Creating a feedback system with the Myo Armband, for home training for frail older adults

Bachelor Thesis for Creative Technology by

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Abstract

Although staying physically active is very important for frail older adults, two thirds of the older adults in the Netherlands does not exercise enough. Roessingh Research and Development (RRD) offers older adults the opportunity to perform exercises at home. Their current Life project offers older adults these opportunities by online explanatory videos and text on how to perform exercises that train the overall fitness. This project however, lacks feedback to the older adult about their performance at the moment. Therefore, the research question for this project is: "*How to design and implement a feedback system, using the Myo Armband, to provide feedback to frail older adults on their performance, regarding the strength exercises related to the upper-body?*".

In order to give feedback to the user, the performance of the user should be measured. The Myo armband (by Thalmic Labs Inc.) offers many capabilities to serve as crucial sensing element in the to be developed feedback system. Through background research more information on how to provide feedback and the opportunities and limitations of the Myo has been gathered. This information, combined with information gathered through brainstorm sessions, and interviews, has led to several application ideas, after which the most feasible application was chosen.

The outcome of this selection process was the application idea to develop a game to provide live feedback to the older adult and at the same time motivate the older adult. The most important requirements of this game are: showing the effort of the user, keeping track of the amount of times the exercises has been performed, providing mostly positive feedback, and to stay honest towards the older adult about their performance. Positive feedback encourages and motivates the older adult, where the honest feedback reminds the user to perform the exercise correctly. The developed game meets all the above announced requirements.

After a functional and user test on the developed prototype, it could be concluded that the users had positive experiences with the system. Users got motivated by and enjoyed the game, while the game had a similar usability rating as the original Life program. Moreover, when using the game, the older adults were similarly secure about their performance, as with using the original Life program. However, some users were confused by the game, because of the occurrence of bugs and the lack of explanatory text. Overall, the game was well received by the older adults.

For future development, the bugs should be fixed and more explanatory text should be added, in order to prevent the occasional confusion among the older adults. Moreover, the game could be made more dynamic and since many users were enthusiastic, more games for different exercises could be made. At last, the effect of sound in the game could also be researched, as sound can be a clear way of providing feedback.

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Table of Contents

ABSTRACT **3**

ACKNOWLEDGEMENTS **5**

TABLE OF CONTENTS **7**

CHAPTER 1: INTRODUCTION **11**

1.1 INTRODUCTION 11
1.2 MYO ARMBAND 12
1.3 ROESSINGH RESEARCH AND DEVELOPMENT 12
1.4 CHALLENGES 12
1.5 RESEARCH QUESTIONS 13
1.6 REPORT OUTLINE 13

CHAPTER 2: BACKGROUND RESEARCH **15**

2.1 INTRODUCTION 15
2.2 STATE-OF-THE-ART RESEARCH: INTERACTIVE HEALTH-CARE APPROACHES 15
2.2.1 Wii-Habilitation *15*
2.2.2 Virtual Reality *16*
2.2.3 Interactive LED Floor *17*
2.2.4 Tovertafel *17*
2.2.5 Conclusion *18*
2.3 LITERATURE RESEARCH: USING MYO ARMBAND TO MEASURE PERFORMANCE WHEN EXECUTING EXERCISES 18
2.3.1 Functionalities of the Myo *19*
2.3.2 Differences Myo and other gesture tracking devices *20*
2.3.3 Myo in Health-Care *21*
2.3.4 Limitations of the Myo *22*
2.3.5 Conclusion *23*

CHAPTER 3: METHODS AND TECHNIQUES **25**

3.1 CREATIVE TECHNOLOGY DESIGN PROCESS 25
3.1.1 Ideation Phase *25*
3.1.2 Specification Phase *26*
3.1.3 Realization Phase *26*
3.1.4 Evaluation *26*
3.2 ANALYSIS OF LIFE PROJECT 28
3.3 STAKEHOLDER ANALYSIS 28
3.4 BRAINSTORM SESSIONS 28
3.5 INTERVIEWS 29
3.6 IPACT & FICS 29
3.7 FUNCTIONAL SYSTEM ARCHITECTURE 30
3.8 REQUIREMENTS 30
3.8.1Functional and non-Functional *30*
3.8.2 MoSCoW *30*
3.9 EVALUATION 31

3.9.1 Functional Test *31*
3.9.2 User Tests *31*

CHAPTER 4: IDEATION **33**

4.1 INDIVIDUAL BRAINSTORM SESSION 33
4.2 STAKEHOLDER ANALYSIS 34
4.3 INTERVIEWS / JOINT BRAINSTORM SESSIONS 35
4.3.1 Interview Physiotherapist *36*
4.3.2 Interview Developer Life *36*
4.3.3 Interviews Older Adults *37*
4.3.4 Conclusion Interviews / Brainstorm Sessions *38*
4.4 ANALYSIS OF LIFE PROJECT 39
4.5 FINAL IDEA 40
4.5.1 Graphical User Interface *40*
4.6 REQUIREMENTS 1ST ITERATION 41
4.7 IPACT 42

CHAPTER 5: SPECIFICATION **45**

5.1 FICS 45
5.2 FUNCTIONAL SYSTEM ARCHITECTURE 46
5.2.1 Level 0: Inputs and Outputs *46*
5.2.2 Level 1: Functions *46*
5.2.3 Level 2: Sub-functions *47*
5.3 ACTIVITY DIAGRAM 50
5.4 REQUIREMENTS 2ND ITERATION 52

CHAPTER 6: REALISATION **55**

6.1 PROGRAMMING SOFTWARE 55
6.2 INPUT DATA SELECTION 56
6.3 GAMEPLAY 56
6.3.1 Calibration Scene *56*
6.3.2 Minigame Scene *57*
6.3.3 Results scene *58*

CHAPTER 7: EVALUATION **61**

7.1 FUNCTIONAL TEST 61
7.2 TEST PROCEDURE 62
7.2.1 Introduction *63*
7.2.2 Warming-up *63*
7.2.3 Test A *63*
7.2.4 Test B *63*
7.2.5 User's Opinion *64*
7.3 TEST RESULTS 64
7.3.1 Observations and Thinking-Aloud Information *64*
7.3.2 Questionnaire Results *65*
7.3.3 Interview Results *70*
7.4 DISCUSSION 71
7.5 CONCLUSION 71

7.6 Requirements 3th Iteration 72

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS 75

8.1 Conclusion 75
8.2 Recommendations 77

REFERENCES 79

APPENDIX 83

Appendix A: Mind-Maps 83
A-1: Individual Brainstorm Session 83
A-2: Joint Brainstorm Session with Physiotherapist 83
Appendix B: Set-up Interviews / Brainstorm Sessions 84
B-1: Physiotherapist 84
B-2: Older Adult (Dutch) 84
B-3: Developer Life Project 86
Appendix C: Informed Consent Interview Older Adults (Dutch) 87
C-1: Information Letter 87
C-2: Consent Form 89
Appendix D: Transcription Interviews / Brainstorm Sessions 90
D-1: Physiotherapist 90
D-2: Developer Life 94
D-3: Older Adults 95
Appendix E: Design Sketches 98
Appendix F: List of Requirements 101
Appendix G: EMG Data Squeezing and Resting 103
..... 103
..... 103
Appendix H: Images of minigame 104
Appendix I: Informed Consent User Tests (Dutch) 105
I-1: Information Letter 105
I-2: Consent Form 107
Appendix J: Administrative Questions User Test (Dutch) 108
Appendix K: Questions of Questionnaire User Test (Dutch) 109
K-1: Questionnaire Questions System 1 (without Feedback / Game) 109
K-2: Questionnaire Questions System 2 (with Feedback / Game) 110
Appendix L: Questions of Structured Interview User Test 111
Appendix M: Administrative Data Participants 113
Appendix N: Transcription Recordings 114
Appendix O: Calculation of SUS Ratings 118
Appendix P: Structured Interview Results 119

Chapter 1: Introduction

In this chapter the situation and challenges related to this graduation project are introduced. Based on these problems and challenges, research questions are formulated. Afterwards, the outline of the report is described. At last, the chapter introduces the Myo Armband and Roessingh Research and Development, since both formed the basis for this graduation project.

1.1 Introduction

Exercising regularly is one of the healthiest things to do for anyone, especially for frail older adults [1]. Older adults can gain a lot by staying physically active, since it helps maintaining the ability to live independently and reduces the risk of falling or fracturing bones [2]. Although staying physically active is very important for frail older adults, two thirds of the older adults in the Netherlands does not exercise enough [3]. Meaning, these older adults do not exercise for more than one hour a week.

In order to increase the total of frail older adults performing exercises, the revalidation centre Roessingh [4] in Enschede, started a project called Life. The aim of this project is to make frail older adults more independent when it comes to improving their motoric skills or to overcome their motion problems. Life is an online website containing videos, which explain how to perform certain physical exercises [5]. The older adults can login to this online platform, watch these explanatory videos and in this way do the exercises at home. By making it possible for the older adults to perform the exercises at home, performing exercises becomes more accessible for them. Normally these older adults would have to go a gym or physiotherapist to perform the exercises. Downside among others of the current Life project is, that the older adults do not receive feedback about their performance. Therefore the older adults are unsure whether they perform the exercise correctly or not.

Therefore the aim of this project is to create a feedback system for the Life project, which provides feedback to the frail older adults about their performance. In order to give feedback about the performance of exercises, the performance of the exercises should be measured. The Myo Armband, manufactured by Thalmic Labs [6], will be used to measure the performance. This device can detect the electrical activity from the user's muscles and the motion, rotation and orientation of the user's arm [7]. Since the Myo Armband can only detect arm- and hand-related muscle activities and movements, this project focusses on exercises only involving the arms and the hands. More specifically, the project focusses on the strength exercises related to the upper-body, offered by the Life project.

1.2 Myo Armband

The Myo Armband ("Myo" in short) is a novel technological device, which is used for this graduation project, therefore the Myo will briefly be introduced in this section. The Myo is able to recognize the users' arm-movement and hand-gestures, by measuring EMG data. It is supposed to be worn around the forearm. Thalmic Labs [6], the manufacturer of the Myo, created a machine learning algorithm, which makes sure the Myo always recognizes gestures, regardless of the person wearing the device.

Figure 1.4.1 The Myo Armband [55]

The Myo can be connected to other technological devices, using a Bluetooth connection. This allows the user to control certain programs using hand-gestures and arm-movements. Moreover, it is possible for people to create their own application for the Myo, using the development kit that comes with the device. Most of the application for the Myo can be found in the Myo Market [8]. The Myo will be further explained in chapter 2.3.

1.3 Roessingh Research and Development

This project will be executed in co-operation with research centre Roessingh Research and Development (RRD in short), and therefore RRD will shortly be introduced. RRD is the largest centre in the Netherlands where a wide range of disciplines such as rehabilitation medicine, movement sciences, psychology, physiotherapy, and biomedical sciences work together on current and future innovations in rehabilitation and chronic care. As an internationally recognised scientific research institute, RRD occupies a unique position between the university and healthcare practice [9].

1.4 Challenges

As explained earlier, this project focusses on providing feedback to the older adults about their performance of the physical exercises (strength exercises related to the upper-body), offered by the Life online website. At the moment the older adults do not know whether they perform the exercises correctly. The Myo armband will be used to measure the performance of the older adult.

The challenge of this graduation project is therefore, to research how to design and implement a feedback system suitable for Roessingh's Life project. Aim of this feedback system is to improve the performance of the older adults executing exercises. This is done by visualizing how they perform and how they could improve their performance. In order to so, first the execution of the exercise should be measured correctly and second this measured performance should be translated into feedback understandable for the older adult. The older adults must be able to improve their performance, based on the feedback provided. Moreover, the feedback should be provided in a positive and engaging way, by providing many compliments.

1.5 Research Questions

Building forth on the above explained challenges, one research question was formulated.

- *RQ: How to design and implement a feedback system, using the Myo Armband, to provide feedback to frail older adults on their performance, regarding the strength exercises related to the upper-body?*

To help answering this research question, three sub-research questions were formulated.

- *SubRQ1: What information about the execution of the daily exercises do older adults need?*
- *SubRQ2: What characteristics, regarding usability, of the Myo Armband should be taken into account?*
- *SubRQ3: How to provide feedback to older adults about their performance when executing exercises, in an engaging way?*

1.6 Report Outline

The total outline of the report is described below. This outline describes all chapters and the purpose of each chapter.

Chapter 2 describes the background research that has been conducted for this project. This background research includes a state-of-the-art research and a literature research. The state-of-the-art is focussed on previous approaches to make health-care processes more interactive using technological devices. The literature research is focussed on the opportunities and limitations of using the Myo Armband. The aim of this chapter is to gain background information, which can be used in the ideation phase of the project.

Chapter 3 describes the methods and techniques used within this project. Here the Creative Technology Design process and other methods and techniques used within this design process are described. The aim of this chapter is to understand the process to answer the research question.

Chapter 4 describes the Ideation phase of the project. Within this phase, the conclusion of the state-of-the-art research forms the basis for creating a variety of different creative application ideas. Using the different methods and techniques described in Chapter 3, one application idea is chosen. This chosen idea will form the basis for the specification phase (Chapter 5). The aim of this chapter is to generate multiple creative application ideas and to choose the most feasible application idea.

Chapter 5 describes the specification phase of the project. Within this phase, the functionalities of the chosen application idea are described, using diagrams and flow charts. The aim of this chapter is to understand the functionalities of the application, which are needed to develop the prototype.

Chapter 6 describes the realisation phase of the project. Within this phase, the development of the prototype is describes. The aim of this chapter is to understand the choices made, while constructing the prototype for this project.

Chapter 7 describes the evaluation phase of the project. Within this phase, the user tests and the results of these tests are described. During the user tests, both the prototype and the original Life program were tested by older adults. The aim of this chapter is to compare the prototype with the

original Life program, and to get to know the user experiences of older adults when using the developed prototype.

Chapter 8 consists of the conclusion and recommendations for future work. The aim of this chapter is to summarize and conclude the project and make recommendations for future work or research related to this project and it's prototype.

Chapter 2: Background Research

In this chapter the background research that has been conducted for this project is described. First, the research method will be discussed. Second, the state-of-the-art research, focussed on previous approaches on providing feedback and making health-care processes more interactive, is described. At last, the literature research, focussed on the use of the Myo to measure the execution of exercises, is described. The background research forms a basis to answer sub-research question 2 and sub-research question 3.

2.1 Introduction

The background research done for this project has been divided into a state-of-the-art research and a literature review. The state-of-the-art research will discuss earlier approaches of using technological devices to provide feedback or make rehabilitation processes more interactive. Because this project is focussed on older adults performing exercises, only rehabilitation processes related to physical rehabilitation will be considered. The literature review will give a more detailed overview on how the Myo Armband could be measure the performance of older adults performing exercises.

2.2 State-of-the-Art Research: Interactive Health-Care Approaches

To get an overview of earlier approaches using technological devices to provide feedback or make rehabilitation processes more interactive, a state-of-the-art research has been conducted. Only previous approaches, related to physical rehabilitation are included. Furthermore, previous approaches interacting with older adults are preferred. In this state-of-the-art research first the wii-habilitation approach will be discussed, followed by a discussion on the use of virtual reality, the interactive LED floor, and the Tovertafel are discussed.

2.2.1 Wii-Habilitation

The wii-habilitation approach makes use of the Nintendo Wii (see figure 2.2.1.1) [10] as a technological device to make rehabilitation processes more interactive and fun. The Nintendo Wii is a gaming device that consists of a console and a controller. An user is supposed to hold the controller in one of his or her hands. The controller measures the arm-movements and rotation of the user, using an accelerometer. This information is then send to the console, enabling the user to play games by moving or rotating his or her arm.

Figure 2.2.1.1 Nintendo Wii [56]

The wii-habilitation approach is already often used in the health-care sector for a broad range of patients. Parkinson disease patients, children, seniors and also stroke patients are examples of patients where the wii-habilitation approach is already being used for [11].

The Wii is a very popular device within rehabilitation processes. Santayayon et al [12] state that the Wii is a great motivational and interesting tool to use. Those playing the games on the Wii generally wanted to have another go, rather than becoming bored of repetitive exercises. The users can also benefit from the visual feedback that the console and controllers offer. Because of the Wii's popularity, there is a decent chance users or relatives from the user own such a device. This offers the opportunity to continue practicing at home. Also Joo et al [13], found that Nintendo Wii gaming was experienced as enjoyable.

Neuroscience Research Australia (NeuRA) [14] have developed a novel rehabilitation strategy, using the Nintendo Wii, and came to similar conclusions. NeuRA states that this strategy can overcome one of the biggest impediments in rehabilitation, patient compliance and motivation. At the moment NeuRA only knows this strategy works. However, they still need to understand how and why it works.

In the end, it can be concluded that the wii-habilitation approach is a successful approach when it comes to motivating and stimulating patients. The general wii-habilitation approach is proven to be working. However, it is at the moment not known why it is working.

2.2.2 Virtual Reality

Virtual reality (VR) is getting a more popular tool to use in physical rehabilitation processes. Virtual reality is the term used to describe a three-dimensional, computer generated environment which can be explored and interacted with by a person. That person becomes part of this virtual world or is immersed in this environment and whilst in this environment, is able to manipulate objects or perform a series of actions [15]. Often an Oculus Rift (see figure 2.2.2.1) [16] is used to create such an virtual reality.

Figure 2.2.2.1 Oculus Rift [57]

Using VR, therapy can be provided within a functional, purposeful and motivating context. Many VR applications present opportunities for individuals to participate in experiences, which are engaging and rewarding [17]. Often when VR is used in health-care it has the purpose to prepare the patient for real life situations / challenges that can occur. The patient experiences these real life situations / challenges in VR, so he or she is familiar with certain situations when they occur later on in real life.

In short, virtual reality offers the opportunity to provide therapy in a functional, purposeful and motivating context. Real life situations or challenges can be simulated and experienced by the patient, using VR. This aids the patient in getting familiar with these situations, prior to experiencing these situation in real-life.

