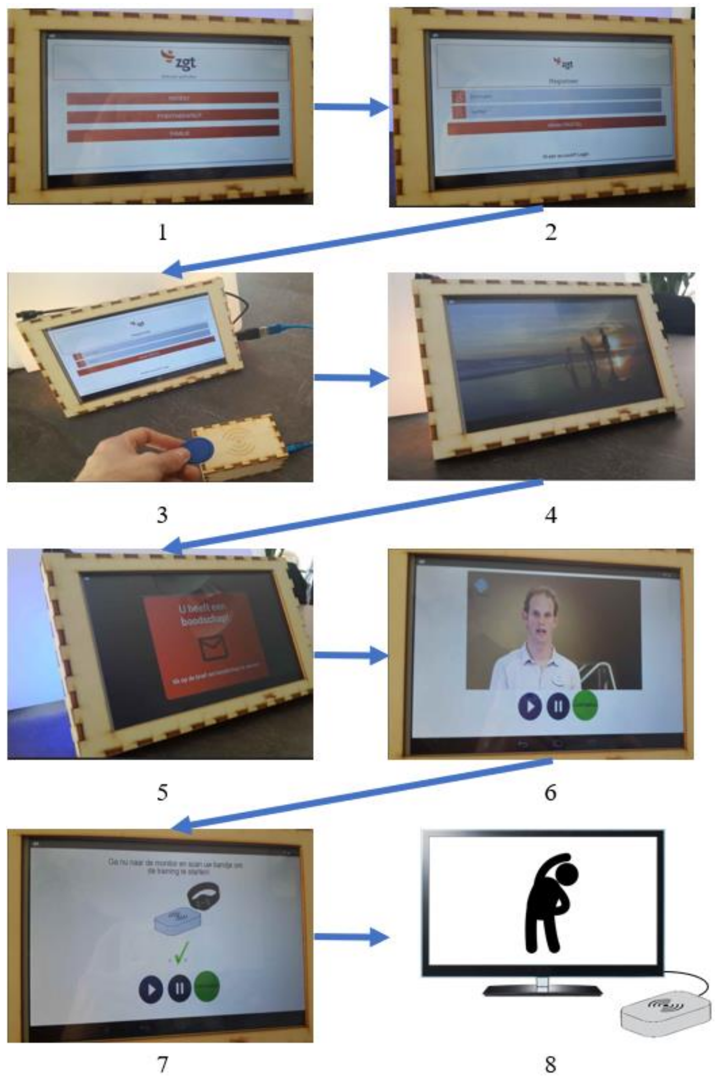


Figure 23: Functional user flow

Action (1) is the initial screen the user will see when using the app for the first time. In this menu, the type of user can be chosen; patient, physiotherapist, or relatives. Action (2) shows the sign-up screen. This is where the user will create an account together with their physiotherapists. After filling in their name and age, action (3) is performed; the user completes authentication by transferring their account data to the RFID tag. Action (4) shows the actual start screen of the photo frame application. This is where the user can see pictures of their interest, such as pictures of their family or nice scenery. When it is time to attend some physical activity, action (5) is performed where the user gets a gets a reminder in the form of a notification. As figure 23 show, the backlight also changes colour during this action to signal the user that a message has been received. After opening the message, the users will start performing action (6); it involves watching the video reminder received from their personal physiotherapist. After watching the video messages, action (7) will explain to the user what to do next in case they have forgotten. The final action (8) involves the users performing the action explained to them during action (7), e.g. starting the exergame and performing some physical activity. During this final action, their account is updated with a notification saying they have done their exercise at the given time.

In addition to the previously described user flow, figure 24 illustrates an overview of the new system architecture that also describes the interactivity between the components.

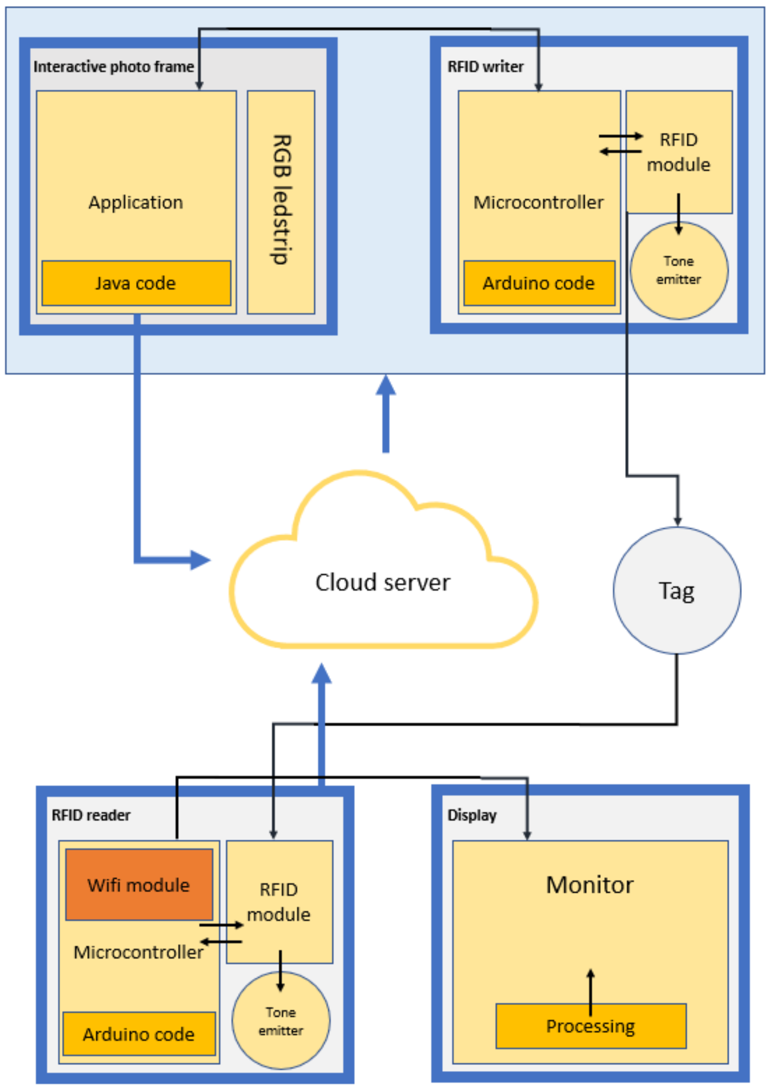


Figure 24: System component architecture

5.4 Component Overview

Table 4: Component overview

ACTION	SYSTEM COMPONENTS	SUBCOMPONENT	SUBCOMPONENT DETAILS
1, 2, 4	Photo frame	Android tablet, application software, backlight	Archos 90b Neon, Android Studio™, RGB led strips
3	RFID writer	Microcontroller, USB connector, RFID reader/writer, wires, tone emitter.	Arduino Uno, USB OTG, MFRC-522 + tag, male-female wires, piezo buzzer
8	RFID reader	Microcontroller + Wi-Fi module, USB connector, RFID reader/writer, wires, tone emitter	NodeMCU v3 + ESP8266, USB mini B cable, MFRC-522, female-female wires, piezo buzzer.
8	Display	Display screen, background program	Laptop, Processing v. 3.3.7
-	Cloud server	Cloud database, authentication, messenger	Firebase™

6| Evaluation

6.1 Functional Evaluation

For proper user evaluation, it was important to realize the functional prototype according to the specifications. For this reason, this section will discuss to what extent these functional requirements have been met. This will be done by assessing the segments listed in table 3.