2.2.3 Interactive LED Floor

LedGo's sensitive interactive LED floor [18] (see figure 2.2.3.1) has been used to develop games for gait rehabilitation. Van Delden et al [19] developed these games for a variety of different users, the slow and quick, the old and young, and the weak and strong. This wide variation in types of users is one of the reasons why personalization has an important role in the games of van Delden et al.

Figure 2.2.3.1 LedGo's interactive LED Floor [58]

For this reason their approach was to develop games that allow to train many aspects of the gait. These games are adaptable by the therapist. In this way the therapist can personalize the game for the current user. The therapist can determine the difficulty of the game and this way personalize the game to the current patient. The results on the games for the interactive LED floor were very positive. In total 33 out of the 37 patients would like to play these games during therapy. Some patients indicated the games would add to the variety of the therapy.

Also therapist were positive about these games, as they recognized the patients enjoyed the game and got stimulated by it. The therapists were positive about the possibility for personalization of the games. However, not all therapists were convinced the games contain functionality that can train therapy aspects outside normal therapy. In this case, normal therapy refers to therapy without the use of games.

2.2.4 Tovertafel

The Tovertafel (Magic Table) is originally designed for people with dementia (see figure 2.2.4.1). The Tovertafel is a small box that can be placed on the ceiling, above a table. Inside this box is a projector, infrared sensors, speaker and processor that work together to project interactive games on the table. These games stimulate both physical and cognitive activity and encourage social interaction [20]. Light is the perfect medium for the Tovertafel, since it is energising, attention-grabbing, clean and completely safe [21].

Figure 2.2.4.1 The Tovertafel [59]

During the design process of the Tovertafel the, so called 'participatory design' or 'co-design' method, was used. This means that the user group was actively involved in the design process. Five different insights were gained from this design process.

First, the Tovertafel game must take initiative to encourage older adults to take part. Older adults will not begin playing without prompting. Second, by constantly reminding older adults what they are doing, they keep active for a longer period of time. Third, light projections that are rich in terms of colour, movement and detail are most valued by older people. Fourth, the older adults must have the feeling that nothing can go wrong during the play. This can be accomplished by creating a safe situation where older adults are free to try things. At last, games in which all older adults, regardless of their disabilities (in this case stages of dementia) can take part, means that no one is excluded. This creates a relaxed, positive atmosphere of 'being together' [22].

2.2.5 Conclusion

This state-of-the-art research discussed four different approaches. Namely, the wii-habilitation approach, the use of virtual reality, the interactive LED floor, and the Tovertafel. All approaches showed that the patient will motivated and stimulated by the given interaction.

The wii-habilitation approach is already a common used approach in rehabilitation processes. Although it has been proven that this approach works, researchers still need to investigate why this approach is working.

Virtual reality (VR) is a less common used approach in rehabilitation processes, however also this approach has proven to be successful. The created experiences in VR are engaging and rewarding and therefore stimulate the patient. The purpose of VR in rehabilitation processes, is to prepare patients for real life challenges by letting them experience these challenges in VR.

The interactive LED floor has been used for gait rehabilitation, by designing personalised games for it. These were experienced as stimulating by the patients using it. The patients also enjoyed the games. Not all therapists, however were convinced these games could be used outside of normal therapy.

At last, the Tovertafel is an interactive table originally designed for people with dementia. Games have been designed for the Tovertafel, which stimulate both physical and cognitive activity and encourage social interaction.

One aspect most approaches have in common is the use of gamification. The wii-habilitation approach makes use of games from the Nintendo Wii, the interactive LED floor has been used for designing personalized games for gait rehabilitation, and also games have been developed for the Tovertafel. Virtual Reality is also often used for games, however no VR games were found for rehabilitation processes. The approaches show that gamification can have a stimulating and encouraging effect in rehabilitation processes. The wii-habilitation approach, the games for the Interaction LED floor ,and the Tovertafel show that the gamification approach can be also be used when designing an application for older adult. This information will be used in the Ideation phase of this project (see Chapter 4).

2.3 Literature Research: Using Myo Armband to Measure Performance when Executing Exercises

To get a more detailed overview on how the Myo Armband could be used to measure the performance of older adults executing exercises, a literature research has been conducted. In this literature review first the functionalities of the Myo are discussed. Second, the differences between the Myo and other

gesture tracking devices are discussed. Third, previous uses of the Myo in health-care are discussed. At last, the limitations of the Myo are discussed.

2.3.1 Functionalities of the Myo

The Myo Armband is a technological device that recognizes gestures and arm movements of the user and sends this information to other technological devices. An user is supposed to wear the armband on the forearm (see figure 2.3.1.1). The device has four main functionalities.

Figure 2.3.1.1 The Myo Armband worn around the forearm [60]

First, the Myo can detect arm-movement. The movement of the arm can be detected in rotational, horizontal and vertical directions [23]. In order to be able to detect the arm-movement and arm-rotation, the Myo makes use of a three-axis accelerometer and a gyroscope [24]. The detection of the arm-movement is mostly used to calculate the position of the user's hand. Therefore it seems most convenient to use the detected arm-movement for calculating the user's hand-position, when designing an application for the Myo.

Second, the gadget measures Electromyography (EMG) signals using eight circularly arranged sensors around the arm muscles of the arm the Myo worn [25]. This EMG data represents the muscle activity of the user and it is used to be able to detect five different predefined hand-gestures. According to Sathiyanarayanan et al [23], these gestures are fist, rest, wave-in, wave-out

Figure 2.3.1.2 Five different predefined gestures of the Myo Armband [61]

and click (see figure 2.3.1.2). This is also stated by other researchers [26], [24]. The Myo uses the data gathered from a calibration step and machine learning to recognize the gestures performed.

Third, it is possible to add new gestures. This can be done using the Software Development Kit (SDK), provided by Myo's creative company Thalmic Labs. The SDK allows to access Myo's device functions and raw data [23]. This raw data includes all eight EMG sensors data and the data from the accelerometer and gyroscope. Lu et al [27], already researched increasing the number of recognizable gestures from five to nineteen. The researchers concluded that more gestures can work confusingly for the user, since the difference between gestures is smaller. Also, experienced users performed better than non-experienced users. Therefore when designing an application for the Myo, the number of gestures should not be too large.

At last, the Myo can synchronize with other technological devices. It can communicate with other technological devices (mostly computer or smartphone) using Bluetooth 4.0 Low Energy Technology [28]. According to multiple researchers the Bluetooth connection is a good feature of the

Myo [23], [24]. Moreover, no complains about the Bluetooth connection were found in the researched papers.

In the end it can be concluded that the four main functionalities of the Myo Armband are recognizing arm-movement in all directions, recognizing five different predefined hand-gestures, adding new gestures, using the SDK to access the raw data of the Myo, and communicating with other technological devices, using Bluetooth. All these functionalities can be used to measure the performance of older adults performing exercises. The feature of recognition of arm-movement and arm-rotation and hand-gestures can be used to measure whether the older adult is performing the exercises correctly. Using the SDK, the gestures necessary for the daily exercises can be added. The measured data can be transferred to an user's laptop or mobile phone and then translated into convenient feedback.

2.3.2 Differences Myo and other gesture tracking devices

Although the use of the Myo Armband was already determined by the graduation project itself, the device has still been compared to other gesture and motion tracking devices. This, to determine whether the Myo is actually most convenient to use to measure the execution of exercises. The Myo has been compared with the Microsoft Kinect (see figure 2.3.2.1) [29], Leap Motion (see figure 2.3.2.2) [30] and smartwatches (see figure 2.3.2.3) [31]. The Microsoft Kinect is a motion-tracking device, which makes use of cameras to track the motion of the user. Also the Leap Motion makes use of cameras to track motion. However where the Kinect is focussed on motion of the total body, the Leap Motion is only focussed on hand movements. At last, the LG G Smartwatch is a smartwatch controlled by wrist movements or rotations of the user.

Figure 2.3.2.1 Microsoft Kinect [63]

First, compared to the Microsoft Kinect and the Leap Motion the Myo Armband offers more flexibility and accuracy. Furthermore, it prevents occlusion. Occlusion refers to the fact that vision-based tracking devices (like Kinect and Leap Motion) will at best get a general sense of finger motion and therefore are not able to distinguish two hands when they are on top of each other [32]. Kutafina et al [24] used armbands as they were not obstructive and they increase the mobility in comparison to cameras, used by the Microsoft Kinect. Also Morias et al [33] state that the Kinect has many disadvantages compared to the Myo. Namely, that the Kinect could be more of a barrier than the Myo when it comes to gesture commands and that the Myo could capture short movements more precisely. Furthermore the Myo prevents the occlusion that occurs when using systems that use cameras, like Kinect and Leap Motion [34].

Figure 2.3.2.2 Leap Motion [62]

However, Morias et al also state some disadvantages of the Myo compared to Microsoft Kinect. Namely that the information gathered using the Myo cannot generate object reference in a 3D world like Microsoft Kinect does [33]. Also the Kinect does not need to train the users with specific gestures and the Kinect

has better performance in navigation tasks [35]. For this project gesture recognition is more important than object referencing, so the advantages of the Myo compared to Kinect and Leap Motion prevail the disadvantages.

Second, compared to smartwatches the Myo Armband is able to detect both hand-gestures and arm-movement, whereas the smartwatches can only detect hand-gestures. Moreover, there is no difference in the accuracy of the hand-gestures between the two devices. At first Kefer et al [36], assumed that smart watches would have a better recognition accuracy, as hand gestures are easier to measure in the wrist than on the forearm. However, after testing the accuracy of a smartwatch (LG G Watch) and the Myo it turned out that they had to reject their hypothesis. The smartwatch was 8% more accurate, however this difference was too small to accept the made assumptions. The use of a Myo instead of a smartwatch therefore, seems justified.

Figure 2.3.2.3 LG G Watch [64]

At last, the biggest advantage of the Myo over the Kinect, the Leap Motion, and the LG G Watch is the fact that the Myo is capable of measuring the muscle activity of the user (using EMG data), whereas the other devices cannot. Muscle activity can be very important when determining whether an older adult performs an exercise correctly, since many exercises are related to strength.

In short, the use of the Myo for this project seems justified compared to other gesture tracking devices. It offers more flexibility and accuracy than the Kinect and Leap. Flexibility and accuracy are both important when it comes to recognizing the execution of exercises. Furthermore, the Myo also prevents occlusion, whereas the Kinect and Leap do not. Occlusion can disturb the recognition of gestures and therefore it is important to be prevented. Compared to smartwatches, the Myo has similar accuracy and can also detect arm-movement, in contrast to smartwatches. The detection of arm-movement is essential to measure the execution of the exercises. At last, the Myo is able to measure muscle activity, whereas the other devices cannot. All together it can be concluded that, the Myo is most suitable for this project, compared to Kinect, Leap and smartwatches.

2.3.3 Myo in Health-Care

The Myo Armband has not often been used in health-care before. However, its main usage if applied in health care, is for amputees and physiotherapy.

First, Matos et al [28], experimented the possibility of using a Myo on a person's leg. The goal of their research was to find a HCI (Human Computer Interaction) solution for upper limb amputees. Results showed that leg gestures can be profiled, using the Myo and that the Myo can also be used to interact with computers while worn around a person's leg. This information can be valuable for future additions to this project, since physical exercises often include leg movement.

Second, Phelan et al [37], use the Myo in combination with the Oculus Rift DK2 and the Kinect to explore the use of virtual reality to help amputees evaluate how a prosthetic arm design might appear and be controlled prior to its individual prescription and purchase. The Myo was used to control the prosthetic arm in the virtual scene, built in the Unity game engine. This research showed that the Myo can easily be combined with other technological devices, using the Unity game design.

Third, Banierink [38] explored the technical capabilities of the Myo as a home-monitoring device for stroke patients. Intensive arm training improves the rehabilitation of stroke patients and normally the supervision of a healthcare professional is needed. It has been tested if the Myo is feasible to use a home monitoring device, for stroke patients performing this arm training. In 84% of the cases, the Myo was able to recognise the hand pose of the subjects. Only in 13% of the cases, the Myo was able to recognise a complete gesture. This means that it is difficult to recognise complete gestures using the Myo. However recognising hand poses is possible.

At last, Sathiyanarayanan et al [23], used a SUS model (System Usability Scale) to understand the performance of doctors using the "doctors' satisfaction metrics", which indicates how satisfied the doctor is with the use of new technological systems. Moreover, another questionnaire was used to discover the ergonomic issues related to the device, like social acceptability, ease of learning etc. Based on the positive results of their research, the researchers proposed that the Myo has a potential to be used for understanding one's arm movements during the physiotherapy stage. They also state that adding more features considering the physiotherapy treatment will attract more doctors and the patients to use the system at home. This means that the Myo has the potential to be used at home for doing physical exercises, normally done at the revalidation centre.

In short, the Myo Armband can be used to detect, besides arm-movement, also leg-movement and the device can easily be combined with other technological devices. Moreover, the Myo can easily recognise hand poses, but it is more difficult to measure complete gestures using the Myo. Moreover, it has the potential to be used for home training, since based on questionnaires both doctors and patients are positive about using the device. It should be taken into consideration that there not many sources available about the use of the Myo in health-care.

2.3.4 Limitations of the Myo

Limitations of the Myo Armband are the limited amount of built-in gestures, the accuracy, the necessary calibration step, and the occasional misclassifications. First, there are only five predefined gestures for the Myo. Mulling et al [34] state that this limited amount of predefined gestures is too few and this limits the possibilities for designing application for the Myo using gestures. This is also stated by other researchers [26], [39]. Adding new gestures also seems rather difficult. For this project one should be aware of this limitation, since the patient's exercises involve gestures that are perhaps not predefined by the Myo.

Second, the device is for some researchers not accurate enough. Silva et al [40], saw the fact that the Myo sensors cannot identify the hand and finger motions as a limitation. They used a Leap Motion device to compensate for this lack of accuracy. Also Sathiyanarayanan et al [23], state that the accuracy of gestures recognition should be optimized, since it frustrates and discomforts the users. Therefore, these accuracy issues should be taken into account when designing an application for the Myo. When analysing raw data instead of making use of the predefined gestures, these accuracy issues can be avoided.

Third, before using the device it has to be calibrated. The calibration has to be done every time a new user is using the device [23]. This is necessary because each user has a different type of skin, and muscle size. Also, when the same user uses the device at a different time or in a different situation the Myo has to be calibrated. Therefore a calibration step needs to be included when designing an application for the Myo.

At last, the Myo has some occasional misclassifications, namely detecting gestures incorrectly. These errors are seen as a big limitation by most researchers, since it influences the user experience [26], [35]. Most errors occur when users frequently change their gestures. Therefore, one has also to be aware of these error when using or designing a Myo application. Again when analysing raw data instead of making use of the predefined gestures, these gesture misclassifications can be avoided.

In short, for this project it should be taken into account that some necessary gestures are not predefined by the Myo and that adding gestures is considered to be difficult. Moreover, the potential lack of accuracy and misclassifications can cause frustration by the users and should be prevented as much as possible. When analysing the raw data, instead of making use of the predefined gestures, these problems can be avoided. At last a calibration step needs to be included when developing an application for the Myo.

2.3.5 Conclusion

This literature research discussed how the Myo Armband could be measure the performance of older adults performing exercises. The functionalities of the Myo, the differences between the Myo and other gesture tracking devices, previous uses of the Myo in health-care and the limitations of the Myo were researched. It the end it can be concluded that, the Myo is a very useful tool to measure the performance of older adults performing exercises. However, it has its limitations, that should be taken into account.

The detection of hand-gestures and arm-movements can be used to measure the execution of the exercises. The SDK allows to add the new gestures necessary for these exercises and the Bluetooth-connection allows for a fast way to provide feedback for both the patient and the physiotherapist.

Compared to other gestures tracking devices the use of the Myo seems justified. The Myo has been compared to the Kinect, Leap Motion and smartwatches. The Myo offers more flexibility and accuracy than the Kinect and Leap Motion. Compared to smartwatches, that can only measure hand-gestures, the Myo is also able to recognize arm-movements. At last, the Myo can detect muscle activity, whereas the other devices cannot. All those advantages are important when measuring the execution of exercises.

Previous use of the Myo in health-care, relate to physiotherapy and amputees. Insights gained from these previous uses are: the Myo is also capable of measuring leg-movement when worn around the leg, this can be useful when measuring the execution of exercises that include leg muscle activity. Moreover, the Myo can easily be combined with other devices, using the Unity game engine, and it has the potential for being used for home-training, since both patients and doctors are positive about the use of the device.

The Myo has some limitations that should be taken into account when designing an application for it. Some gestures necessary for the project may not predefined and should be added manually. Furthermore, the potential lack of accuracy and misclassifications must be prevented as much as possible. This can be done by analysing the raw data, instead of using the predefined gestures. At last, the necessary calibration step should be included when developing an application for the device.

All information on the Myo Armband, gathered during this literature research will be used in the specification phase (Chapter 5) and realisation phase (Chapter 6) of this project. The gathered

data from this literature research is namely valuable when developing the functionalities of a Myo application and when determining proper requirements for such an application.

Chapter 3: Methods and Techniques

In this chapter the different methods and techniques used within this research are described. Also, within this chapter the motivation why these methods and techniques were applicable to use for this research are described.

3.1 Creative Technology Design Process

The "Creative Technology Design Process" has been used as a guideline for the design process of this project. The "Creative Technology Design Process" is a possible example of a design process suitable for Creative Technology bachelor students [41] and can be found in figure 3.1.1.

This design process has an alternating divergent-convergent structure. In the divergence phase the design space is opened up and defined, where in the convergence phase the design space is reduced, until a certain solution is reached. This process can be repeated multiple times.

The design process consists of four phases, namely the ideation phase, specification phase, realisation phase and evaluation. Each phase and their implementations within this project are described below.

3.1.1 Ideation Phase

The ideation phase is the first phase of the "Creative Technology Design Process". This phase starts with a design question and results with an elaborated product idea, together with preliminary requirements. Inspirational sources to get to this product idea can be technology, user needs and, creative ideas. For this project the user needs are related to the first sub-research question, the technology is related to the second sub-research question and the creative ideas are related to the third sub-research question.

Technology

The technology used for this project is the Myo Armband. This graduated project was focussed on designing an application for the Myo, and therefore the ideation phase for this project started with the technology. To get a better overview of the potential use of the Myo for this project a background research in the form of a literature research has been conducted (see Chapter 2.3). Furthermore, the tinkering technique was used by the researcher to experience the use of the Myo by himself. This technique means simply using and testing the technology to get to know the technology better. Knowing the technology better is a set-up for conducting brainstorms.

User Needs

At first a stakeholder analysis (see Chapter 3.3) has been conducted to identify and describe all possible users. Afterwards interviews were conducted with these identified users to get a better understanding of the needs of the users. Using all information gathered in these interviews, a detailed description of the user was formed, using personas (see Chapter 3.6).

Creative Ideas

At first existing engaging technology used in health-care has been researched, using background research in the form of a state-of-the-art research (see Chapter 2.2). This research will provide insights into what is already out there and methods to engage people using technology. Afterwards individual brainstorm sessions and joint brainstorm sessions (see Chapter 3.4) with the users were conducted to get a broad range of novel and creative ideas.

At the end of the ideation phase all information gathered will be used to reach one final product idea. Here after, design sketches will be made to determine the look of the product idea.

3.1.2 Specification Phase

The product idea that resulted at the end of the ideation phase is the basis for the specification phase. Within the specification phase the different functionalities the system will have are identified and explained. A list of requirements the system must have is generated, based on the information gathered in the ideation phase. Furthermore the product idea will be presented using functional system architecture (see Chapter 3.8), to understand the interaction between the user and the system and to get an overview of the complexity of the design.

3.1.3 Realization Phase

Within the realization phase, a prototype for the project is constructed. This prototype is based on the list of requirements and functional system architecture provided in the specification phase. In the realization phase the prototype itself and how it works is explained. This prototype can be used for evaluation.

3.1.4 Evaluation

The prototype created in the realization phase will be used for evaluation to test if the system meets its requirements and which aspects of the system need to be changed or improved. The evaluation phase consists of two parts, namely the functional test and the user test. During the functional test, the researcher will test if all functionalities are working in the prototype. During the user test, the prototype and the original Life project are tested by test participant from the target group. The created prototype and the Life project are afterwards compared with one another. Also, the interaction between the prototype and the user is evaluated, in order to determine the positive and negative aspects of the prototype.

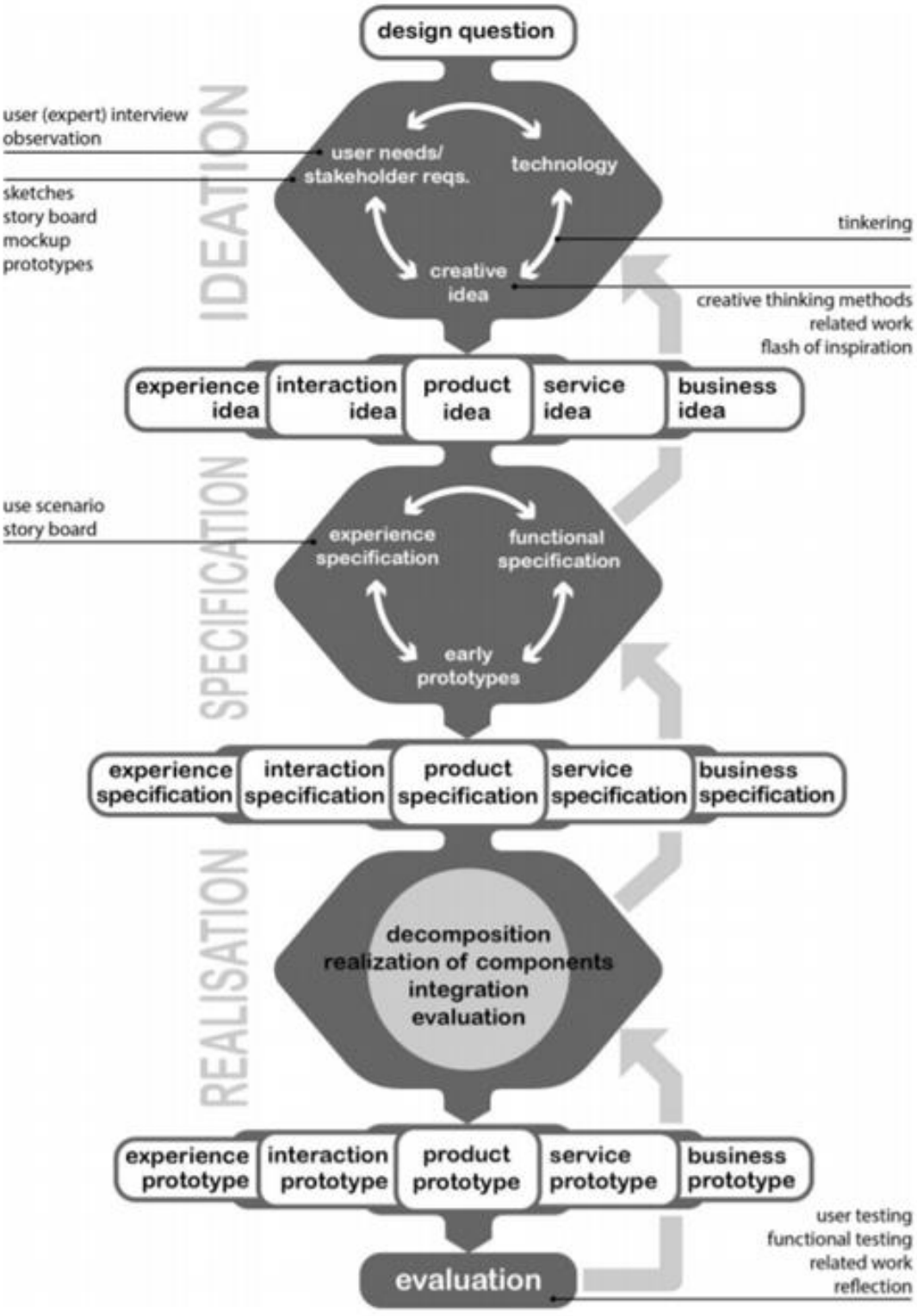

Figure 3.1.1 Creative Technology Design Process

3.2 Analysis of Life Project

This project is related to the Life project of Roessingh Research and Development. This project has the aim to include feedback about the performance of the exercises to the user to this Life Project. To understand the aim of the project, the developer from Life has been interviewed and to understand the functionalities of the Life website, the website has been analysed.

For the analysis of the website, first all functionalities are identified and described. Afterwards these functionalities are analysed to determine which functionalities are important for this project.

3.3 Stakeholder Analysis

A stakeholder analysis was conducted to identify the relevant stakeholders for this project. Stakeholders need to be identified to understand their power and interest in the project.

A stakeholder in an organisation can be defined as "any group or individual who can affect or is affected by the achievement of the organisation's objectives", in this the project [42]. Sharp's [43] approach for identifying stakeholders is focussed on requirements engineering. This approach identifies stakeholders using four categories:

- **Users:** the people, groups or companies who will interact with the software and control it directly, and those who will use the products (information, results etc.) of the system.
- **Developers:** developers of the system and mainly involved in the research and development process.
- **Legislators:** institutions that can produce guidelines that will affect the development and/or operation of the project.
- **Decision-makers:** managers, and financial controllers of both the developer and user organisation.

For each category the stakeholders for this project will be named. Afterwards each stakeholder will be rated in terms of influence and interest (High, Medium, Low). The level of influence indicates the amount of influence the stakeholder can have on the project and the level of interest indicates the amount of interest the stakeholder would have in the end result of the project.

3.4 Brainstorm Sessions

To generate ideas for novel ways of providing feedback to the user about the performance of the exercises, individual and joint brainstorm sessions are conducted. First the individual brainstorm session was conducted to generate the first product ideas , based on the information gained in the background research. More ideas are generated during the joint brainstorm sessions with the physiotherapist, older adults and developer of Life.

During the brainstorm sessions the mind-map technique will be used to generate and organizing ideas [44]. Mind-maps will be used, because using mind-maps it is possible to quickly identify and understand the structure of a subject, and help remembering information.

3.5 Interviews

During the ideation phase, interviews with physiotherapists, the developer of Life and older adults were conducted in order to gain more information about the execution of exercises, the Life project and the user group. There are three techniques that can be applied when conducting an interview, namely structured, semi-structured, and unstructured interviews [45]. In structured interviews the interviewer asks a predefined set of questions to each interviewee, meaning there is no possibility to deviate from the pre-determined set of questions. Semi-structured interviews are organised around a set of predetermined open-ended questions, with other questions emerging from the dialogue between interviewer and interviewee. Unstructured interviews are more or less equivalent to guided conversations, since the interviewer bases his or her questions on the conversations made of the interviewee.

For the ideation phase of this project the semi-structured interview technique will be used. The semi-structured interview technique has been chosen over the unstructured and structured technique for the ideation phase, because the researcher has certain topics to discuss with the interviewees, however the answers to these questions can lead to new insights for further discussion. Therefore the researcher will start in a structured way. When new insights occur, the researcher will change to a unstructured approach and start a conversation about this new insight. The information gained in these interviews will be used to set-up the requirements.

3.6 iPACT & FICS

During the ideation phase and specification phase, scenarios are written to describe the system from different perspectives. The iPACT method is used within the ideation phase and has the aim to describe the concept from the user perspective. The FICS method is used within the specification phase to describe the concept from the perspective of the system.

iPACT

The term iPACT stands for ***i****ntention*, ***P****eople*, ***A****ctivities*, ***C****ontext*, ***T****echnologies* [46]. The intention section is used to clarify the goal of the system towards the user. The people section describes the users of the system, using personas. The activities section describes the activities of the persona in which the system would be helpful. The context section gives a brief description of the context in which the system would be used. At last, the technology used to realize the system is described in the technology section. Afterwards a user scenario is written, combining all the above announced sections and describing the concept from the user's perspective.

FICS

The term FICS stands for ***F****unctions*, ***I****nteractions*, ***C****ontent*, ***S****ervices* [46]. In the functions section the functionalities and events of the system are described, meaning all actions and reactions. The interactions section describes how the user interacts with the system. The content section shows the information transmission of the system. At last, in the services section the used services for the project are described. Afterwards a user scenario is written, combining all the above announced sections and describing the concept from the system's perspective.

3.7 Functional System Architecture

The iPACT and FICS scenarios created using the method described in Chapter 3.7, will form a basis to develop the functional system architecture. This functional system architecture provides an overview of all functionalities of the final application idea, resulting from the ideation phase. The architecture of the system of this final application idea will be described in three different decomposition levels.

Within, the first level, the inputs and outputs of the prototype in general will be described. Within the second level, different functionalities of the system are described and portrayed using blocks in a diagram. Where each block represents a different functionality of the system. Between the different blocks, the transfer of data will be portrayed. Within the third level, a decomposition of each of the functionalities described in the second level will be made, meaning the sub-functionalities of the system are described.

The functional system architecture provides a basis for the realization phase of the project. The prototype will be developed according to the functional system architecture.

3.8 Requirements

The requirements are obtained from the interviews, analysis of the Life project, functional system architecture and user tests. The list of requirements will be updated in multiple iterations. At the end of the ideation phase a first list of preliminary requirements is defined, based on the information gathered from the interviews and the analysis of the Life project. At the end of the specification phase the list of requirements is updated according to the information gained from the functional system architecture. At last, at the end of the evaluation phase the list of requirements is updated for the last time, based on the information gained from the user tests.

The requirements will be divided into functional and non-functional and will be prioritised according to the MoSCoW method (see below).

3.8.1Functional and non-Functional

The requirements will be divided into functional and non-functional requirements. Here, functional requirements describe *what the system should do*, while non-functional requirements describe *how the system works* [47]. In other words, functional requirements are more related to functionality of the system, whereas non-functional requirements are more related to performance, and usability.

3.8.2 MoSCoW

In order to prioritise the requirements, the MoSCoW method will be used. The MoSCoW method stands for functions the system [48]:

- **Must** have;
- **Should** have if possible;
- **Could** have if it does not affect anything else;
- **Won't** have at this time, however would like in the future.

By prioritising the requirements it is clear, when developing the prototype (realisation phase) which requirements should be implemented first.

3.9 Evaluation

After developing the prototype within the realization phase, it is evaluated. The prototype is evaluated in two ways. First through a functional test and afterwards through a user test. Within the functional test, the researcher checks if the prototype meets its requirements. Within the user test, participants from the user group will interact with the interact, to determine the positive and negative aspects of the prototype. Moreover, within the user tests it is checked if the non-functional requirements of the prototype are met.

3.9.1 Functional Test

The functional test must be executed before the user test, to make sure the prototype functions properly before the user test take place. Within this functional test, the researcher will check if the developed prototype meets the functional requirements set up at the end of the specification phase. The prototype has to meet all of its "Must Have" requirements (see Chapter 3.8). It is preferred that the prototype also meets some of the "Should Have" and "Could Have" requirements. If the prototype meets enough requirements, the user test can be conducted, else the prototype has to improved.

3.9.2 User Tests

The user test is divided into two parts. In the first part, the original Life project and the developed prototype are compared to one another. In the second part, the positive and negative aspects of the prototype are determined. This is explained below.

Comparison original Life project and prototype

The test participants will perform the exercises using both the original Life project (system 1) and the developed prototype (system 2). This is a so-called test-retest method. The participant will first test one system and afterwards test another system. In order for the test results to be reliable, the order in which both systems will be tested will alternate for each test participant. Afterwards the participants rate both systems on four different topics, namely, usability, stimulation, insecurity, and pleasure, via a questionnaire. The usability ratings for both systems will be determined using the system usability scale (SUS) [49]. The SUS is a simple, ten-item *Likert* scale giving a global view of subjective assessments of usability. In other words, the test participants will have to rate ten different statement on how much they agree with these statements. This rating will be from one to five, where an one means "Totally disagree" and a five means "Totally agree". The ten statements are:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with the system.

To determine the SUS-rating: for all odd numbered statements, the rating contribution is the scale position minus 1. For the even numbered statements, the contribution is 5 minus the scale position. Afterwards, the sum of the scores is multiplied by 2.5 to obtain the overall value of the system usability. The SUS-rating is always between 0 and 100.

After determining the SUS-ratings for both systems the Intraclass Correlation Coefficient (ICC) will be used to determine if the both SUS-rating are correlated to one another. The ICC is used to determine the level of correlation between two repetitive measured values [50]. Meaning, the ICC is used to see if the two SUS-ratings of both systems are similar or not.

To determine the stimulation, insecurity, and pleasure of both systems, again a *Likert* scale has been used. The participants had to give a rating between one and five on how stimulating the system was to use, how insecure they were about whether they performed the exercise correctly, and on how much of a pleasure it was to use the system. At the end, the participants are asked what their preferred system is out of the two. The participants can write down their answers in the questionnaire.

Positive and negative aspects of prototype

After the original Life program and the prototype have been compared, the positive and negative aspects of the prototype will be determined, using a structured interview (see Chapter 3.5). The structured interviews will be conducted after the user tests. During the structured interview the researcher will ask questions and the participants have to answer these questions. The questions will be asked in the same order for every participant.

Besides this structured interview, conducted after the user test, the thinking-aloud method and observations from the researcher will be used during the user test, to gain information about the interaction between the user and the prototype. When using the thinking-aloud method, participants are asked to verbalize their thoughts [51]. The researcher records all verbalizations and analyses these. The thinking aloud method can be used for three types of goals, namely to find evidence for models and theories of cognitive processes, to discover and understand general patterns of behaviour in the interaction with application, and to test specific applications in order to troubleshoot and revise [51]. During this evaluation the thinking-aloud method will be used for the last type of goal. It will namely be used to, determine potential difficulties in the interaction between the user and the prototype that needs to be fixed.

Chapter 4: Ideation

In this chapter the ideation phase of this project is described. This phase is focussed on idea generation and conceptualising these ideas. The information gathered during the background research (Chapter 2) has been used to generate and conceptualise these ideas. Chapter 4 is constructed as follows:

1. Individual brainstorm session conducted by the researcher;
2. Stakeholder analysis;
3. Interviews / joint brainstorm sessions conducted with relevant stakeholders;
4. Analysis of current Life project;
5. Description final idea and design sketches to conceptualise this idea;
6. First iteration of requirements the final idea has to meet;
7. iPACT scenario.

4.1 Individual Brainstorm Session

To generate ideas about how to provide feedback about the performance of the exercises to the older adults, an individual brainstorm session, using the mind-map approach (see Chapter 3.4) has been conducted by the researcher. The mind-map generated as a result of the brainstorm session can be found in Appendix A-1. All ideas generated during the individual brainstorm session have been categorized into four different categories, namely Text; Avatar; Visualisation and Online Coach. An idea that combines multiple of these categories is also possible.

Text
Using text messages to provide feedback to the user – these messages can be motivational, informal or be a score / rating based on the performance of the exercises by the user.

Avatar
Using an avatar on the computer screen to provide feedback to the user – the avatar can do the exercises together with the older adult, motivate the older adult, become fitter over time as well just like the older adult or the older adult can take care of the avatar by performing the exercises correctly.

Visualisation
Using visualisations to provide feedback to the user – these visualisations can show the improvement the older adult has made so far, which muscles the older adult should focus on while performing the exercises or showing the amount of power or effort the older adult is putting in, using a bar chart.

Online Coach
Using an online coach to provide feedback to the user – the online coach can motivate the older adults, provide them the feedback that the physio normally gives or be the physio him or herself, using an online connection.