6.1.1 Registration

The registration segment fully works; it takes in the input from the users, e.g. name and age, and creates an account for them when proceeded. No passwords or email addresses are required. After the account is created the user is forwarded to the page where they complete authentication by letting the RFID unit write their information to their tag. Successful data transfer is indicated with three emitted tones. When writing to the RFID fails, it is indicated with one lower tone. Writing to the tags only works when the external RFID unit is connected before the user is forwarded to this page. When connected afterwards there seems to be no communication between the two devices and the app gets stuck for some yet inexplicable reason.

6.1.2 home screen

There is not much to the functionality of the home screen since its usage is that of a picture display. The initial idea was to let the pictures alternate over time. However, for this prototype, it has been left out since it is not of that much relevance for the usability test. Also, the question menu has been left out for this prototype version. Even though these two features are not present in the current prototype, the possibility of having them in future versions has still been evaluated to measure their relevance and potential.

6.1.3 Notification/Popup

After the results of the first usability test, the notification has been altered accordingly. A direct video message can be sent from the Firebase cloud, but it is also possible to schedule the messages so that the recipient receives them at set times. As soon as a message is received, a big dialogue block pops up while a notification sound is played. At the same time, the backlight can change colour to support the indication of a received message. However, for this prototype only a simple RGB led strip with controller has been used. Additionally, the pop up has been made clearer by means of telling the users how they have to interact with it.

6.1.4 Video message

The video messages that can be sent from the Firebase cloud, can be any type of video messages. Yet, while testing the functional prototype it came to the attention that either the cloud or the Android program is less compatible with MP4 files. For this reason, only MOV files will be used. Ones the user opens the popup message he/she has received, the photo frame application automatically downloads the corresponding video from the cloud which is like the protocols used by conventional messaging such as WhatsApp™(Soni,2018).

6.2 Login

Although the application is built in such a way that it will always run on the foreground (e.g. users don't exit the application since the pictures and messages should always be displayed) the possibility that the app closes for any reason, should always be taken into account. Therefore, a login screen is included to provide to the possibility to return to the personal home screen. Ideally, this login screen only requires one to scan his/her tag. Nonetheless, this scenario seemed highly unlikely to happen during the usability test and for that reason the login screen is quickly implemented with authentication by name and a fake password. This is solely for convenience while testing the app and won't be used by the test subjects.

6.2.1 RFID exercise startup

In the realization, it is mentioned already that the RFID exercise startup is implemented as a proof of concept reasons. Instead of an exergame, an exercise video, shown on a monitor has been used. When scanning the tag, a video on the monitor will start playing. Yet, for some inexplicable reason, this setup only works when resetting the RFID unit once after it is plugged in the monitor. Not doing this causes the monitor not to respond. Whilst the video is playing, any interaction with the RFID station does not have any influence on the program that's being run on the monitor. Only after the video stops one can scan the tag again to startup another video. Any other interaction with the video while it's playing, is also not possible (e.g. pausing, stopping or fast forwarding the video).

Every time someone scans their tag at this RFID unit, a timestamped update is sent to the account in the database. This is possible due to the Wi-Fi module mentioned in chapter 5. Although this is working most of the time, the setup lacks some flexibility. For example, the Wi-Fi module present on the NodeMCU v3 is currently set up for one location. When the system needs to run on another location, it has to be programmatically set up according to the Wi-Fi that's offered on that location. This means that the SSID and password on the module have to be changed by connecting the module to the laptop, altering the SSID and password to the ones from the current location, and finally uploading the new code to the module. This is quite inconvenient and should be changed in future implementations. Besides all this, the unit doesn't provide feedback yet in case there is no connection with Wi-Fi, or when the transfer of the timestamped update has failed.

6.3 User Evaluation

The usability test conducted for this prototype takes an approach similar to the paper prototype usability test described in chapter 4 and aims for qualitative results. Before the actual test, a Hallway usability test has been conducted to identify any potential hiccups. Also, results from the previous test have proved that it is of great significance to well inform the test subjects on the context of the design project, what the purpose is, and what each individual component does without revealing how it should be used. In addition to the usability test performed in chapter 3, the test subjects were asked questions while performing the tasks; these questions are asked to measure the quality of user experience. In the end, the participants were asked whether they had additional comments. Because this usability test was performed with the functional prototype, there was no need for a laptop anymore to run the test. Moreover, this test did not utilize screen capture but only recorded audio instead.

The aim was to test the system on five participants. However, one of the participants bailed out due to illness so only four participants were used. Because of this, the set of participants only consisted of females this time. They all varied age 70 to 84. Two of the participants also participated in the previous usability test. The questions that were asked during the usability test are shown in table 5. They're categorized per task, so the first set of questions are asked when performing the registration and the second set of actions is asked when entering the home screen. These questions and the corresponding answers can be found in Appendix F Also, the participants had to fill in a 10-question long form again at the end of the test.

Table 5: User test questions

Task	Questions
Registration	- What is your opinion on the registration window? - Do you have difficulties scanning the tag?
Entering home screen	- Do you think personal pictures or any pictures of the user's interest would add value to the system's application? Why? - Do you think personalization of the system's application is of significance? - Would you rather have one fixed picture, or different pictures alternating over time?
Receiving message	- Is the popup clear enough? - Did you notice the colour of light changing? - What is your opinion on having light as an indicator? - What would you change to the notification sound?
Watching video message	- Do you think the video message adds value to the system's application? - What do you think of the general layout of this window? Would you change anything? Is it clear? - Would you rather have your personal physiotherapist in the video message, or someone else?
Starting exercise video	- Do you have difficulties interacting with the reading unit? - Would you prefer to use the conventional remote for starting an exercise video, or this RFID unit?
Additional questions	- Do you think that this system, in general, would persuade you, or any other rehabilitating older adult, to take initiative in the rehabilitation process?