The mind-map will be expanded and more categories will be added after the interviews / brainstorm session with the physio, older adults and developer of Life have been conducted (see Section 4.3).

4.2 Stakeholder Analysis

There are several stakeholders involved in this project that can be identified. Using the method described in Chapter 3.4, the stakeholders are identified as follows:

Users – The system has several potential users. The system will mainly be used by the older adults. However also physiotherapists, caretakers or family members, activity managers and the Ouderfonds [52] are potential users of the system. All users have an interest in the system. The older adults have because, they would use this system in their daily life, every day. Physiotherapists can recommend this system for patients to use at home. Caretakers or family members and activity managers potentially have to help the older adults with performing the exercises or assist them with the technology involved. At last the Ouderenfonds can use this system to promote physical activity among older adults.

Developers – The system will have multiple developers, namely the researcher, Roessingh Research and Development (RRD) and Thalmic Labs. First, the researcher (Max Slutter) will be developing the feedback system itself. Second, RRD (see Chapter 1.5) have developed the Life project , where the feedback system will be developed for. At last, Thalmic Labs have developed the Myo Armband, which will be used to measure the performance of the user.

Legislators – Potential legislators for this system are, in general, lawyers and, more specific, medical policymakers. Lawyers are potential legislators for every project, since lawyers can produce guidelines that affect the development / operation for every project. Medical policymakers are more closely related to this project, since this project is within the health-care sector. Therefore the health-care policies should be taken into account while developing the system.

Decision-Makers – The system has several decision-makers. First, the researcher (Max Slutter) is a clear decision-makers. Also the supervisors of the researcher are decision-makers. The supervisors are from RRD (Jan Willem van 't Klooster) and from the Creative Technology program of the University of Twente (Erik Faber). Furthermore, RRD and the Creative Technology are both decision-makers themselves as well. RRD is a decision-maker, because this project is in cooperation with RRD and therefore they can do further research on this topic. The Creative Technology program is also a decision-maker, because the design process of the program has been used for this project (see Section 3.1). At last, since the older adults and physiotherapists will be involved in the design process of the system, both are decision-makers as well. However the older adult and physiotherapists will mostly considered to be users.

Each stakeholder has been rated in terms of influence and interest. The results can be found in the table below.

Stakeholder	Category	Interest	Influence
Older adults	Users / decision-makers	High	Medium
Physiotherapists	Users / decision-makers	Medium	Medium
Caregivers / family members	Users	Medium	Low
Activity Managers	Users	Medium	Low
Ouderenfonds	Users	Medium	Low
Max Slutter	Developers / decision-makers	High	High
RRD	Developers / decision-makers	Medium	Medium
Thalmic Labs	Developers	Low	Medium
Lawyers	Legislators	Low	Medium
Medical Policymakers	Legislators	Low	High
Jan Willem van 't Klooster	Decision-makers	High	High
Erik Faber	Decision-makers	High	High
Create Program	Decision-makers	Medium	Medium

Table 4.2.1 – All stakeholders rated in terms of interest and influence

The results from table 4.2.1 have been combined into one chart, displaying the stakeholders' interest vs their influence. This chart can be found in figure 4.2.2.

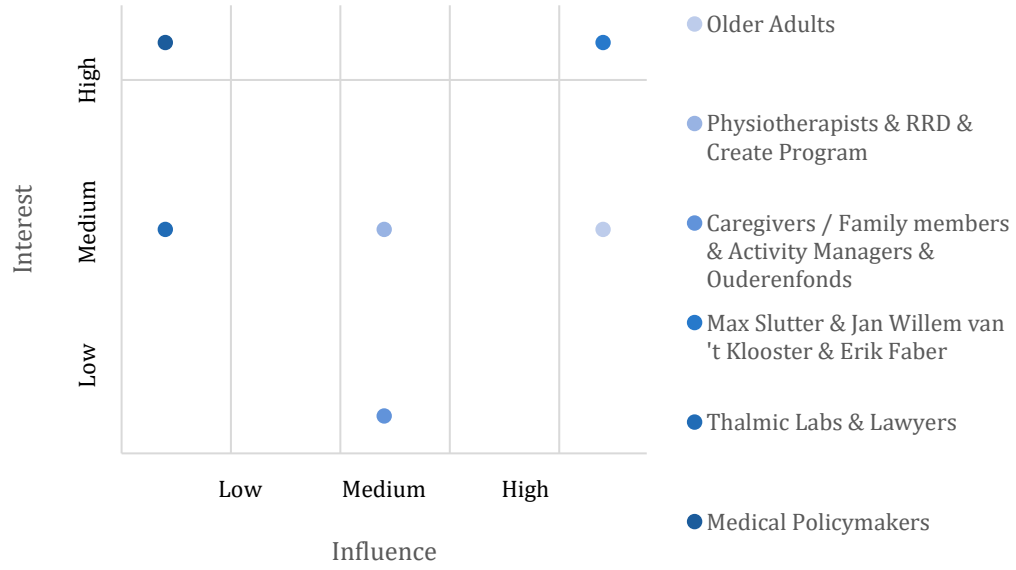

Figure 4.2.2 Chart showing the influence level and interest level of each stakeholder

In short, the most important stakeholders for this project are the researcher (Max Slutter) and the supervisors Erik Faber and Jan-Willem van 't Klooster. Moreover, the older adult and the physiotherapist are important users, and therefore these two stakeholders will be involved in the design process of the project.

4.3 Interviews / Joint Brainstorm Sessions

In total six people were interviewed, namely one physiotherapist, the developer of the Life project, and four older adults who were previous users of Life and therefore potential users of this product. Physiotherapists, older adults and RRD (Developer of Life represent RRD) are namely important

stakeholder and therefore they have been included in the design process. Goal of these interviews was to gain an insight in the user needs and to get new ideas on how to provide feedback to the user. The set-up of each interview / brainstorm session can be found in Appendix B. The informed consent necessary for the interviews / brainstorm sessions with the older adults can be found in Appendix C. The main points of interest from these interviews / brainstorm sessions are summed up below. The full transcription of the interviews / brainstorm sessions can be found Appendix D.

4.3.1 Interview Physiotherapist

At first, the interview / brainstorm session with the physiotherapist was conducted. Main insights gained from this interview / brainstorm session are listed below:

- Connect a concrete goal to the exercises, since this stimulates people.
- Breathing techniques are important when performing exercises related to arm-movement and arm-muscles.
- If the patient's pain gets worse, this can be caused by performing the exercise incorrectly or by performing the exercise too often.
- Mostly give positive feedback to patients. First make a compliment and then afterwards tell the patient what needs to be improved.
- For older adults the frequency of executing an exercise is the most important.
- Be aware of the maximum power of people, do not cross this border.
- Coordination is also very important when training muscles.
- Ideas generated during brainstorm:
    - Adding sport element
        - Tennis match / training
        - Volleyball
        - Basketball
    - Adding game element
        - For the squeeze exercise, squeeze a sponge, orange or hamburger.
        - For the spreading exercise, make a flying simulation.

The ideas generated during this brainstorm sessions are combined into two mind-maps. These mind-maps can be found in Appendix A-2. The physiotherapist suggested to include a game element into the ideas, which is in line with the information gathered during the state-of-the-art research (see chapter 2.2). Therefore this game element idea has been included in the mind-map and has been used as a suggestion in the following interviews.

4.3.2 Interview Developer Life

Afterwards the interview / brainstorm session with the developer of the Life project was conducted. Main insights gained from this interview / brainstorm session are listed below:

- Seniors can do the exercises by themselves at home.
- Finding the website was difficult for the seniors, no problems occurred when the website was reached.
- Users like to perform the exercises together with the lady in the instruction video.

- Show the users how close they are to reaching the amount of times the exercise should be executed.
- Users do not per se need to reach the pre-defined number of executions. As long as they are improving, it is fine.
- Keep the design simple, so not give the older adults too much input.
- Do not give too much negative feedback.
- The idea of using minigames is nice.
- In general, people above 75 years old have more difficulties with performing exercises and handling computers.

4.3.3 Interviews Older Adults

At last, the interviews / brainstorm sessions with four older adults were conducted. All older adults were above 65 years old and therefore they were all within the user group. Main insights gained from these interviews / brainstorm sessions are listed below:

User 1 (Woman) and 2 (Man), couple:

- Competition is motivating.
- Stimulate users by giving them a lot of compliments.
- Still be strict for the user, to make sure they keep doing the exercises.
- Users that just start performing exercises have to build up slowly.
- Remind the users to do their exercises, preferably at the same time every day.
- Do not lie to the users, if they perform an exercise wrong you have to tell them.
- Show users what muscles they have to focus on.
- Use blocks to stimulate the user to get to the next block each time.
- Distract user for the pain they feel by playing music or showing a professional sportsman / woman in action.
- Let the users measure their weight once a month, so they can check if they made progress.
- A message on your computer that directs you to the website by clicking on it would make it easier to find the website.
- Would be better if the instruction videos also executes the exercise the same amount of times as we had to do.
- Using minigames is a nice idea and can work very stimulating. The visual result on the screen can work stimulating.
- Later on you could separate the amount of effort men and women have to do. In the beginning this is not necessary.

User 3 (Man) and 4 (Man), couple:

- Life program has potential for people that do not sport regularly.
- Expected the warming-up to be more intensive.
- Announce it advance what tools are needed for the exercises.
- Performing exercises with others could work stimulating.
- Finding website was difficult.

- Performing the exercises together with the instruction video is preferred, then our tempo and frequency were good.
- Movement done outside the exercises is not taking into account (for example working in the garden).
- Make it possible to also enter your social activities.
- Do not punish the user, simply point out what they did wrong.
- You have to tell the users if they did not perform the exercises correctly.
- I would like to enter a time that suits me into the system and that the system reminds me at this time to do the exercises.
- Warming-up and cooling-down were the same, which felt conflicting.
- Sometimes the information did not fit on one page.
- Use a line or blocks to indicate the amount of effort.
- Both were also positive about the minigame idea.

4.3.4 Conclusion Interviews / Brainstorm Sessions

Based on the insights gained during the interview / brainstorm sessions it can be concluded that all older adults and the developer of Life were positive and enthusiastic about the minigame idea. Therefore the prototype will be focussed around this idea. Furthermore, based on the insights gained from the interviews the prototype should first, have a simple design; second, make sure the instruction video executes the exercise the same amount of times as the user should do; third, give mostly positive feedback; fourth, stay honest towards the user; and at last, use blocks to indicate the effort put in by the user.

4.4 Analysis of Life Project

The current Life project has been analysed to gain more knowledge about what information older adults need about the exercise. This knowledge could potentially lead to requirements for the prototype.

The current lay-out of the webpages of the Life project can be found in figure 4.4.1. The current lay-out has four main elements, namely a header (1), the instruction video (2), the instruction text (3) and two navigation buttons (4).

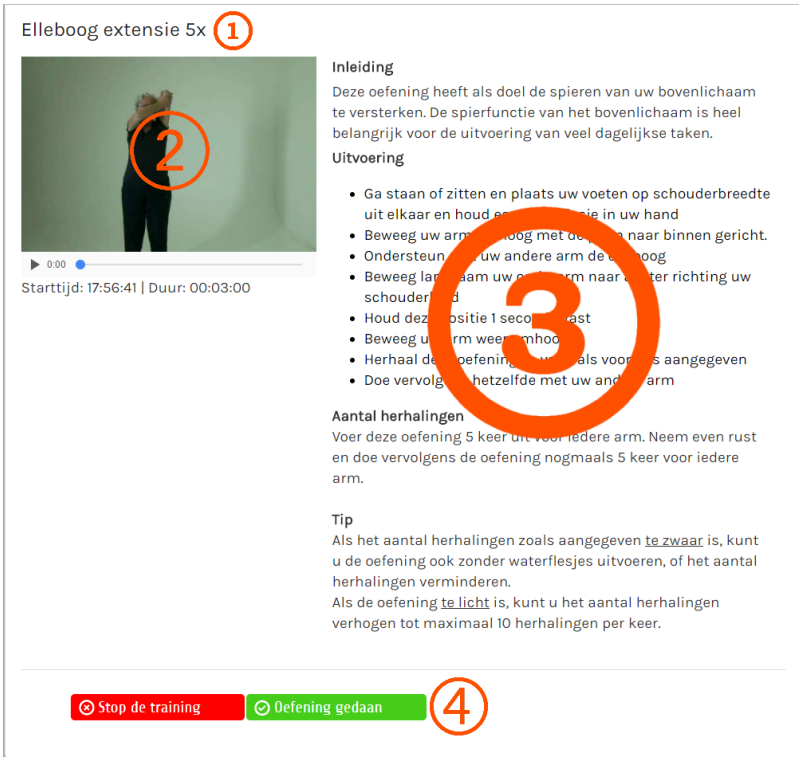

Figure 4.4.1 Lay-out of Life project webpage

The header includes the title of the exercise and the amount of times this exercise should be executed. From the interviews conducted with the older adults, it is known that the older adults find it unpleasant when the amount of times the exercise should be executed is not noted in the header.

In the instruction video the way to perform exercise is shown to the older adult. It also possible to change the volume, maximize the screen of the video and to download the video. These options however, were not often used by the older adults. From the interviews conducted with the older adults it is known that the older adults would like the video to perform the exercise the same amount of times as they have to do. In this way the older adults could perform the exercises together with the instruction video.

The instruction text explains the exercise in a textual way. The instruction text consist of an introduction, an explanation of how to perform the exercise, the number of times the exercise should be performed and a tip. The introduction explain the purpose of the exercise, so which muscles will be trained and why this is important to do. The explanation of how to perform the exercise, explains the older adult step by step how to perform the exercise. The tip explains methods to reduce or increase the intensity of the exercise. The older adults read the instruction text before and during the execution of the exercise. So it is important that the instruction is visible and readable for the older adults while performing the exercises.

The navigation buttons allow the older adults to stop the training or to finish the exercise and go to the next exercise. It must always be possible for the older adult to stop the training, to prevent the older adult from over-exercising.

4.5 Final Idea

The insights gained from the interviews, brainstorm sessions, and the analysis of the Life project, led to a final product idea. The final idea will be a minigame, because all interviewees were enthusiastic about this idea. Moreover, the state-of-the-art research (see Chapter 2.2) showed that gamification is a more and more common used approach within health care and that this approach is having a positive effect on the motivation and pleasure of the patients.

The minigame of this project will be focussed on the squeeze exercise of the Life project. For this exercise the older adults have to squeeze intensively into a ball for 5 seconds. They have to repeat this exercise three times. The minigame related to this exercise will involve a sponge and a bucket. The goal of this minigame is to fill the bucket with water, gathered by squeezing the sponge. Every time the older adult performs the squeeze exercise correctly, the bucket will get filled with water from the sponge. Furthermore, the interviewed older adults suggested to include a visualisation of their effort, therefore the minigame includes an effortbar, visualising the effort of the user. Just like the older adults suggested, this effortbar uses blocks to visualise the amount of effort the user is putting into the game. The amount of visible blocks indicate the amount of effort, where more blocks mean more effort.

A graphical user interface (GUI) of the minigame on a webpage has been designed (see the section below).

4.5.1 Graphical User Interface

In total five design sketches of the GUI of the prototype were made. All design sketches can be found in Appendix E. For each design sketch a short description and the pros and cons of the design are described. All designs consist of a header, the instruction text, the instruction video, the navigation buttons and the minigame. In all design sketches the sponge minigame related to the squeeze exercise has been used.

After comparing all the pros and cons of the GUI of each design, it has been decided to use the design shown in figure 4.5.1.1. This design fits on one webpage, which makes it easier for older adults to understand. The older adults are still able to read the instruction text while performing the exercises, which is essential, and the live effortbar constantly shows the older adult how he or she is performing. Possible cons of the design are that the older adult can be distracted by the minigame and therefore skip the instruction text. Moreover, the minigame, instruction video and effortbar in one window can be too much information for the older adult to handle. These cons are speculated and during the user tests it would turn out of these speculated cons are actual cons of the design.

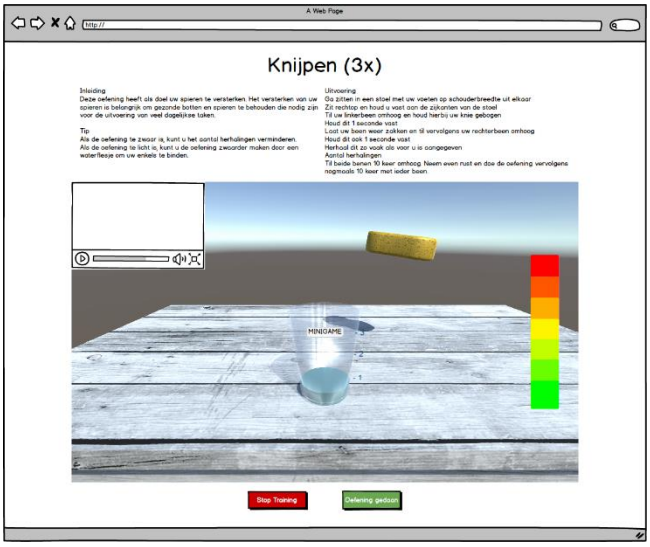

Figure 4.5.1.1 Design sketch of GUI

4.6 Requirements 1st Iteration

As the final concept (minigames) and the design has been chosen, a first list of preliminary requirements can be determined. These requirements are based on the information gathered from the stakeholder analysis, interviews and the analysis of the Life project. In this section the requirements are named, divided within functional and non-functional requirements, and prioritised according to the MoSCoW technique (see Chapter 3.8.2). The full list of preliminary requirements and their origin can be found in Appendix F.

Must

1. User has to be able to perform the exercises together with the instruction video (non-functional).
2. Show how close the users are to reaching the amount of times the exercise should be performed and keep track of the amount of times the exercise has been executed (functional).
3. Show real-time effort put in by the user (functional).
4. User must always be able to stop the training. Then the system should stop the exercise (functional).
5. System should not force users to complete the total number of executions, as long as they make progress it is fine (non-functional).
6. Mostly give positive feedback in the form of compliments (non-functional).
7. Stay honest towards the user, tell if the exercises are not performed correctly (non-functional).
8. Must be possible to read the instruction text, while performing the exercises (functional).

Should

9. Show the progress the users have made every month (functional).
10. Make it possible to perform the exercises together with others (non-functional).
11. Keep design simple, not a lot of input for the user to handle (non-functional).
12. Provide a clear instruction of the use of the Myo Armband to the user (non-functional).

Could

13. Remind users to do their exercises (functional).
14. Show what muscles to focus on for the exercise (functional).
15. Announce in advance what tools or objects are needed for the exercises (functional).

Won't

16. User has to be able to enter the time he or she wants to perform the exercises (functional).
17. In a later stage, separate the amount of effort men and women have to do (non-functional).
18. Movement done by the user outside of exercises should be registered as well (functional).
19. Make it possible for the user to also enter their social activities into the systems (functional).
20. Warming up should be more intensive than it currently is (non-functional).

4.7 iPACT

In this section, the system will be explained using the iPACT method (see Chapter 3.6). Using this method, the system will be described through the eyes of the user.

Intention – The intention of the system is to provide feedback to older adult performing exercises. This feedback will be related to their performance and has the aim to make sure the older adults perform the exercises correctly and to keep them motivated.

People – A potential user of the system would be Mark. Mark is a frail, 67 years old man. He does not exercise at the moment, however he wants to. He has difficulties with getting started to exercise.

Activities – The feedback system that will be created, will be used by older adults when performing exercises. The system will provide direct feedback about the performance of the adults performing exercises.

Context – The feedback system is an addition to the Life project of Roessingh Research and Development and it will therefore be designed to use within the home of the user.

Technology – The technology used to realise this feedback system is the Myo Armband. This armband will be used to measure the performance of the older adults performing exercises.

User Perspective Scenario

Mark is a frail, 67 years old man. Mark wants to stay fit for as long as possible. Mark is a retired forklift truck driver. At the moment Mark does not sport or exercise and he wants to change that. He knows that exercising is important for his health, especially at his age. Therefore he starts using the Life project offered by RRD (Roessingh Research and Development). This is an online website where instruction for useful exercises can be found.

In general Mark has difficulties using new technology, therefore navigating through the Life website is not easy for him. Although it is difficult for him to navigate through the website, he still manages to perform the exercises every day. Mark feels that he is getting fitter, once he starts using Life. Later on, it is difficult for him to motivate himself to keep doing the exercises. Also he is unsure whether he is performing the exercises correctly. Furthermore Mark likes to perform the exercises together with his wife, since this stimulates him. In the beginning Mark feels that the exercises are relatively easy for him. However, when he gets to the more intensive exercises he often cannot finish them. When he has to perform an exercise ten times, he sometimes only gets to perform it four times and then has to stop the training.

This discourages Mark as well. In general Mark likes the Life project and he also experiences that the project is useful for him. However, he lacks motivation at the moment. Then the Life project got updated and the feedback system designed during this project, was added to the Life project. Mark wanted to try this new updated version of the Life project. Mark enjoyed using this new updated version, because it gave direct feedback on his performance. In this way Mark was confident about the way he executed the exercises. This and the many positive feedback messages, encourage him to keep performing the exercises every day. Mark had to wear the Myo armband, while executing the exercises. At first, this was strange for him, however afterwards the armband was no problem to wear or use.

The updated version involved games. Mark was at first a bit sceptical about using games, because he normally does not feel taken seriously while playing games. For Mark, exercising is

serious, so he also wants to be taken serious. However, then Mark discovers this game supports him to perform the exercises correctly. The game stays honest towards the user and Mark appreciates this. Mark now trains every day and he enjoys training more than ever before. The games stimulate to keep performing the exercises and Mark feels he gets fitter every day.

Chapter 5: Specification

Within the specification chapter a closer look of the functionalities of the creative idea, resulting from the ideation phase is provided. First, a FICS scenario is written to describe the functionalities and user interaction of the system. Afterwards a more detailed overview of the functionalities of the system is given, using a functional system architecture. This functional system architecture is based upon the FICS scenario. Furthermore, an activity diagram is provided, to give a more detailed overview of the interaction between the system and the user. At last, a second iteration of requirements is given.

5.1 FICS

In this section, the system will be explained using the FICS method (see Chapter 3.6). Using this method, the system will be described through the eyes of the designer.

Functions – The three main functions of the system are: analysing the incoming signals, generating feedback based on the analysed incoming signals, and displaying this feedback to the user.

Interactions – The user interact with the system by performing the exercise. By performing the exercise correctly, the user will proceed in the game.

Content – The analysing function of the system will send a rating, based on the performance of the user, to the generating feedback function. The feedback generation function will then send the feedback messages that need to be displayed to the displaying feedback function.

Services – The only service needed for this system is: a reliable Bluetooth connection. The Myo armband namely communicates using Bluetooth (see Chapter 2.3).

Designer Perspective Scenario

For this designer perspective scenario the same persona (Mark) as in Chapter 4.7 will be used. This scenario is written through the eyes of the designer.

Mark is a frail 67 years old man and therefore wants to exercise to stay fit. In order to be able to perform the exercises at home, Mark uses the updated version of the Life project. Within this updated version, a feedback system has been implemented. This feedback system makes use of a Myo armband, to measure the performance of the user executing exercises.

Marks starts-up the program and the program gets loaded. First, the instructions on how to wear the Myo are shown to Mark. When Mark wears the Myo correctly and synchronizes the device with the Myo connect program correctly, by performing the 'waving-out' gesture, the warming-up gets loaded. Mark will perform the warming-up exercises and in the meantime the Myo warms-up as well.

Before performing the actual exercise, Mark needs to perform a calibrations step. This is needed to calibrate the Myo on its current user and situation. Afterwards Mark plays the minigame, by performing the exercises. Every time he performs the exercise correctly, he will proceed in the game. The game will give a lot of positive feedback messages, to stimulate and motivate its users. When Mark does not perform the exercise correctly for multiple, consecutive times, the game will a provide a more negative feedback message. This feedback message contains information on how the

user has to improve his or her performance. At any time it is possible for Mark to stop the training. If the set number of executions are met by Mark, the system will load the next exercise.

5.2 Functional System Architecture

The architecture of the system is described in three levels, 0 to 2. Here, level 0 is a simplified overview of the system and level 1 gives a more detailed overview of the system. Level 2 is a decomposition of the functions described in level 1.

5.2.1 Level 0: Inputs and Outputs

Level 0 of the functional system architecture refers to the most abstract level of the system. It only gives an overview of the in- and outputs of the system (see figure 5.2.1.1).

The system has two inputs, namely the information it receives from the Myo and the information it receives about the exercise performed. The information received from the Myo are the EMG signals and the movement signals. The EMG signals refer to the muscle activity of the user, where the movement signals refer to the rotation and movement of the arm (see chapter 2.3).

The system has one output, namely displaying the feedback, regarding the performance of the exercises, to the user.

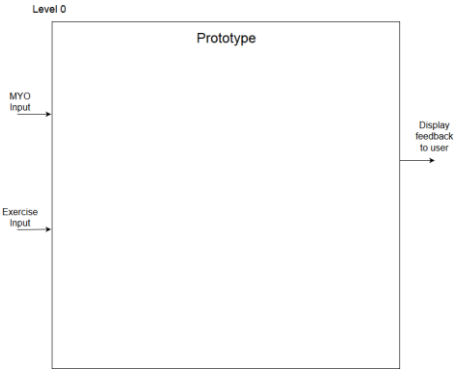

Figure 5.2.1.1 System Architecture Level 0

5.2.2 Level 1: Functions

The overview of the system architecture in level 0 can be portrayed in a more detailed overview. A more detailed overview of the functional system architecture includes, besides the inputs and outputs of the system, also the different components of the system and their relations to one another. Level 1, provides such a detailed overview (see figure 5.2.2.1). Level 1 is divided into three main subjects, namely Analysis, Controller and Display.

Analysis

In the analysis part the input signals of the system are analysed and processed. The raw input data is translated into understandable data for the controller part. The analysis part of the system includes two main components, namely Data Analysis and Exercise ID & Select Analysis Signals. The Exercise ID & Select Analysis Signals component checks what exercise will be performed by the user and sends the exercise ID to the video controller. Also it determines what input signals from the Myo are related to the current exercise, meaning what EMG or movement signals are important for the current exercise. This information is then send to the Data Analysis component, which uses this information to analyse the correct signals out of all the EMG and movement signals it receives from the Myo. The Data Analysis component then determines a rating on the performance of the user executing the exercise. This rating is based on analysing the incoming signals, related to the current exercise. Afterwards, the Data Analysis component sends this to the Minigame Controller.

Controller

In the controller part the analysed data is used as inputs for the video and the minigame. The exercise ID determines which instruction video will be selected by the Video Controller. The corresponding video will be send to the Update Display component. The rating resulting from the Data Analysis is send to the Minigame Controller. The Minigame Controller uses this information to, determine the quality of the performance, count the number of times the exercise has been performed and produce an meaningful feedback message. All information is send to the Update Display component.

Display

The display part consists of only one component, namely the Update Display component. Within this component the information received form the Minigame Controller is used to update the look of the minigame, and to display the feedback messages. Furthermore, the incoming video, from the Video Controller is displayed as well.

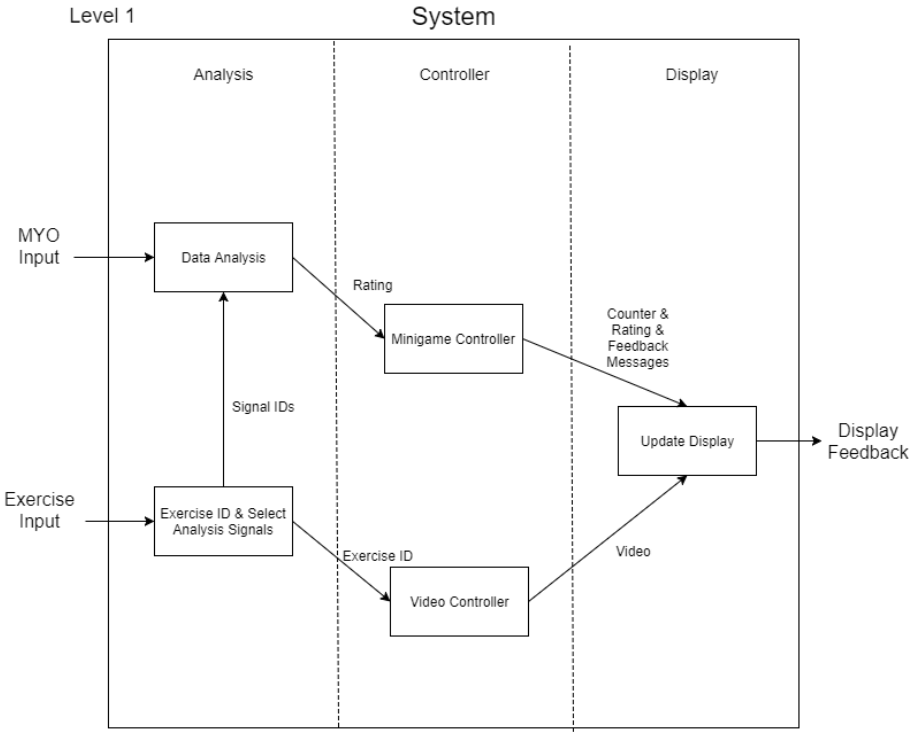

Figure 5.2.2.1 System Architecture Level 1

5.2.3 Level 2: Sub-functions

Level 2 of the of the functional system architecture shows the sub-functions of level 1. There are 5 sub-systems present, namely Exercise ID & Select Analysis Signals, Data Analysis, Minigame Controller, Video Controller and Update Display.

Exercise ID & Select Analysis Signals

This sub-functions receives the exercise input from the website. It retrieves the Exercise ID and forwards this to the Video Controller. It also determines which EMG and movements signals need to

be analysed, based on the Exercise ID. This information is then forwarded to the Data Analysis function.

Data Analysis

The Data Analysis receives input from the Myo and the Exercise ID & Select Analysis Signals function. From the Myo it retrieves the raw EMG and movement data and it uses the input from the Exercise ID & Select Analysis Signals function to select the relevant EMG and movement data out of all incoming EMG and movement data from the Myo. Afterwards this data is analysed to determine a rating based on the performance of the user. In order to determine this rating, a calibration step is included within the Data Analysis component. A calibration step is needed because of the different measurement data of the Myo per person (see Chapter 2.3). This way, the current performance can be compared to the calibrated performance, to calculate the rating. This rating is forwarded to the Minigame Controller function.

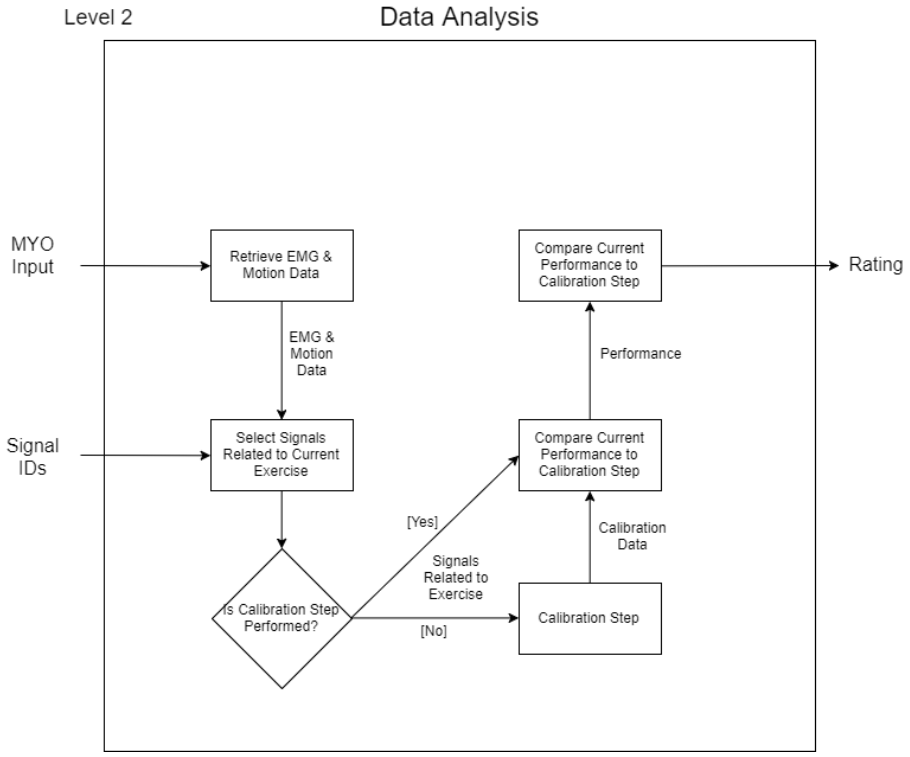

Figure 5.2.3.1 System Architecture Level 2 – Data Analysis

Minigame Controller

The Minigame Controller receives the rating from the Data Analysis function. It uses this rating to update the Effortbar and the resulted Quality of Performance is forwarded to the Update Display function. It also checks if the rating is above or below a certain threshold. If the rating is sufficient (above the threshold) the event counter will be activated, otherwise the event counter will not be activated. In both cases the feedback will be generated. This feedback is positive or negative based on the performance. If the event counter is activated, the number of times the exercise has been performed sufficiently will be updated. All information will be forwarded to the Update Display function.

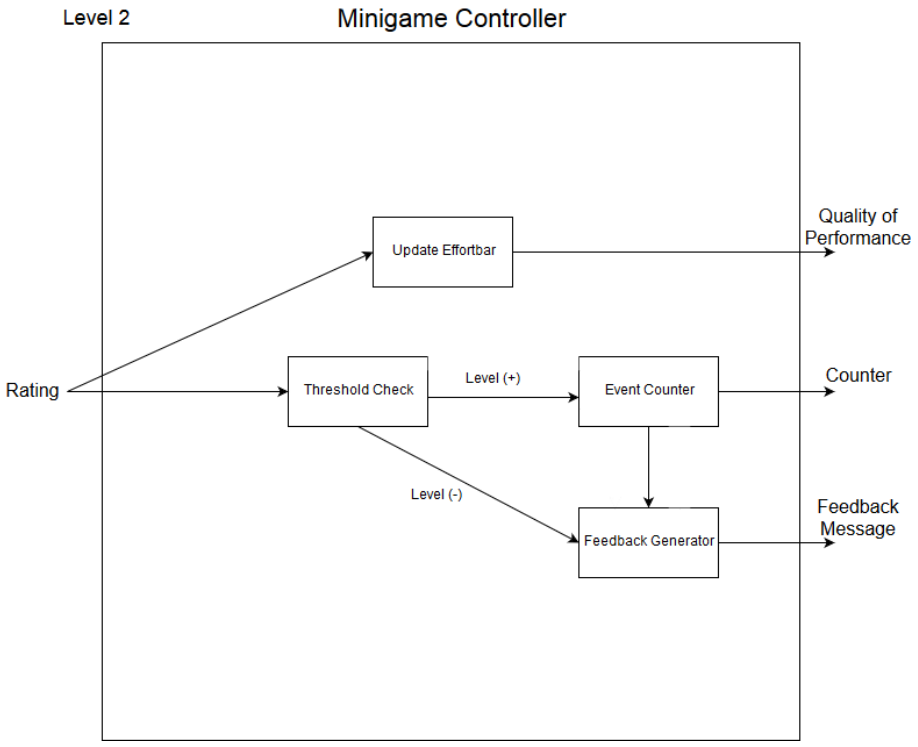

Figure 5.2.3.2 System Architecture Level 2 – Minigame Controller

Video Controller

The Video Controller receives the Exercise ID from the Exercise ID & Select Analysis Signals function. It uses this Exercise ID to select the related instruction video and sends this video to the Update Display function.