	-	If there is to be an extra menu to automatically send questions to your physiotherapist, by means of using voice recording, would you be interested in seeing this feature in future implementations? Do you think other potential users would be interested in having this ability?
Remarks	-	Do you have any further comments or remarks?

The results from the test were significantly better compared to the previous one. The reasons could possibly lie in the facts that: participants were better informed about the context, purpose, and operation; having an actual physical prototype prevented confusion, unlike the first time; two of the participants were already a bit familiar with the system; critical feedback from the previous session had been processed and implemented in this prototype. In general, the participants were satisfied with the performance of the system. All of them saw potential in the system persuading older adults to take initiative in the rehabilitation process. Nonetheless, there was also some criticism on some of the elements present in the photo frame application. For example, one of the participants said that the text font of the registration screen was too small and almost impossible to read. On the other hand, the person knew that this task would normally be done together with the caregiver and therefore was satisfied enough with it. The same participant found the "play" and "pause" icons on the video display window very confusing and made the mistake of going to the home screen instead of watching the video. It was suggested to change the icons to text for more clarity.

Regarding the home screen, most of the participants were quite satisfied with the possibility to have their own pictures displayed. One argument against this was that people with dementia might get distracted by it because they could start talking about what they see instead of performing the task that they would have to do. Another argument was that it might be depressing because the patient might think "I cannot do that anymore".

The pop-up message that appears when a message is received, was very clear to all the participants. Every time such a message appeared, the light would change from a warm orange colour to a blue colour as well, but most of the participants didn't even notice this colour change. They all explained that this was because their attention was drawn to the UI, but that they find this feature very important to increase awareness when a message is received; especially when a user has decreased hearing capability.

When looking at the video message itself, the majority of the participants indicated that they prefer having a message coming from their own physiotherapist, since this increases personalization of the system which, according to most of them, could be of relevance to the rehabilitating patients. Regarding the layout of the video message window, there were no major issues aside from the one already mentioned. Although it was only one person that mentioned the icons as a difficulty, it should be taken into considerations for future implementations since this issue might occur with more people when conducting a bigger user test.

A suggestion that was made by one of the participants, was to add the possibility to redo exercises after they're completed since it might be the case that they forget how to do a specific exercise. When the participants were asked whether they would like to see a feature where they can ask questions to their physiotherapist by means of voice recording, the opinions were divided. Some of them thought of this as something very convenient, while others didn't really feel the need for such a feature. Those that weren't really convinced of this feature did understand that it might offer great convenience to other potential users. However, this would depend on the person.

All the participants did not have any difficulties interacting with the system through RFID and would prefer using RFID wristbands over the conventional remote. Also, the majority did not seem to have any difficulties interacting with the photo frame UI. Some of them mentioned that it might take one or two times to be fully confident in using, but ones you've tried it, there's nothing difficult to it. Yet, one of the participants indicated in the usability survey that she found the entire system quite difficult to understand and that it was too complicated. Seeing this was very unexpected since it contradicts the performance and comments during the test with this participant. Besides that, the participant also didn't give a clear indication of why it was difficult for her to use and understand. Be that as it may, when asking the participants whether they think this system would persuade them and rehabilitating older adults to take initiative in the rehabilitating process, they all gave a positive answer. One of the participants' answer translated to English, is as follows: "If I would receive a message that would say that I have to do something, it is more likely that I would do that task than when I wouldn't receive a reminder at all. People tend to be very busy and easily forget their exercises". Another answer translated into English: "I can very well understand how this could work out. I often have to go to the physiotherapist myself and afterwards I have to do the exercises. I sometimes skip these and later I think by myself "how did that exercise go again? ". Then I don't remember how to do the exercise anymore and I just stop doing it.".

Computing the SUS score for this usability test leads to an average value of 81.9. With a score of 81.9, this would mean that this rehabilitation system is very user-friendly for the target population according to the graph in figure 16, created by Sauro (2011). According to Sauro (2011) the sample size, in this case, four, and reliability are unrelated. This means that SUS can even be used on a small sample size and still be reliable. On the other hand, Sauro (2011) also mentions that "small sample sizes generate imprecise estimates of the unknown user-population SUS score. Then again, there is not that much variability among the individual SUS scores generated from the Likert scales, so this score could be considered as a reliable indication of usability of the rehabilitation system.

Even though the score generated from the SUS shows very promising results, for future test it would probably be better evaluate a bigger sample size and for a longer time. Not only to cover the unknown user-population SUS score mentioned above but also to get a clearer vision of what malfunctions are still there and how the system is experienced by a bigger variety of potential users.

7| Discussion

7.1 Development Process

This design project had several questions that needed to be answered to effectively reach the goal stated in the introduction; creating a solution for changing the behaviour of rehabilitating older adults in such a way that they take more action on their own in their rehabilitation process, ultimately increasing their activity adherence and autonomy and therefore resulting into an increase of self-management in the rehabilitating older adult. First, it had to be defined what the current situation was for rehabilitating older adults. The research that was done for this subject prior to this design project, had shown that, to reach self-management in rehabilitating older adults, at least five components must be present. However, three of these components are currently missing in many of the rehabilitating older adults, e.g. *competence*, *knowledge* and *skill*. Besides consulting this research, a visit was paid to ZGT to see the situation from a different perspective. From this, it came forward how extensive the dependency of the rehabilitating patients on their caregivers is. From the findings of this research and the visit, an initial set of requirements had been set. Including in this set were requirements derived from the FBM.

Next, with these requirements in mind, a SOTA research had been conducted to find out how current technologies support self-management in rehabilitating older adults. However, it must be pointed out that there was not that much available regarding this topic and because of that, the focus of the SOTA research was more shifted to support in the life of elderly people to obtain as much information as possible. The SOTA research also served as a source of inspiration for the current design project. One of the findings from the SOTA was, that there are technological applications that fulfil some of the requirements, but never to the full extent. Yet, the category exergames seemed to fulfil most of the requirements and several applications from this category have already been distributed on the consumer market. Nonetheless, many of the exergame applications seem to focus on only motivating the older adults to adhere to daily activity but appear to neglect important factors such as simplicity and triggering events, which are also important to effectively support the missing factors from Goolkate (2018). For example, a technological application that is very easy to use can increase the confidence of the older adult, hence increase their feeling of competence. The potential of exergames combined with the components that they are currently lacking, gave reason to use it as a basis to extend from.

With the findings from the SOTA research, a prototype had to be designed that would fulfil the missing requirements and support the three components from Goolkate (2018). Initially, the caregivers and physiotherapists were also taken into consideration in this design process. Think of for example a separate UI adapted to their needs. This can also be seen from the second mind map created in section 3.1.2. However, for this design project, it was found more relevant to prioritize the primary user (the older adult) since the functional prototype would serve more as a proof of concept, showing it can persuade the user to take action during rehabilitation, rather than a fully working and implemented system. Because the secondary user was not fully included in the design process, even though it is still relevant, it has been decided to include this any future implementations.