Update Display

The Update Display function receives input from the Minigame Controller and the Video Controller. It uses the Quality of Performance input to update the display of the effortbar. This effortbar is then displayed to the user. This sub-function also uses the counter input to update the display of the minigame itself. When the counter value is increasing the look of the minigame will be updated. Furthermore, the feedback messages received from the Minigame Controller are displayed to the user. At last, video received from the Video Controller is displayed to the user as well.

5.3 Activity Diagram

Based on the scenario described in Chapter 5.1 an activity diagram (see figure 5.3.1) has been made. This activity diagram is divided into three parts, namely the user, the display and the software. The user part represents the possible actions of the user. The display part represents what is displayed on the screen and therefore visible for the user. The software part represents the underlying software of the system. The software part is not visible for the user.

The user has to activate the system manually, by visiting the Life webpage. Before the user can start exercises the Myo must be worn correctly, therefore the instructions for the Myo will be shown first. After following the instructions the user can do the warming-up. Meanwhile the Myo is warming-up as well. Without warming-up, the Myo will not be adapted to the user's body and therefore, will be less accurate. The warming-up process of the Myo can take up to 5 minutes. This is the reason that the user has to wear the armband first and then he or she can start doing warming-up. The Myo is then fully warmed-up and ready to use during the actual exercises.

Afterwards the system will ask the user to perform the calibration step. As explained in chapter 2.3 a calibration step is needed before using the Myo. Afterwards the system will load the exercise instructions and the minigame. When loaded the system will display the instructions and the minigame. The user can choose to either perform the exercise or stop the training. When the user decides to stop the training, the system will be shut down. When the user decides to perform the exercise the system checks if the exercise has been performed sufficiently. If the user did not perform the exercise correctly three times in a row, the system will display a message on the screen, telling the user what to improve. The system will not display a message every time the user does not perform the exercise correctly, since this can be experienced as annoying by the user. If the user performs the exercise correctly the system will keep track of the amount of times the exercise has been executed and the minigame will be updated accordingly. If the pre-set number of executions has been met, the system will display a positive message and the user can decide to go to the next exercise. If the pre-set number of executions is not met, only the minigame will be updated. At any time the user can decide to stop the training.

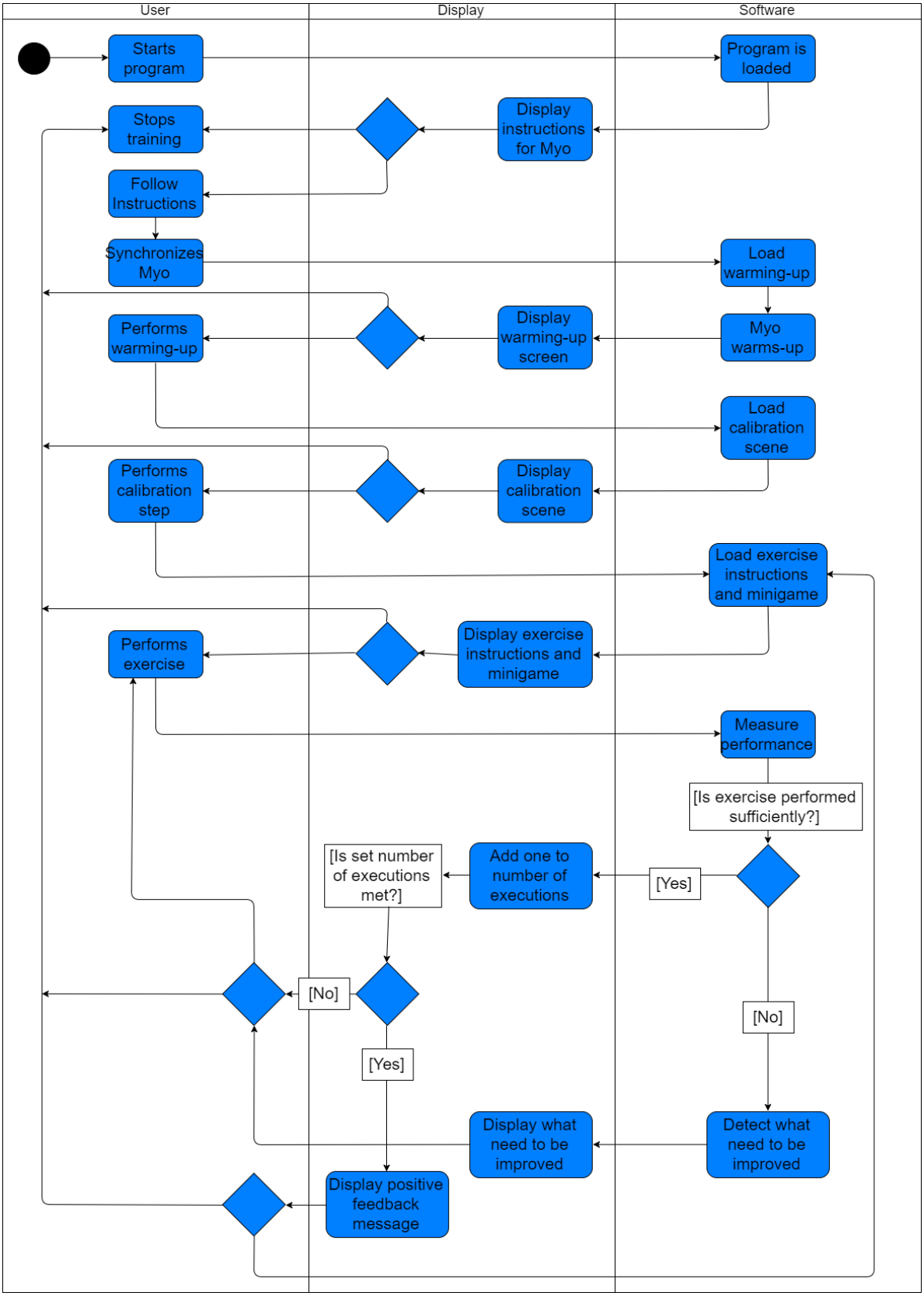

Figure 5.3.1 Activity Diagram. Block meaning an action and a diamond meaning a choice or decision.

5.4 Requirements 2nd Iteration

Based on the functional system architecture and the activity diagram the list of requirement can be updated. Only functional requirements are added in this second iteration of requirements. The newly added requirements are listed below:

Must

1. User has to be able to perform the exercises together with the instruction video (non-functional).
2. Show how close the users are to reaching the amount of times the exercise should be performed and keep track of the amount of times the exercise has been executed (functional).
3. Show real-time effort put in by the user (functional).
4. User must always be able to stop the training. Then the system should stop the exercise (functional).
5. System should not force users to complete the total number of executions, as long as they make progress it is fine (non-functional).
6. Mostly give positive feedback in the form of compliments (non-functional).
7. Stay honest towards the user, tell if the exercises are not performed correctly (non-functional).
8. Must be possible to read the instruction text, while performing the exercises (functional).
21. A calibration step should be added before loading the actual minigame, to make sure the performance of the exercises is measured correctly at any case (functional).
22. The exercise should be performed sufficiently for the system to count it (functional).

Should

9. Show the progress the users have made every month (functional).
10. Make it possible to perform the exercises together with others (non-functional).
11. Keep design simple, not a lot of input for the user to handle (non-functional).
12. Provide a clear instruction of the use of the Myo Armband to the user (non-functional).
23. The instructions on how to wear the Myo should be before the warming-up, to make sure the Myo is warmed-up while performing the exercises (functional).
24. Only display feedback messages after performing an exercise insufficiently for three times in a row (functional).

Could

13. Remind users to do their exercises (functional).
14. Show what muscles to focus on for the exercise (functional).
15. Announce in advance what tools or objects are needed for the exercises (functional).

Won't

16. User has to be able to enter the time he or she wants to perform the exercises (functional).
17. In a later stage, separate the amount of effort men and women have to do (non-functional).

18. Movement done by the user outside of exercises should be registered as well (functional).
19. Make it possible for the user to also enter their social activities into the systems (functional).
20. Warming up should be more intensive than it currently is (non-functional).

Chapter 6: Realisation

In this chapter the realisation phase of the project is described. Within this phase the actual prototype for this project is developed. The prototype is based on the functional system architecture and activity diagram described in chapter 5 (the specification phase). First the used programming software will be described. Afterwards, the data selection procedure is described. At last, the actual gameplay of the prototype is described.

6.1 Programming Software

One of the first decisions that needs to be made by the researcher, regarding the development of the prototype, is what programming software will be used. Since the prototype will be a game, game engine software will be used. Input for the game will be coming from the Myo armband. Therefore, a game engine with a pre-programmed connection with the Myo Armband is optimal.

Thalmic Labs [6], the manufacturer of the Myo Armband, developed a software development kit (SDK) for the Myo. In this SDK, Thalmic Labs included a Unity package. This package allows to use the Myo sensor data within the Unity game engine. Moreover, the researcher already has experience with using the Unity game engine, making the Unity game engine optimal to use.

Unity [53] is a game engine designed to develop both 2D and 3D games. Unity has four different versions, namely Personal, Plus, Pro and Enterprise. The four versions of Unity have been ranked from least features to most features, respectively. For this project the Personal version of Unity was used, because this version is free to use and it includes all features needed to develop the prototype for this project. Within Unity, programming scripts can be written in two languages, namely C# and JavaScript.

6.2 Input Data Selection

Because of the limited time available, only one game for one exercise will developed. This game will be for the squeezing exercise. For this exercise the user has to squeeze in a ball with as much power as possible. The user had to squeeze three times with both the right hand and the left hand. For simplicity reasons and the fact that only one Myo Armband was at hand, the game will be designed for squeezing in the ball with either the right or the left hand, not both. This section explains the input data selection of the prototype, corresponding to the *Exercise ID & Select Analysis Signals* function of the functional system architecture (see Chapter 5.2).

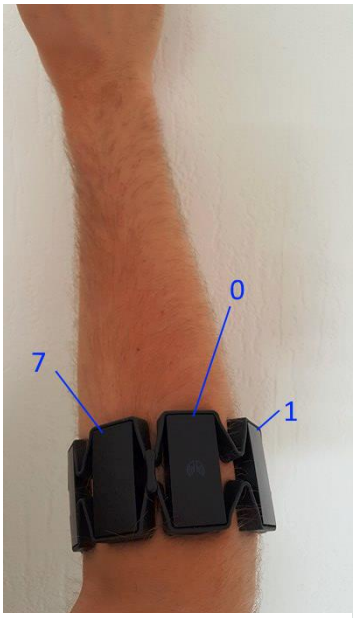

Figure 6.2.1 – Corresponding EMG signals for upper muscles.

As explained in Chapter 2.3 the Myo outputs the data from eight different EMG signals, an accelerometer and a gyroscope. These data will be input for the game, however not all data from all different sensors is needed in order to measure the performance of the user executing the squeezing exercise. The squeezing exercise does involve neither arm movement nor arm rotation, therefore the data from neither the accelerometer nor the gyroscope, respectively, is needed. Upon squeezing the upper muscles in the forearm are tensioned. This corresponds to the data from the EMG sensors 0, 1, and 7 (see figure 6.2.1). In Appendix G the difference in EMG data between squeezing and resting can be found. Main differences are an increased peak-to-peak value (amplitude) and frequency when squeezing compared to resting. Therefore the peak-to-peak and frequency data from EMG sensor 0, 1, and 7 will be used as input for the game. To be more specific, the performance of the user will be determined by the summed number of peaks above a certain threshold of the EMG signals 0, 1, and 7.

6.3 Gameplay

Before being able to play the game, the Myo has to be synchronized with the Myo Connect program. This is to make sure the Myo keeps connected. The Myo Connect program is offered by Thalmic Labs. The game developed for this project consists of three different scenes, namely the calibration scene, the minigame scene, and the results scene. At first the user will see the calibration scene, afterwards the minigame scene and at last the results scene. Every scene has the same lay-out as the original Life webpage, although these scenes are not a webpage themselves. All text written in the scenes is in Dutch, because all users will be Dutch as well.

6.3.1 Calibration Scene

In the calibration scene the game will be calibrated according to the maximum force of the user, as measured with the Myo. A calibration is needed, because the output of the EMG sensors of the Myo is different for any person in any situation (see Chapter 2.3). In this scene the user has to squeeze in the ball with as much power as possible, so that the game will know what the maximum measured force is in this situation. Later on, in the minigame scene (see next section), the game can compare the

current force with the maximum force measured in the calibration step and in this way determine the current effort put in by the user.

The look of the calibration scene can be found in figure 6.3.1.1. The title of the exercise is displayed on top of the screen and below it is the explanation, just like in the original Life webpage. Below the explanation text the game is shown. The translation of the text in the gameplay from top to bottom: “Calibration Step”, “Now, squeeze with as much force as possible”, “This is necessary to adjust the Myo to you”.

After the calibration step has been fulfilled the game will automatically load the minigame

Figure 6.3.1.1 Look of the calibration scene

scene.

6.3.2 Minigame Scene

In the minigame scene the actual game is displayed. As explained in Chapter 4.5 the goal of the game is to fill the bucket with water, by performing the squeeze exercise. Every time the user performs the squeeze exercise correctly, water will drop from the sponge into the bucket. The game is finished when the bucket is filled with water, so in this case when the user has performed the squeezing exercise three times correctly. After the minigame has been finished, the result scene will be loaded automatically.

The look of the minigame scene can be found in figure 6.3.2.1. The minigame scene includes the bucket, the sponge, water, the explanatory video in the upper left corner, live effortbar at the right side of the screen, a “try to use more power” pop-up message, and a “well done” pop-up message. The water has been programmed using the tutorial of Rose [54]. The explanatory video is the same video as the one used on the original Life website. This video starts automatically when the scene is loaded, so the user does not have to press the play button. The live effortbar consists of six, green coloured, boxes. From top to bottom the boxes are coloured from dark green to light green. The effortbar is updated according to the current physical effort of the user. This effort rating is calculated by using the following formula:

$$Effort\ Rating = \frac{Live\ Strength\ Rating}{Calibrated\ Strength\ Rating} * 6$$

The green-coloured boxes of the effort bar correspond to the effort rating, meaning that the number of visible green boxes, from bottom to top, is equal to the effort rating. When the live effort rating is above or equal to six, all six green boxes will be shown.

The bucket will be filled with water if the exercise is performed sufficiently. The exercise is

Figure 6.3.2.1 Look of the minigame scene

considered to be performed sufficiently if the live effort rating is above or equal to four. When the bucket is successfully filled to the top with water, the "well done" pop-up message is shown. When the users performs the exercise insufficiently (so a live effort rating of three or lower) the "try to use a bit more power" pop-up message is shown. More images of the minigame scene can be found in Appendix H.

6.3.3 Results scene

In the results scene an overview is given of the performance of the user. This is the last scene of the game and therefore the game is finished at this scene.

The look of the results scene can be found in figure 6.3.3.1. The results scene includes three effortbars and a feedback message. The effortbars correspond to the performance of the user in the minigame, meaning these effortbars represent the level of strength / effort put in by the user each time he or she performs the squeeze exercise. More specific, the left effortbar visualises the level of strength / effort of the first time the user performs the squeeze exercise, the effortbar in the middle is related to the second time the user performed the exercise, and the right effortbar visualises the third time the user performed the squeeze exercise. As explained earlier, the exercise is considered to be performed sufficiently if the effort rating is above or equal to 4, therefore all effort ratings in the results scene will be above or equal to 4 as well.

The feedback message is related to the combined score of the effortbars. If the summed score of the effortbars is above or equal to seventeen the "*Perfectly done! Keep this going!*" feedback message is shown. Else if, the summed score of the effortbars is between fifteen or sixteen the "*Very*

well done. It was almost perfect, keep it going!" feedback message is shown. At last, if the summed level of the effortbars is below fifteen the "*Well done. Try to use a bit more power next time!*" feedback message is shown.

Figure 6.3.3.1 The look of the results scene

Chapter 7: Evaluation

In this chapter the test performed with the prototype, developed within the Realisation phase, are described. First, a functional test has been performed by the researcher, to check if the developed prototype meets its requirements. Afterwards, the test procedure and test results of the user tests are described. Then the test results are discussed, before conclusion of the test results are described. At last, a third iteration of requirements is given, which can be used for future work.

7.1 Functional Test

Before the prototype can used in the user tests, a functional test needs to be conducted. The functional test will be conducted to make sure the prototype meets most of its requirements. All of the "Must have" requirements from the list of requirements should be met in the prototype. It is preferred that the prototype also meets most of its "Should have" and "Could have" requirements. The requirements are determined within the ideation and specification phase of the project. In table 7.1.1 all requirements are listed and for each requirement it is determined if the prototype has met this requirement.

#	Requirement	Checked off
	Must Have	
1	User has to be able to perform the exercises together with the instruction video.	X
2	Show how close the users are to reaching the amount of times the exercise should be performed and keep track of the amount of times the exercise has been executed.	X
3	Show real-time effort done by the user.	X
4	User must always be able to stop the training. Then the system should stop the exercise	
5	System should not force users to complete the total number of executions, as long as they make progress it is fine.	
6	Mostly give positive feedback in the form of compliments.	X
7	Stay honest towards the user, tell if the exercises are not performed correctly.	X
8	Must be possible to read the instruction text, while performing the exercises	X
21	A calibration step should be added before loading the actual minigame, to make sure the performance of the exercises is measured correctly at any case.	X
22	The exercise should be performed sufficiently for the system to count it.	X
	Should Have	
9	Show the progress the users have made every month.	
10	Make it possible to perform the exercises together with others.	
11	Keep design simple, not a lot of input for the user to handle.	X
12	Provide a clear instruction of the use of the Myo Armband to the user.	
23	The instructions on how to wear the Myo should be before the warming-up, to make sure the Myo is warmed-up while performing the exercises.	
24	Only display feedback messages after performing an exercise insufficiently, three times in a row.	X

Could Have		
13	Remind users to do their exercises.	
14	Show what muscles to focus on for the exercise.	
15	Announce in advance what tools or objects are needed for the exercises.	