Multiple design iterations were made, and the further the progress of the system design, the more its focus shifted from the initial set requirements to more specific functional requirements. This could be argued by some since the user should always be in the centre of the design process, but the initial requirements have always been present at the core of every iteration. On top of that, multiple prototype evaluations, also with users, have been conducted to discover the user's needs in the design of a rehabilitation system; this eventually leading to the more specific functional requirements and specifications.

After coming up with the final specifications for a functional prototype, e.g. a cloud-based RFID architecture utilizing an interactive photo frame to trigger users in adhering to their daily physical activity, the research question had to be answered: Has the functional prototype satisfied the requirements and therefore fulfilled the goal of creating a system that will change the behaviour of older adults, potentially resulting in an increase of activity adherence and autonomy? During the specification, a list of functional requirements was created which was used during the realization of the functional prototype. Although this list of functional requirements was quite extensive, it doesn't mean that it includes everything needed to create a fully functioning product ready for distribution. The main reason for this was that the interactivity between the photo frame and the older adult was considered most difficult to design properly, unlike the interaction with RFID, and therefore required more care than other system components. Moreover, as already mentioned, the aim was to design a functional prototype as a proof of concept, and it was therefore considered more important to build the core functionality first. An alternative approach would have been to design a prototype with all the desired components. For example, a UI for both primary and secondary users including all its features, the ability to send pictures to the user to be displayed in the photo frame, an evaluation menu where the patient could see their rehabilitation progress, and the ability to send questions to the physiotherapist or caregiver. These additional components are all mentioned in the initial requirements but adding these would not have fit the time frame of this design project and eventually would have resulted in a prototype with little actual functionality. Because of this, the current prototype has been realized as it is.

Both evaluations with the paper prototype and the functional prototype gave quite some promising results. Many of the older adults seemed to understand the interaction with both the photo frame and the RFID architecture. Moreover, when asking about its potential as supporting tool in the rehabilitation process, they all believed it would help the older adults taking initiative in their rehabilitation process. Besides that, the SUS scores computed also gave promising results. On the other hand, some potential flaws in the evaluation must be considered. Similar to the first evaluation, there is a chance that the second one was biased as well. This is because two of the participants also participated in the first evaluation, possibly giving them an advantage over the others. Also, the second test was conducted with only four participants instead of five, which undoubtedly influenced the average SUS score. Nevertheless, the test conducted were aimed at obtaining qualitative results and during the last test is had been observed that the qualitative results were more promising than the results from the first test. Anyhow, future test will be approached differently by doing it on a greater scale, without participants already familiar with the system. On top of that, these tests have only evaluated the system's interaction and its potential as a tool for supporting self-management in rehabilitating older adults. To evaluate the actual effectiveness of the rehabilitation system, a long-term test at a nursing home with real patients is required. This would also mean that further development of this rehabilitation system is required and an actual exergame, of which this rehabilitation system is an extension, must be present to obtain the full experience.

7.2 Reflection

Certain design considerations of the technological application, realized during this design project, are based on scientific literature like the ones discussed in the SOTA. For example, the choice that has been made to use an interactive photo frame has been partially derived from research done by Kobayashi et al. (2011), Page (2014) and Voumvakis (2014); all evaluating the use of touchscreen technology by older adults. The last usability test has shown that the results derived from it, are in line with the expectations raised from the research of Kobayashi et al. (2011), Page (2014) and Voumvakis(2014); e.g., older users are perfectly able to use devices like smart tablets, as long as the interface fulfills the user's needs. This was also the case for novice touchscreen users. Likewise, Umemuro (2004) and Schneider et al. (2008) have shown that older adults (60 to 76 years old) where less afraid of using a touchscreen to perform certain tasks than those who had to use the conventional keyboard and mouse configuration, and that a touchscreen offers better affordance when it comes to input from the user. On the other hand, Page (2014) states that one of the potential sources of difficulty, when using something like a tablet, generally results from things like unclear icon depictions. The same problem was found when evaluating the interaction with the photo frame. However, proper UI design should be able to avoid this according to many of the researches mentioned above.

The final usability test has also shown the acceptance of the RFID architecture among the older adults. This is mainly owing to the expected simplicity of RFID in general, as suggested by Joshi (2015) and Raad et al. (2018). Moreover, Heinz et al. (2013) have shown that older adults are able to adopt new technologies as long as the usability and usefulness surpass feelings of incompetence. Besides that, a study conducted by Mitzner et al. (2010) suggests that older adults with high self-efficacy, are more likely to be less scared to use technology. This would imply that the system proposed in this design project would encourage the older adults to use it, due to its support of the components *competence*, *knowledge*, and *skill* together with its factors simplicity and triggers. Thus, with the above in mind, it can eventually contribute to more self-management and a higher frequency of physical activity adherence.

7.3 Future Implementations

Right now, the design product's target audience consists of rehabilitating older adults and possibly caregivers as secondary users. However, in the future, besides having a system with more functionality, it is desired to have a more broad and diverse target population. Diverse in the sense that it will also be able to support for example MS patients, heart patients, and more patient groups other than the lower limb fracture patient. Recent research studies have already shown that exergames have a positive influence on such patients (Klompstra et al. 2014; Ortiz-Gutiérrez et al. 2013). Also, it should be accessible to societal segments of varying age, instead of only older adults. Another possible future extension is to allow the system to be implemented in, for example, a home-based setting or other environments where it might be relevant. Doing this should be possible in an easy and intuitive way; almost like purchasing it as an add-on to the current environment. Achieving this goal solely depends on the final product's flexibility and appeal towards different organizations.

When thinking of the negative side of this design project, it could be assumed that people opposing this design idea might argue that leaving rehabilitation in the hands of technology is dangerous and not accurate enough. Moreover, they might find a reason to believe that such RFID based systems might damage the safety of the user's privacy. Still, those people probably fail to understand that the exercise programs in exergames will be built by specialists in the field, and the patient's behaviour will be (continuously) monitored by those specialists. Leakage of sensitive user information is not desired by these specialists since it will also damage their integrity, so this will be considered as well in the design of the system. It is also highly possible that opposers would have fair criticism on the narrow target design due to the fact that, if it will be implemented for a broader target audience, it will most probably be only interesting to the older adults and has little to none impact on other age segments. This can be considered as a realistic scenario, because younger people might not need the reminders mentioned earlier, or do not value personal pictures as much as the older population. Moreover, the UI might not appeal to a younger target population. For these reasons and many more, it is important to organize more user evaluations when working on the future implementations, and eventually alter the UI and other components for usage by a diverse target population. Nonetheless, no evidence has been found of other rehabilitation systems that are both as extensive and possibly flexible as the proposed implementation of this system. For this reason, this system could be considered as a "state-of-the-art" technology when it comes to self-management in rehabilitating older adults.