Table 7.1.1 Functional Test – All requirements and if they are checked off

Most of the "Must Have" requirements and some of the "Should Have" requirements are checked off. First, the instruction video is visible while performing the exercises and therefore the user can perform the exercises together with the instruction video. Second, the measurement scales on the bucket indicate how often the user already performed the exercise and how often they still have to perform the exercise. Third, the real-time effort of the user is visualised using the effortbar. Fourth, mostly positive and rewarding feedback is given to the user. Fifth, when the user performs the exercise incorrectly for three times in a row, a slightly negative feedback message is shown. In this way the systems stays honest towards the user. Sixth, the instruction text is displayed above the minigame window and therefore it is possible to read the instruction text whilst performing the exercise. Seventh, a calibration step is added in the calibration scene. Eighth, the exercise is considered to be performed sufficiently if the effort rating is above or equal to 4. Only when the exercise is performed correctly the system will count it. Ninth, the design is kept simple, so the user can easily understand it. At last, the slightly negative feedback negative message is only shown when the user performs the exercise incorrectly for three times in a row.

The two "Must Have" requirements that are not met in the prototype, can be compensated by the researcher. The researcher can stop the training if the test participants want to and the researcher can make sure the test participants are not forced to complete the total number of executions. Meaning, that the prototype can be used for the user tests.

7.2 Test procedure

The user test can be divided into five sections. First, the researcher will inform the test person about the research in general and the meaning of the upcoming user test. Second, the test person will put on the Myo Armband and perform the warming-up. Third, the user will perform the squeeze exercise using the original Life project, so without the minigame and without the feedback about the user's performances (Test A). Fourth, the user will perform the exercises using the created prototype, so with the minigame and with feedback about the user's performances (Test B). This is called a test-retest, since participant will interact with two different systems, after one another. The order in which Test A and Test B will be conducted will be alternated for every test person. This, to keep the test results reliable. During both interaction sessions between the user and the two systems, the thinking-aloud method [51] will be used, meaning that the user is asked to share his or her experiences with the researcher. At last, the user will give his or her opinion about the prototype. For this last section structured interviews and questionnaires will be used (see Chapter 3.9). The System Usability Scale (SUS) [49] is integrated into the survey (see Chapter 3.9). In total the user test will take approximately 20 minutes.

7.2.1 Introduction

In this section the researcher informs the test person about the research and the user test. First the researcher shows the informed consent to the participant (see Appendix I). Then the researcher explains the aim of the research and coming part of the user tests. The incorporation of the audio and video recordings is also explained. Moreover, the thinking-aloud method is explained to the test person, because then the test person knows he or she has to share his or her experiences during the test sessions. Afterwards the researcher asks the test persons to sign the consent paper. The test person will sign the consent paper if he or she agrees with the content of it.

Before the test persons start interacting with the prototype or the original Life project, the researcher will ask the test persons to answer some questions. These are administrative questions and will be asked using the structured interview method (see Chapter 3.5). The questions aim to get to know the age, the experiences with performing exercises and the use of a training program, the experiences with previous versions of the Life program, the experiences with playing games (board games or apps), and the attached value to performing exercises, of the test person. The full list of administrative questions can be found in Appendix J (in Dutch).

7.2.2 Warming-up

In this section the test person will perform the warming-up session of the standard Life project. Before starting the warming up the test person will start wearing the Myo Armband. Instructions on how to wear the Myo Armband will be provided. The test person has to start wearing the Myo Armband before performing the warming-up to make sure the Myo is fully warmed-up when the test person starts performing the actual exercises. The time for the Myo to warm-up can be rather long, therefore the Myo has to be warmed-up before performing the exercises, even when starting with Test A. The test person will be wearing the Myo until he or she has completed all exercises. The thinking-aloud method will be used in this section, so the test person will be asked to share all his or her experiences live with the researcher.

7.2.3 Test A

In this section the test person will perform the squeeze exercises three times, using the standard Life program. The test person will wear the Myo Armband, however the data from the armband will not yet be used in this section. Also in this section the thinking-aloud will be used, so the test person will be asked to share all his or her experiences live with the researcher.

7.2.4 Test B

In this section the test person will again perform the squeeze exercise three times, using the created prototype. This means this time the test person will receive feedback on his or her performance. The test person will again wear the Myo Armband, however this time the data retrieved from the armband is used to provide the feedback. The test person has to first complete the calibration step, by squeezing with as much power as possible. Afterwards, the test person has to complete the minigame, by squeezing three times. When completed, the test person will see the results and a feedback message. Also during this section the thinking-aloud method is used.

As explained before the order of Test A and Test B will be alternated for every test person.

7.2.5 User's Opinion

In this section the test person will give his or her opinion about the prototype. The test person can now stop wearing the Myo Armband and no video recordings are made anymore. At first the test persons will fill in a survey. This survey aims to gain information about the different experiences the test persons had with both systems (with and without feedback). Afterwards, the structured interview method will be used to gain information about the positive and negative aspects of the prototype. The structured interview questions are only related to the prototype itself, the comparison between the two systems will not be discussed. The list of questions of the questionnaire and the structured interview can be found in Appendix K and Appendix L, respectively.

7.3 Test results

This section will list the results of the questionnaires and the structured interviews conducted after the user tests, as described in section 7.2. Also the information gained from the thinking-aloud method and from observations from the researcher are included in this section.

In total eight participants conducted the user test. The participants were between 67 and 82 years old, with an average age of 72,6 years old. This means all test persons were within the user target group of this project. From the eight participants, three were man and five were woman. Furthermore, three out of eight participants already had experience with the Life project. At last, three out of eight participants play computer games / app games, where the other five participants only play board games or do not play games at all. All administrative data gathered about the participants can be found in Appendix M.

7.3.1 Observations and Thinking-Aloud Information

During the user tests information was gathered about the interaction between the user and both systems, using the thinking-aloud method and observations of the researcher. During all user tests audio and video recordings were made and the transcription of these recordings can be found in Appendix N. The main points of interest gathered from the recordings are listed below.

Participants finished exercise faster using game – The time it took to complete the exercise using both systems has been compared. It took the participants on average 93 seconds to Test A, where Test B took on average 73.1 seconds for the participants to finish.

Some bugs occurred in the game – While the participants were testing the game, two bugs were discovered. First, occasionally the game crashed when switching from the calibration scene to the minigame scene. This mostly happened when the participants kept squeezing for a longer period of time. To solve this bug the game had to be restarted. The second bug that was discovered was related to the minigame itself. Often when the participants performed the exercise, the bucket was filled to the top when the participants performed the exercise only one or two times. This was mainly caused by the fact that when squeezing for a longer period of time the strength level fluctuates, causing the game to think the user squeezed for multiple times. This last bug had a negative impact on the interaction between the user and the system, since it confused the users. The participants were confused if they already finished the exercise or not.

Almost no participants play the instruction video – In order to see the instruction video the participants had to manually start the video when using the website. Only one participant actually started the video, the other performed the exercise without the use of the explanatory video. When using the game, the explanatory video would start automatically. All participants followed the instructions given when the video was played automatically and therefore playing the video automatically seems better than having to start it manually.

Connection between scenes in game is confusing – Many participants did not see the connection between the different scenes in the game. They did not know whether the calibration step was part of the actual exercise or not. While squeezing for the calibration step it was unclear if this squeeze was already part of the exercise or not. Furthermore the link between the minigame scene and the results scene was causing some confusing among the participants. It was uncertain what the results scene represented and how this was connected to their performances in the game.

7.3.2 Questionnaire Results

The questionnaire was used to compare both systems (with and without feedback / game) on four different topics. As explained in section 7.2 these topics are usability, stimulation, insecurity, and pleasure. Furthermore, the last question of the questionnaire asked the participants what their preferred system was. The results are described below.

Usability – In order to measure the usability ratings of both system the System Usability Scale (SUS) has been used, as explained in section 3.10. The resulting SUS rating for the system without feedback or game is 84,4, where the system with feedback and game got a SUS rating 89,4. The maximum SUS rating is 100, so the SUS ratings for both systems can considered to be very high. Meaning, both systems were easy to use. The full calculation of the SUS ratings can be found in Appendix O.

In order to determine if the SUS ratings of both systems are correlated to one another, the Intraclass Correlation Coefficient (ICC) has been used [50], as explained in Chapter 3.10. This coefficient measures the reliability of measurements from data that has been collected into groups. For the evaluation of this project, the data was collected within two groups. Namely, the data collected from both systems, the system with- and the system without feedback / game. The results of the ICC test can be found in the table 7.3.2.1.

The Intraclass Correlation rating for Average Measures from the table, can be used to determine if the SUS ratings of both systems are correlated to one another. This value represents how consistent the SUS values of both systems are on average and it is equal to 0.807. A rating of 0.807 is very high and therefore indicates there is a reliability. Meaning, it can be assumed both SUS ratings are correlated to one another. Concluding, the two systems (with and without feedback / game) are assumed to have an equal usability rating.

Intraclass Correlation Coefficient

	Intraclass Correlation[a]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.677[b]	.174	.907	5.605	9	9	.009
Average Measures	.807[c]	.296	.951	5.605	9	9	.009

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. Type A intraclass correlation coefficients using an absolute agreement definition.

b. The estimator is the same, whether the interaction effect is present or not.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 7.3.2.1 Intraclass Correlation Coefficient values of the SUS ratings of the system with and the system without feedback / game.

Stimulation – In order to determine how stimulating both systems were, the participants were asked to rate the following statement: "*I got stimulated by using this system*". The participants had to give a rating between one and five on how much they agreed with the statement. A five meaning they felt very stimulated by using the system and an one meaning they did not feel motivated by the system.

The results are shown in figure 7.3.2.2, where system 1 represents the system without feedback / game and system 2 representing the system with feedback / game. Overall, the participants thought the game (system 2) was more stimulating to use than the website (system 1). On average the game received a rating of 4.3 out of 5, where the website received a grade of 3.6 out of 5. Besides the average rating of all participants, figure 7.3.2.2 also shows the average ratings the men, women, participants with and without experience with the Life program, and participants who did and did not play video-games or apps often gave to both systems regarding stimulation. Interesting to see is the fact that the participants with experience with the Life program clearly thought the game was more stimulating than the website. The game received a 4 out of 5, where the website received a 3.3 out of 5. Also interesting is the fact that participants who often played video-games or apps gave the highest ratings to both systems, regarding stimulation. This could be because, they are more familiar with graphical user interfaces, resulting in having more understanding of what was going on.

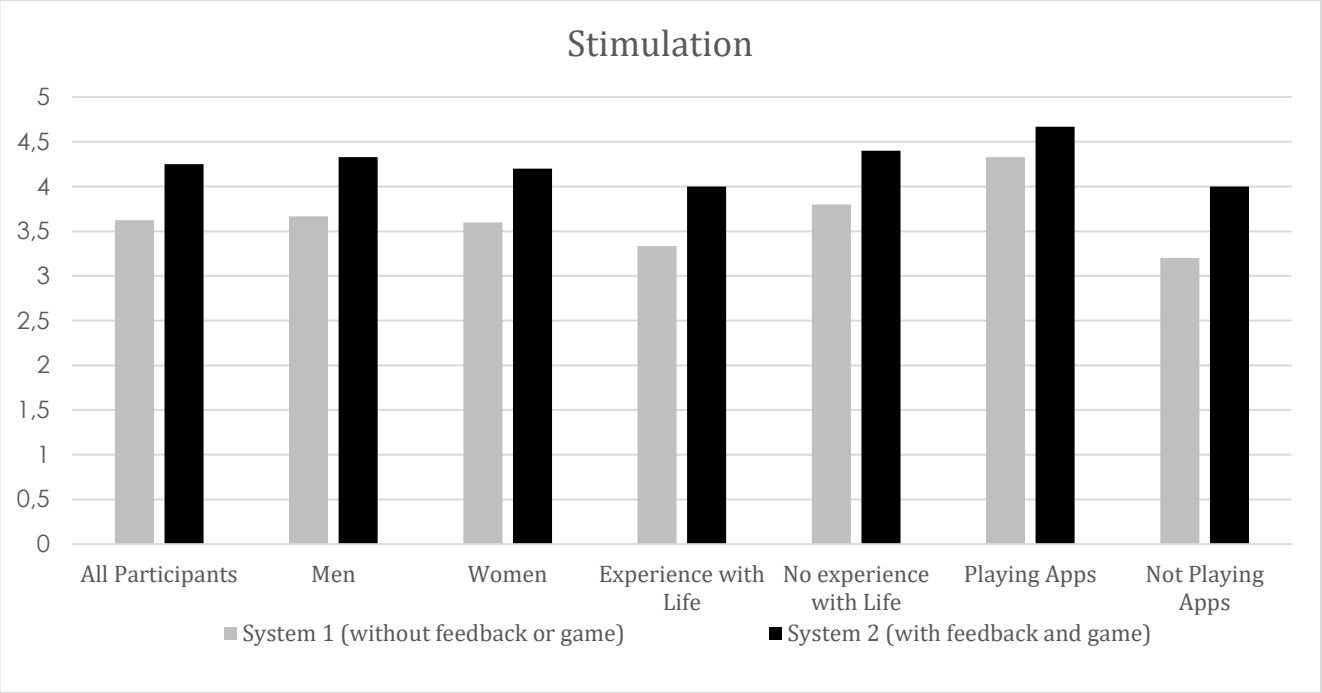

Figure 7.3.2.2 Ratings given by the participants, regarding the level of stimulation of both systems

Insecurity – In order to determine how insecure the participants were about whether they performed the exercise correctly when using both systems, the participants were asked to rate the following statement: "*I felt insecure whether I performed the exercise correctly when using this system*". The participants had to give a rating between one and five on how much they agreed with the statement. A five meant they felt very insecure whether they performed the exercise correctly when using the system and an one meant they did not feel insecure at all when using the system.

The results are shown in figure 7.3.2.3. Overall, the participants did not feel insecure whether they performed the exercise correctly in both systems. On average, both systems received a rating of 1.4 out of 5, meaning when using both systems the participants did not feel insecure. Besides the average rating of all participants, figure 7.3.2.3 also shows the average ratings the men, women, participants with and without experience with the Life program, and participants who did and did not play video-games or apps often gave to both systems regarding insecurity. Interesting to see is that, unlike the stimulation topic, not all participant groups agreed upon one system being better than the other. Where the game (system 2) scored better than the website (system 1) for every participant group, regarding stimulation, the results are more mixed for the insecurity topic. The ratings for the game from each participant group were consequent, having all ratings between 1.3 and 1.6. The website, on the other hand, received more inconsequent ratings, having ratings between 1 and 2. Therefore it could be that the opinions, regarding insecurity, on the website are more participant group based, where the opinions on the game are shared by everybody. Clear example is the difference in ratings between the participants with and without experience with Life. Both participant groups gave a similar rating for the game, but a significantly different rating for the website. The participants with experience gave a 2 out of 5 for the website, where the participants without gave a 1 out of 5 for the website. Meaning, that the participants with experience with Life,

while having more experience with the exercises, were more insecure about their performance when using the website. They saw the game as an improvement on this topic.

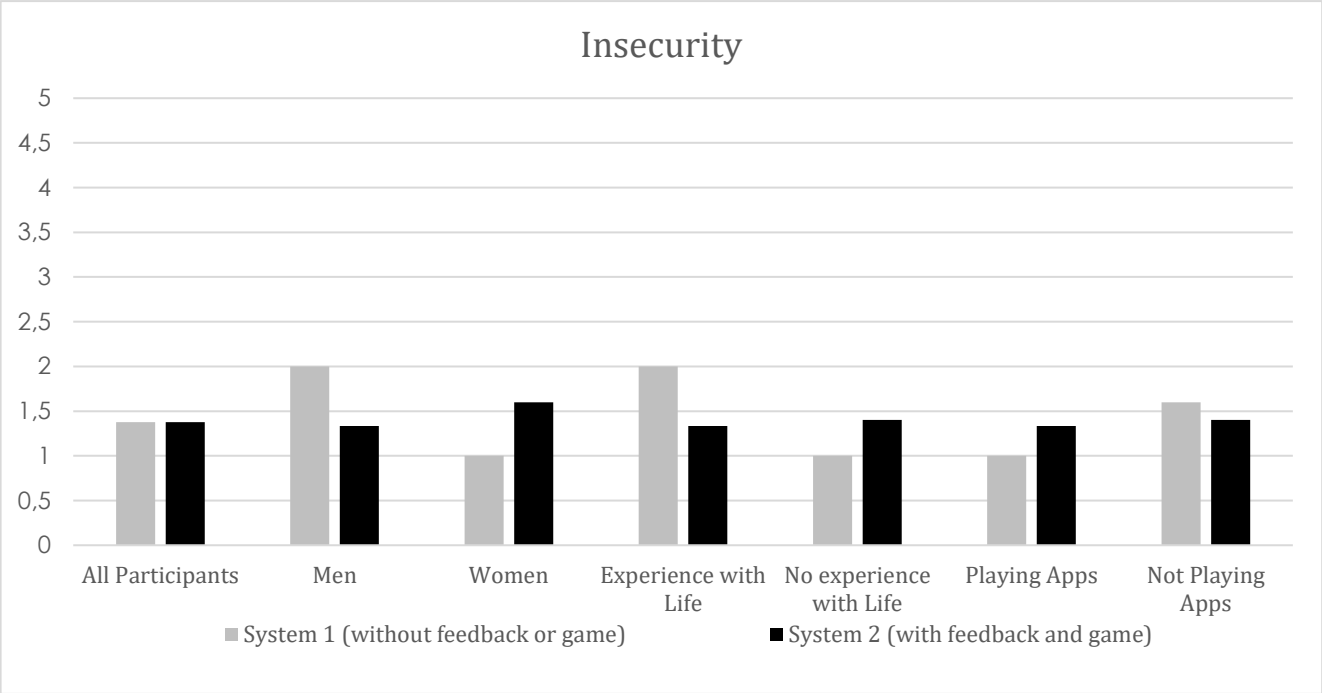

Figure 7.3.2.3 Ratings given by the participants, regarding how insecure they were whether they performed the exercise correctly, with using both systems

Pleasure - In order to determine how pleasurable both systems experienced were, the participants were asked to rate the following statement: "*I got stimulated by using this system*". The participants had to give a rating between one and five on how much they agreed with the statement. A five meant they felt it was a pleasure to use the system and an one meant it was not a pleasure at all to use the system.