8| Conclusion

The goal of this design project was to come up with a system that will support self-management of rehabilitating older adults in a motivational manner by means of creating a technology that changes the behaviour of older adults in such a way that they take more action on their own, ultimately increasing their activity adherence and autonomy. Reaching this goal was done by first establishing requirements derived from preliminary research and then conducting a SOTA research which resulted in the decision of using exergames as a fundament to extend from. Continuing from this point onward, a functional prototype has been developed; a light and sound emitting photo frame that serves as a personalized trigger, and a cloud-based RFID architecture to back up the user's data and provide the user with the simplicity possible with this technology. Results from the usability tests have shown that this functional prototype provides the user with both simplicity and triggers, and therefore fulfils the requirements of the FBM. In addition to that, when combining it with exergames it can answer for the missing components *competence*, *knowledge* and *skill*. First of all, competence, because its simplicity and encouraging feedback can create confidence in the user. Secondly, knowledge because the exergames provide the user with knowledge of how to perform exercises and what their performance is like, but also because the photo frame serves as an extension of the user's cognition by reminding them of their daily physical activity adherence. Finally, skill, because the entire system provides training and feedback tailored to the user's needs and abilities. For these reasons, it is believed that the entire system, including the exergames, can provide the older adults with the support they need to be self-managing in their rehabilitation process. Hence, causing them to take more action on their own, increasing their activity adherence, and ultimately shorten their rehabilitation process.

9| Appendices

9.1 Appendix A

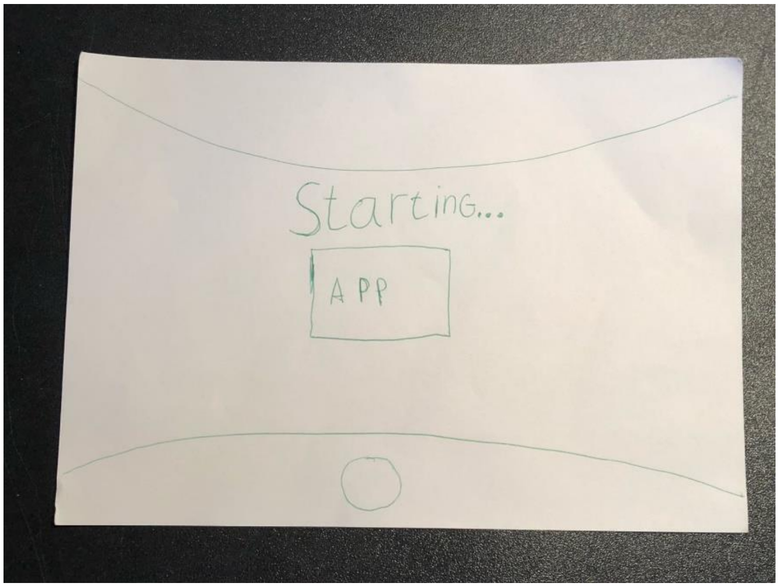


Figure 25: Start screen

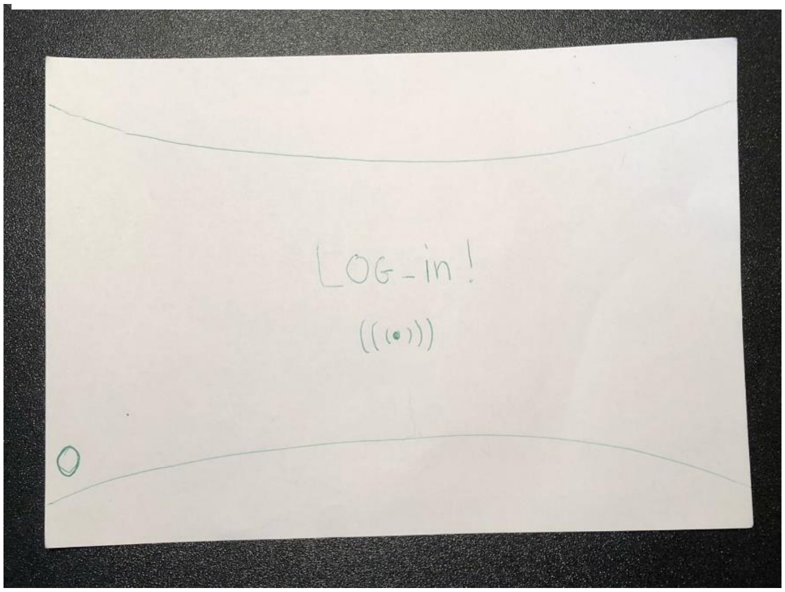


Figure 26: RFID login

Figure 27: Home screen

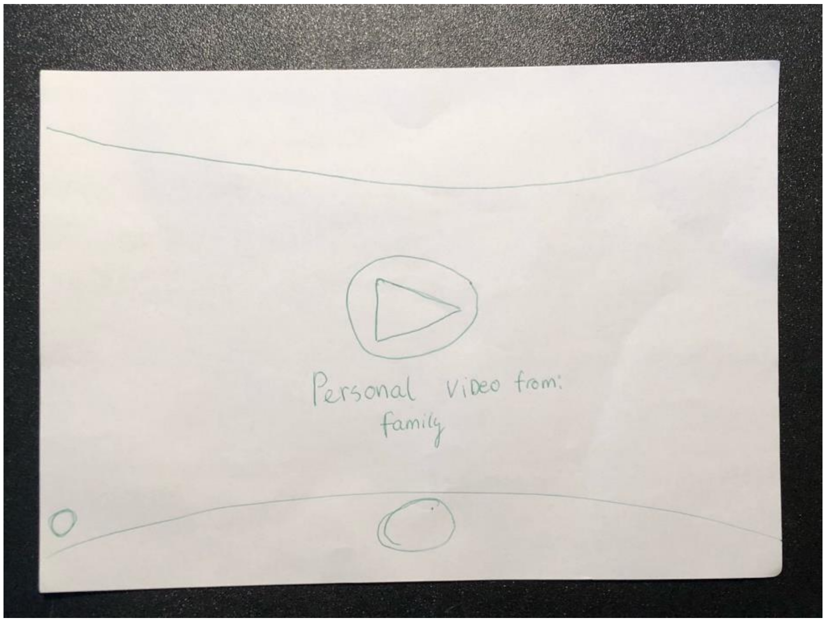


Figure 28: Opening a video message

9.2 Appendix B

Introductie
Zelfregie van rehabiliterende, oudere heupfractuur patiënten is van groot belang aangezien dit het herstelproces van de oudere kan versnellen. Echter, de meerderheid van de oudere patiënten neemt geen initiatief tijdens het rehabilitatieproces ondanks hun motivatie om zo snel mogelijk terug te keren naar hun oude leven. ZGT wil daarom dat de patiënten gebruik gaan maken van een systeem/applicatie die motiverende middelen aanbiedt om zelfregie te ondersteunen. Naar aanleiding hiervan ben ik begonnen met het ontwikkelen van een extensie van *exercise games* (exergames) zoals Silverfit[1]. De extensie zal bestaan uit een interactief fotolijstje (photo frame application), dat de ouderen helpt herinneren aan het uitvoeren van hun dagelijkse oefeningen, en een RFID architectuur die er voor zorgt dat de ouderen met weinig interactie de exergame kunnen opstarten met hun persoonlijke profiel en vooruitgang van de vorige oefensessie.

Doel
Het doel van de usability test is om inzicht te krijgen in de gebruiksvriendelijkheid van de *photo frame* applicatie die uiteindelijk onderdeel zal worden van de exergame architectuur. Het gaat hier met name om de algemene interactie van de patiënt met de applicatie, navigatie, en het begrijpen en uitvoeren van bepaalde taken. Met dit in gedachten probeer ik potentiële problemen in het gebruik van het prototype te achterhalen en eventueel mee te nemen in de volgende design iteratie.

Methode
De test wordt afgenomen door middel van een individuele synchrone test met 'hardopdenkmethode'. Dit betekent dat de testleider aanwezig is in dezelfde ruimte als de gebruiker om aanwijzingen te geven op vastgestelde momenten. Daarnaast wordt de gebruiker gevraagd om tijdens de interactie met het prototype zijn/haar gedachten hardop uit te spreken. Tijdens de test wordt er gedocumenteerd door middel van camerabeelden en aantekeningen. Na de tijd worden er nog korte vragen gesteld ter aanvulling.

Doelgroep
De doelgroep van de usability test is ouderen. Aangezien het gaat om de gebruiksvriendelijkheid van de applicatie zelf, is het niet nodig om heupfractuur patiënten te vragen voor de test. Om geldige resultaten te behalen, is het van belang om minstens *vijf* personen de applicatie te laten testen.

Taakomschrijving + testscript
Tijdens de usability test wordt de gebruiker gevraagd om de volgende taken te voltooien:
- Maak samen met de testbegeleider een profiel aan door middel van uw polsbandje.
- Neem een vraag op en en verstuur de vraag naar uw fysiotherapeut
- De knop ' *vooruitgang' is buiten gebruik, dus die kunt u achterwege laten*
- Bekijk de videoboodschap van uw fysiotherapeut wanneer u die ontvangt; door de tekst onderaan het video kader te lezen.
- Keer terug naar het hoofdmenu.
- Voltooid!

Data
Er zijn een aantal metingen die gedaan worden tijdens het testen.
kwantitatief:
- Tijd
- Aantal fouten
- Aantal vragen die gesteld worden

Kwalitatief:
- Gedachten
- Knooppunten
- Houding en emoties
- Aanvullende opmerkingen

Testomgeving
Indien mogelijk zal de test uitgevoerd worden in een van de ruimtes in Humanitas.

9.3 Appendix C

Video documentatie tijdens gebruikerstest ten behoeve van observatie van testmetingen

- Ik ben door de testbegeleider van *Universiteit Twente* vóór het afnemen van de test op [datum] op de hoogte gebracht van
  - Context van het project
  - Het doel van de test
  - De testmethoden
  - Wat er met mijn persoonsgegevens gebeurt
  - Hoe mijn privacy wordt gewaarborgd

- Data verzameld tijdens de test, wordt uitsluitend gebruikt voor wetenschappelijk onderzoek en zal anoniem worden verwerkt. Alle gegevens zullen alleen toegankelijk zijn voor de onderzoeker **Jan Andres Galvan**

- Ik geef uit vrije wil toestemming om de volgende gegeven te melden bij de testbegeleider

Algemene gegevens: ja nee

Leeftijd; geslacht

- Ik geef uit vrije wil toestemming om de gebruikerstest door middel van **video & audio** te laten vastleggen

ja nee

Datum: ___ /___ /___

Naam van testbegeleider en onderzoeker van *Universiteit Twente*:

Jan Andres Galvan

Naam van cliënt:

Handtekening:

9.4 Appendix D

Vragenlijst gebruiksvriendelijkheid

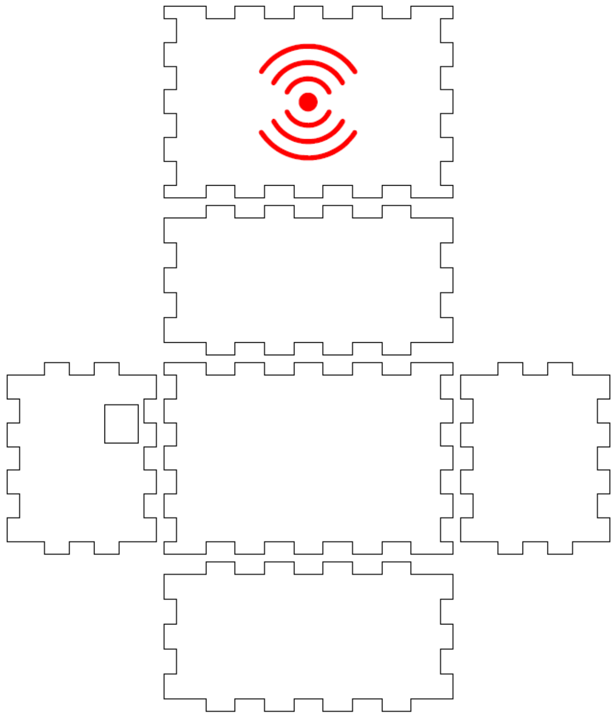
	sterk mee oneens				sterk mee eens
Ik denk dat ik deze app vaker zou willen gebruiken.	1	2	3	4	5
Ik vond de app onnodig ingewikkeld.	1	2	3	4	5
Ik vond de app gemakkelijk in gebruik.	1	2	3	4	5
Ik denk dat ik hulp nodig heb om de app te kunnen gebruiken.	1	2	3	4	5
Ik vond de verschillende functies in dit systeem goed geïntegreerd.	1	2	3	4	5
Ik denk dat er veel tegenstrijdigheden in de app zitten.	1	2	3	4	5
Ik kan me voorstellen dat veel mensen snel leren hoe ze de app moeten gebruiken.	1	2	3	4	5
Ik vond de app er omslachtig/lastig in gebruik.	1	2	3	4	5
Ik voelde me erg zelfverzekerd tijdens het gebruik van de app.	1	2	3	4	5
Ik moet nog veel leren voordat ik de app kan gebruiken.	1	2	3	4	5

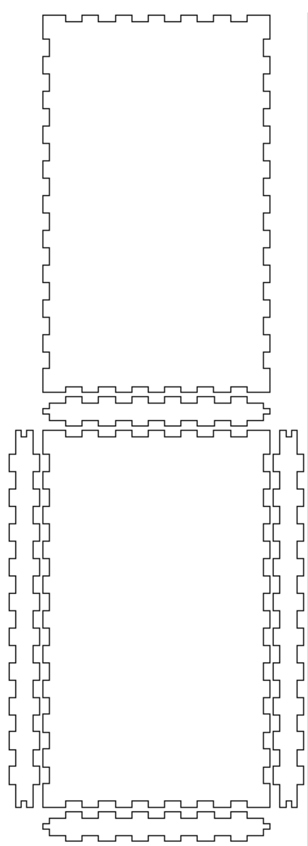
Even vragen: Score = Schaalpositie -1

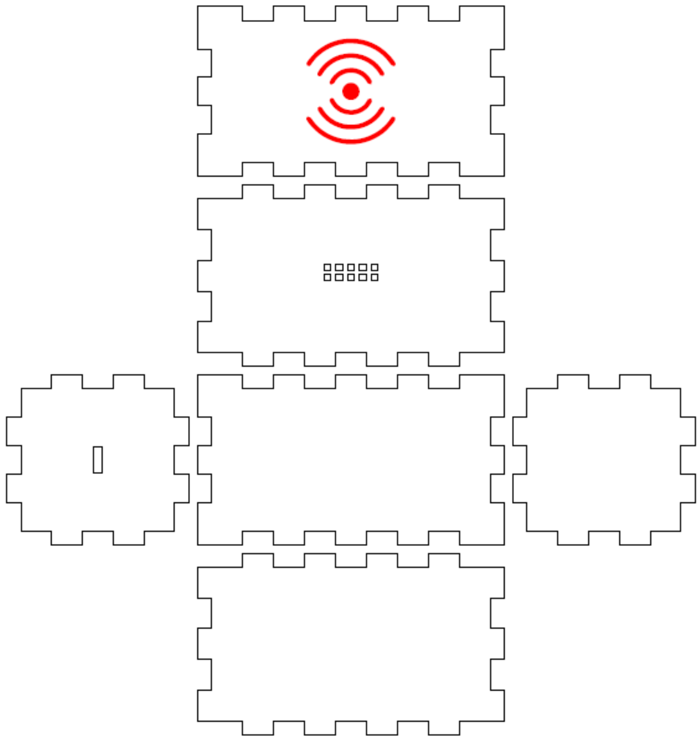
Oneven vragen: Score = 1-Schaalpositie

SUS = Totaal * 2.5

9.5 Appendix E







9.6 Appendix F

Deelnemer 1

Task	Questions	
Registration	• What is your opinion on the registration window? • Do you have difficulties scanning the tag?	- Als je het samen doet, is het wel te doen. Het is een voordeel dat je geen email en ww hoefd te gebruiken want die vergeet je. - Nee geen moeilijkheden
Entering home screen	• Do you think personal pictures or any pictures of the user's interest would add value to the system's application? Why? • Do you think personalisation of the system's application is of significance? • Would you rather have one fixed picture, or different pictures alternating over time?	- Ik denk dat ik dat wel leuk zal vinden. Alleen, als je dat inderdaad doet met mensen die dement zijn, die zouden er wel afgeleid door kunnn worden want die zouden praten over wat ze zien, in plaats van de taak uitvoeren. - - - Een foto want anders wordt het te druk
Receiving message	• Is the popup clear enough? • Did you notice the colour of light changing? • What is your opinion on having light as an indicator? • What would you change to the notification sound?	- Ja - Ja - Ik denk het wel. Mijn tante is hartstikke doof dus die zou er wel wat aan hebben. - Hangt er een beetje vanaf want als mensen in de keuken bezig zijn, en ze zijn een beetje doof, dan horen ze het niet. Ik zou het geluid iets harder doen
Watching video message	• Do you think the video message adds value to the system's application? • What do you think of the general layout of this	• Dat denk ik wel • Nu lijkt het alsof je verder moet met dat pijltje (afspeel

	window? Would you change anything? Is it clear? • Would you rather have your personal physiotherapist in the video message, or someone else?	knop). Wat gebeurt er als je op die middelste drukt? Dat is voor mij verwarrend, dat zou ik niet weten. Met tekst zoals "begin" en "start" zou het wel werken • Ik zou wel graag mijn eigen fysiotherapeut zien.
Starting exercise video	• Do you have difficulties interacting with the reading unit? • Would you prefer to use the conventional remote for starting an exercise video, or this RFID unit?	• Dit is ideaal • Vaak zien oudere mensen die lettertjes niet (op de knoppen) dus dit is dan ideaal
Additional questions	• Do you think that this system, in general, would persuade you, or any other rehabilitating older adult, to take initiative in the rehabilitation process? • If there is to be an extra menu to automatically send questions to your physiotherapist, by means of using voice recording, would you be interested in seeing this feature in future implementations? Do you think other potential user would be interested in having this ability?	• Ik denk het wel wel, want er zijn echt mensen die ik dan zie in het verpleeghuis, die nog redelijk goed zijn, maar toch dingen vergeten. • Dat zou ik wel mooi vinden
Remarks	• Do you have any further comments or remarks?	• Letter van registratie scherm zijn erg klein. "Die lettertjes zijn heel klein". • Wanneer de video start: aah hier! Dit is ideaal. • Wat ook een idee is, als de patient een oefening gedaan heeft en zich afvraagd "hoe was dat nou ook alweer", de mogelijkheid aangeboden wordt om het nog een keertje te doen.

Deelnemer 2

Task	**Questions**	
Registration	• What is your opinion on the registration window? • Do you have difficulties scanning the tag?	• Als het uitgelegd wordt, dan is het goed • Nee, geen problemen
Entering home screen	• Do you think personal pictures or any pictures of the user’s interest would add value to the system’s application? Why? • Do you think personalisation of the system’s application is of significance? • Would you rather have one fixed picture, or different pictures alternating over time?	• Dit vind ik erg leuk • Ja ik denk het wel. Het is leuk om zo’n foto te hebben als mooie herinnering van bijvoorbeeld de vakantietijd • Af en toe veranderen. Meer foto’s!
Receiving message	• Is the popup clear enough? • Did you notice the colour of light changing? • What is your opinion on having light as an indicator? • What would you change to the notification sound?	• Dat is hartstikke mooi! Erg duidelijk! • Nee want ik was op het scherm aan het letten • Ik denk zeker dat het veranderende licht zal helpen als signaal wanneer je een bericht ontvangt • nee
Watching video message	• Do you think the video message adds value to the system’s application? • What do you think of the general layout of this window? Would you change anything? Is it clear? • Would you rather have your personal physiotherapist in the video message, or someone else?	
Starting exercise video	• Do you have difficulties interacting with the reading unit? • Would you prefer to use the conventional remote for starting an exercise video, or this RFID unit?	• Helemaal niet. Ik denk dat het erg handig is om de interactie op deze manier te veranderen • Het is erg handig. Dus dit.
Additional questions	• Do you think that this system, in general, would persuade you, or any other rehabilitating older adult, to take initiative in the rehabilitation process? • If there is to be an extra menu to automatically send questions to your physiotherapist, by means of using voice recording, would you be interested in seeing this feature in future implementations? Do you think other potential user would be interested in	- Ja ik denk het wel zolang je goed uitlegd van te voren hoe het werkt. Ik denk dat mensen twee keer nodig hebben om het helemaal te

	having this ability?	begrijpen - Jazeker. Misschien krijg ik twijfels of krijg ik pijn. Dan kan ik vragen hoe ik iets moet doen.
Remarks	• Do you have any further comments or remarks?	• Prima dat je geen wachtwoord en email hoeft te gebruiken • Geluid is wel belangrijk (RFID). • Ik denk dat het ongeveer 2 keer gaat duren voordat iemand het volledig begrijpt en alleen kan.

Deelnemer 3

Task	Questions	
Registration	• What is your opinion on the registration window? • Do you have difficulties scanning the tag?	• Geen opmerkingen • Nee
Entering home screen	• Do you think personal pictures or any pictures of the user's interest would add value to the system's application? Why? • Do you think personalisation of the system's application is of significance? • Would you rather have one fixed picture, or different pictures alternating over time?	• Weet ik eigenlijk niet. Het kan, maar het kan ook een beetje deprimerend zijn omdat ze dan misschien denken "dat kan ik niet meer" • Af en toe veranderen
Receiving message	• Is the popup clear enough? • Did you notice the colour of light changing? • What is your opinion on having light as an indicator? • What would you change to the notification sound?	• Dat is wel goed genoeg • Nee dat kan ik niet zeggen • Ik denk dat licht wel heel belangrijk is • *De test persoon was slechthorend*. Geen opmerkingen
Watching video message	• Do you think the video message adds value to the system's application? • What do you think of the general layout of this window? Would you change anything? Is it clear? • Would you rather have your personal physiotherapist in the video message, or someone else?	• Ik denk wel dat het iets toevoegd. • Nee ik begreep het • Ik zou toch wel graag iemand zien die ik ken
Starting exercise video	• Do you have difficulties interacting with the reading unit? • Would you prefer to use the conventional remote for starting an exercise video, or this RFID unit?	• Ik denk niet dat ik en patiënten moeite zullen hebben met het gebruiken van een armbandje • Ik denk dat ik liever dit gebruik
Additional questions	• Do you think that this system, in general, would persuade you, or any other rehabilitating older adult, to take initiative in the rehabilitation process? • If there is to be an extra menu to automatically send questions to your physiotherapist, by means of using voice recording, would you be interested in seeing this feature in future implementations? Do you think other potential user would be interested in having this ability?	• Ik denk het wel omdat je er uiteindelijk een beetje vertrouwd mee raakt. • Ik denk dat ik zou zeggen "nee dat hoeft van mij niet"; dat is vanuit mijn perspectief. Ik denk dat het vooral van de sitatie afhangt.
Remarks 	• Do you have any further comments or remarks?	• Het is voor mij wel een klein beetje onduidelijk allemaal.

Deelnemer 4

Task	Questions	
Registration	• What is your opinion on the registration window? • Do you have difficulties scanning the tag?	• Geen opmerking • Nee
Entering home screen	• Do you think personal pictures or any pictures of the user's interest would add value to the system's application? Why? • Do you think personalisation of the system's application is of significance? • Would you rather have one fixed picture, or different pictures alternating over time?	• Ja, vooral als je lang moet rehabiliteren • Ik denk dat het persoonlijk maken van een systeem zoals dit, waarde toevoegd voor de patiënt • Een beetje afwisselend is ook wel mooi
Receiving message	• Is the popup clear enough? • Did you notice the colour of light changing? • What is your opinion on having light as an indicator? • What would you change to the notification sound?	• Ja het is duidelijk • Nee dat is mij niet echt opgevallen. Ik was op het scherm aan het letten. • Ik denk dat het wel handig zou zijn als signaal • Geen opmerking
Watching video message	• Do you think the video message adds value to the system's application? • What do you think of the general layout of this window? Would you change anything? Is it clear? • Would you rather have your personal physiotherapist in the video message, or someone else?	• Het werk wel. Zodra je de video binnenkrijgt en de boodschap zegt "begin met de oefening", dan doe je het automatisch lijkt mij. • Geen opmerking • Ik denk dat ik toch wel liever een boodschap ontvang van mijn fysiotherapeut
Starting exercise video	• Do you have difficulties interacting with the reading unit? • Would you prefer to use the conventional remote for starting an exercise video, or this RFID unit?	• Nee. Als je het weet, dan is het makkelijk. • Het gebruiken van een armbandje lijkt me makkelijker
Additional questions	• Do you think that this system, in general, would persuade you, or any other rehabilitating older adult, to take initiative in the rehabilitation process? • If there is to be an extra menu to automatically send questions to your physiotherapist, by means of using voice recording, would you be interested in seeing this feature in future implementations? Do you think other potential user would be interested in	• .Ja dat denk ik. Als ik een bericht zou zien waarin staat dat ik iets moet doen, dan zou ik dat veel sneller doen dan wanneer ik geen herinnering krijg. Een mens heeft al gauw geen tijd of denkt er niet aan

	having this ability?	• Licht er aan wat voor persoon de gebruiker is. Ik zou het zelf niet gebruiken. Ook denk ik dat de fysiotherapeuten daar helemaal geen tijd voor hebben want ze zijn over het algemeen best wel druk.
Remarks	• Do you have any further comments or remarks?	• Ik vind het verder heel duidelijk. • Ik kan me heel goed voorstellen hoe dit kan werken. Ik moet zelf ook wel eens naar de fysio en daarna moet ik oefeningen doen. Ik sla dat nog wel eens over en dan denk ik later “hoe moest dat ook alweer?”. Ik weet dan niet meer hoe het moet en dan doe ik het ook niet.

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