The results are shown in figure 7.3.2.4. Overall, the participants thought the game (system 2) was more fun to use than the website (system 1). The game having an average rating of 4.4, where the website received an average grade of 3.6. Besides the average rating of all participants, figure 7.3.2.4 also shows the average ratings the men, women, participants with and without experience with the Life program, and participants who did and did not play video-games or apps often gave to both systems regarding pleasure. Interesting to see is that the game received a higher rating than the website for every participant group. Also interesting to see is the fact that the difference in rating between the website and the game, received from the participants who have experience with Life. The game received a rating of 4.3 and the website a rating of 3.3, from the participants with experience with Life. Also interesting to see is that both systems received very high grades from the participants who plays video-games / apps often. This can be caused by the fact that participants playing video-games / apps would be more familiar with graphical user interfaces. Therefore both systems would be easier to handle for them and therefore both systems would be more fun to use.

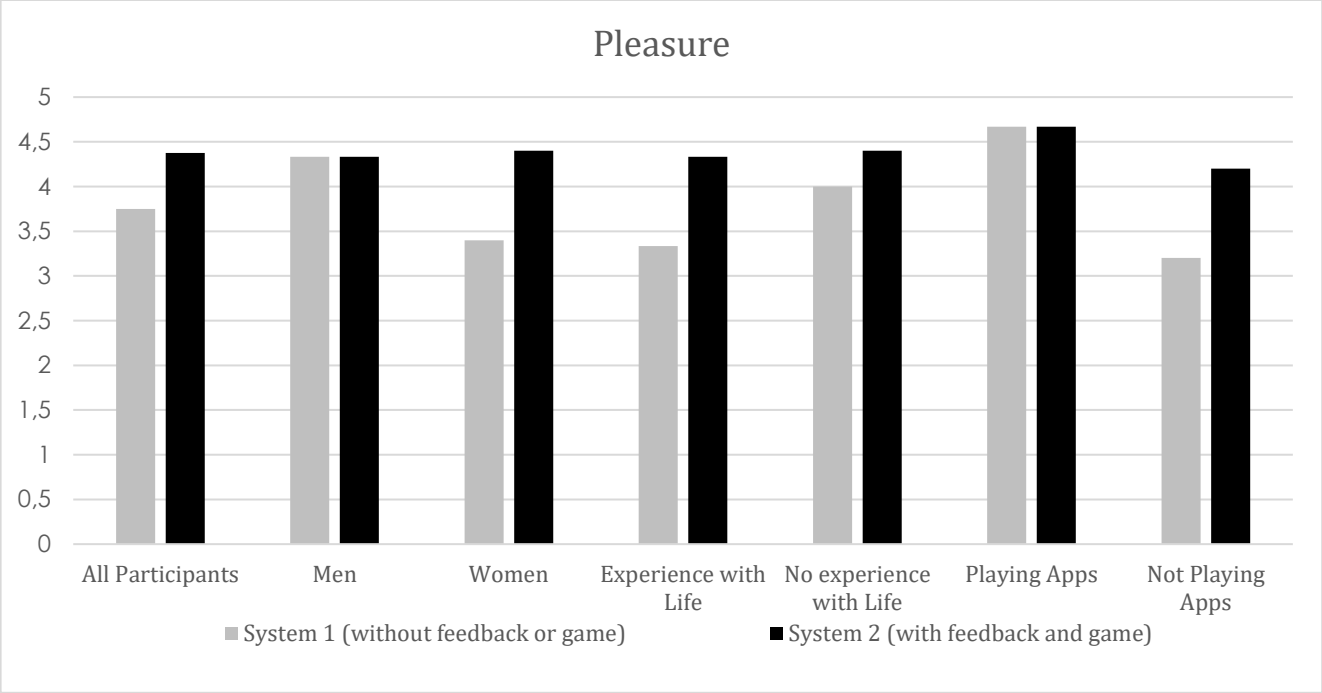

Figure 7.3.2.4 Ratings given by the participants, regarding the level of pleasure of both systems

Preferred system – Last question of the questionnaire was focussed on the preferred system of the participant. The question was: "*Which of the two system do you prefer and why*?". It was an open question, so the participants could type in their preferred system and motivation.

Five out of eight participants preferred system 2 (with feedback and game). Motivations given by these participants are:

- "*Because, system 2 visualises your muscle activity*"
- "*Using system 2, I could see what I was doing on the screen and I felt stimulated to put in more effort.*"
- "*The second system gave more insight on results than the first system.*"
- "*System 2 showed direct results, which stimulated me to do even better the next time.*"
- "*The second system, because by squeezing in the ball you can show-off more of your force*" **Note:** This last motivation to prefer system 2 does not seem justified, since both systems included the ball.

The other three participants had no preference for one of the systems. There motivations were:

- "*Both systems were useful. Performing the exercise itself was already good enough, then no system is needed.*"
- "*Both systems were good, since I could use them both easily.*"
- "*One system was not better than the other, because both times the exercise was not difficult.*"

So, in general the participants preferred system 2 over system 1. Meaning, they preferred the game over the website. This was mostly because of the (direct) results the game gave on the performance of the user. The participants liked the direct results of their efforts, visualised in the game.

7.3.3 Interview Results

The structured interviews were used to gain information about the prototype. The questions of the structured interviews were only focussed on the game, the website was excluded. The aim of this interview was to get to know the positive and negative aspects of the game and what should be improved. Moreover, the interviews were conducted to check if the requirements had been met. The points of interest gained from these interviews are listed below. All information gathered during these interviews can be found in Appendix P.

Visualising input from user is a positive aspect– Many participants mentioned that the visualised effort of the user in the game was a very positive aspect. Many participants stated that they got stimulated, because of the effects their effort had on the game.

Myo armband was no problem to wear – None of the participants experienced the Myo armband as annoying or disturbing. No problems occurred, because of wearing the device. Providing clear instructions, the older adults should be able to wear and calibrate the device correctly. Also the vibrate function of the armband was no problem for the participants. The researcher announced in advance when the armband was going to vibrate, so the participants were prepared.

More explanatory text is needed – According to the participants the game lacks explanatory text. Many participants would like to have more text explaining what is going on and what is going to happen. Examples are, the goal of the game is not described and the result scene is not explained.

Participants liked the positive feedback – Many participants liked the positive approach of the game. Most participants got encouraged by the positive feedback.

Game was fun to play – Almost all participants thought the game was very fun to play. Some participants got stimulated by the raising water level, where others said the game had no effect on the amount of effort they were putting in. However in general, almost all participants had fun when playing the game.

More games should be made for more different exercises – When asking what could be improved, many participants said they would like to see more games to be made for more different exercises. Also the suggestions was made to add more different levels within the game. In this way the users could get even more motivated, because they could move to the next level.

Many participants would use this system at home – Many participants would like to use this system at home. Especially when more different exercises would be added to the system. However, not all participants would use this system at home. Mostly because they said not be the kind of person for this or they would only use it when suffering from something. This can be explained by the fact that most test participants performed exercises or sports frequently.

7.4 Discussion

Before any conclusions can be drawn from the user tests, a number of issues have to be discussed, regarding the reliability of the test results. First, in order to be able to draw quantitative results more participants are needed.

Second, the participants only had to perform the exercise itself. They did not have to navigate through menus or start the game and therefore the usability scores for both systems will be higher. In order to determine the usability of the total system all functionalities of the system should be included. Third, seven out of eight test persons liked to exercise and performed exercises or sports more than one time a week (see Appendix M). Therefore, the pleasure ratings for both systems will be positively influenced. Fourth, the exercise the participants had to perform was rather easy to execute, therefore the insecurity ratings can be influenced. Many participants said not to feel insecure, because the exercise was very easy to perform. All of above announced discussion points should be taking into account before drawing any conclusions.

7.5 Conclusion

Overall the game has proven to be an improvement for the Life project. All participants saw potential for the game and most participants would like to have such a system at home, especially when including more different exercises. When comparing the game to the website the following insights occur:

- **The game and the website have a similar level of usability –** Both systems received a very high SUS rating from the participants and after determining the ICC value it can be concluded both systems have a similar usability rating. As explained in section 7.4, it should be taken into account that the participants only had to perform the exercises.
- **The game was more stimulating to use than the website –** The game received a higher rating than the website regarding stimulation. Many participants said the game was more stimulating, because it showed direct results of their effort.
- **When using both systems the participants were not insecure about whether they performed the exercise correctly –** When using both systems the participants did not feel insecure about whether they performed the exercise correctly or not. The participants were certain that they performed the exercise correctly when using both systems, however as explained in section 7.4, this can be caused by the fact that the squeeze exercise was rather easy to perform.
- **The game was more fun to use than the website –** The game received a higher grade from the participants than the website, regarding pleasure. Many participants said the game with the bucket and the sponge was fun to use and wanted to see more games to be developed for more different exercises.
- **Game is preferred over the website –** Five out of eight participants preferred the game over the website, mostly because it gave a direct response on their effort. The other three participants had no preferred system, since they thought both systems were good.

When combining all information gathered from the interviews, thinking-aloud method, and the observations, the following insights occurred:

- **More explanatory text is needed in the game –** Often participants got confused by the different scenes in the game. The connection between the different scenes was difficult for them to make, and therefore more explanatory text about what is going to happen in the game is needed.
- **Bugs in the game need to be fixed –** Some bugs occurred in the game and they influenced the interaction between the user and the system in a negative way.
- **The participants had no problem with wearing the Myo armband –** None of the participants had any difficulties or complains with wearing the Myo armband. Also the vibrate functions was not disturbing for them.
- **Participants liked the positive approach of the game –** The participants liked the positive approach of the game towards the user. By giving the user a lot of compliments, the users enjoyed the interaction more.

7.6 Requirements 3th Iteration

Based on the test results of the user tests, the list of requirements can be updated. These new requirements can be used for future work. The new requirements can be found below:

Must

1. User has to be able to perform the exercises together with the instruction video (non-functional).
2. Show how close the users are to reaching the amount of times the exercise should be performed and keep track of the amount of times the exercise has been executed (functional).
3. Show real-time effort put in by the user (functional).
4. User must always be able to stop the training. Then the system should stop the exercise (functional).
5. System should not force users to complete the total number of executions, as long as they make progress it is fine (non-functional).
6. Mostly give positive feedback in the form of compliments (non-functional).
7. Stay honest towards the user, tell if the exercises are not performed correctly (non-functional).
8. Must be possible to read the instruction text, while performing the exercises (functional).
21. A calibration step should be added before loading the actual minigame, to make sure the performance of the exercises is measured correctly at any case (functional).
22. The exercise should be performed sufficiently for the system to count it (functional).
25. System must not consists any bugs, negatively influencing the user experience (functional).

Should

9. Show the progress the users have made every month (functional).
10. Make it possible to perform the exercises together with others (non-functional).
11. Keep design simple, not a lot of input for the user to handle (non-functional).
12. Provide a clear instruction of the use of the Myo Armband to the user (non-functional).

23. The instructions on how to wear the Myo should be before the warming-up, to make sure the Myo is warmed-up while performing the exercises (functional).
24. Only display feedback messages after performing an exercise insufficiently for three times in a row (functional).
26. System should have much explanatory text, on what is happening and what will happen in the game (non-functional).
27. System should explain the link between the minigame and the result scene to the user (non-functional).

Could

13. Remind users to do their exercises (functional).
14. Show what muscles to focus on for the exercise (functional).
15. Announce in advance what tools or objects are needed for the exercises (functional).
28. System could automatically play the instruction video (functional).
29. Effortbar could be more clear / visible (non-functional).

Won't

16. User has to be able to enter the time he or she wants to perform the exercises (functional).
17. In a later stage, separate the amount of effort men and women have to do (non-functional).
18. Movement done by the user outside of exercises should be registered as well (functional).
19. Make it possible for the user to also enter their social activities into the systems (functional).
20. Warming up should be more intensive than it currently is (non-functional).

Chapter 8: Conclusion and Recommendations

In this chapter the overall conclusion of this graduation project is provided. In this chapter the main- and sub- research questions, stated in Chapter 1.3, will be answered. Furthermore, recommendations for future work will be described.

8.1 Conclusion

This was focussed around providing feedback to older adults about their performance, regarding the execution of exercises. To provide this feedback, a game has been developed. The game consists of a bucket and a sponge. The goal of the game is to fill the bucket with water, gathered from squeezing the sponge. The older adult would perform the squeeze exercise in real life to squeeze the sponge in the game. A Myo armband has been used to measure how much effort the older adult is putting into the game. The game updates according to this effort, also feedback messages are provided according to the effort. The game was a success according to the older adults testing it. They enjoyed the game and got stimulated by it.

In chapter 1.3 one main research questions and three sub research questions were proposed. In order to answer the main research question, first the sub-research questions will be answered. Information has been gathered using literature research, state-of-the-art research, interviews, brainstorms, user tests, and user evaluations, in order to answer these research questions.

First, information has been gathered about what information the older adults need about their performance, regarding the execution of the exercise. During the ideation phase of this project interviews were conducted with potential users of the system, the developer of the Life project and a physiotherapist, in order to gain information about this topic. From the interviews with both the developer of Life and the physiotherapist, it was determined that the frequency of an exercise is very important to know for older adults. So, the older adults need to know how often they already performed the exercise and how often they still have to perform the exercise. From conducting the interviews with the potential users, it was determined that the users themselves would like to see their own strength or effort to be visualised. They stated it would work stimulating to see your own strength or effort to be visualised.

To summarize, the answer to SubRQ1, "*What information about the execution of the daily exercises do older adults need?*", is:

- **Frequency**: how often is the exercise executed already and how often does the exercise still be performed.
- **Strength**: visualise the live strength or effort of the user.

Second, information has been gathered about the characteristics of the Myo, regarding usability, that should be taken into when designing an application for the device. A literature research has been conducted to gather information about this topic. During this literature research the

functionalities and limitations of the Myo have been researched. Also has the Myo been compared to other gesture and movement tracking devices. One of the better functionalities of the Myo is its ability to measure EMG signals, making it suitable to measure the strength of the user. As explained before, information about strength is information older adults want. This also makes the Myo more suitable to measure the performance of older adults while executing exercises, than other movement and gesture tracking devices, which cannot measure EMG signals. Largest limitation of the Myo armband is the fact that it has different outputs for all people and in different situations, therefore it needs to be calibrated each time before it can be used sufficiently.

To summarize, the answer to SubRQ2, "*What characteristics, regarding usability, of the Myo Armband should be taken into account?*", is:

- **The Myo armband is most sufficient to use compared to other motion and gesture tracking devices:** the Myo can measure EMG signals and therefore it is most capable of measuring the performance of an older adult executing exercises.
- **The Myo armband needs to be calibrated:** Each time before using the Myo armband, the device should be calibrated.
- **The Myo armband has a limited amount of pre-defined gestures:** The Myo has a limited amount of pre-defined gestures. This however was not a problem, since the raw EMG data of the Myo was used to measure the performance of the older adult executing exercises.
- **The Myo armband has occasional misclassifications:** The Myo armband can have occasional misclassification when detecting the pre-defined gestures. As explained earlier, the pre-defined gestures were not used within this project, therefore the potential misclassifications did not occur.

Third, information has been gathered on how the feedback, on the performance of the exercise, should be provided towards older adults in an engaging way. A state-of-the-art research has been conducted to find previous solutions on how to provide feedback to older adults. The result from this state-of-the-art research was that, gamification is more often used approach to provide feedback to older adults, nowadays. This gamification method has been used for development of the prototype for this project and tested during the user tests. During the user tests, the developed game and the original website of the Life project were compared. It was discovered that gamification is more stimulating and more fun to use for the older adults, while the usability rating and insecurity about whether the exercise is performed correctly stay similar as compared to the original Life website.

Furthermore, during the ideation phase interviews were conducted with potential users, a physiotherapist and the developer of Life. During this interviews it was determined that a positive approach is needed when providing to older adults. However staying honest towards the user is important. This positive, but still honest, approach was also tested during the user tests. The developed prototype included many positive feedback messages, while also providing feedback about what needs to be improved, when the older adult performed the exercise incorrectly. Especially the positive feedback messages were experienced as pleasant and stimulating by the older adults.

To summarize, the answer to SubRQ3, "*How to provide feedback to older adults about their performance when executing exercises, in an engaging way?*", is:

- **Use a gamification approach:** This approach will stimulate the older adults to perform the exercises, while it also makes it more fun to perform to the exercises.
- **Use a positive approach:** Provide many positive feedback messages about the performance of their exercises to the older adults, this is experienced as pleasant and stimulating.
- **Stay honest towards the user:** Tell the older adults when he or she does not perform an exercise correctly.

When combining all answers from the sub-questions, the main research question, "*How to design and implement a feedback system, using the Myo Armband, to provide feedback to frail older adults on their performance, regarding the strength exercises related to the upper-body?*", can be answered. The answer to this main research question is:

- **Provide feedback about both the frequency and the strength / effort:** Count the amount of times the older adult performed the exercise and show how often they still have to perform the exercise. Also provide feedback about the strength / effort of the older adult.
- **The Myo is the most suitable gesture / movement tracking to use, however take into account the calibration step needed:** Compared to other gesture / movement tracking devices, the Myo is most suitable to use to measure the performance of older adults performing exercises. In order for the Myo to work sufficiently a calibration step is needed before every use.
- **To provide feedback, use the gamification method, with mostly positive and when needed negative feedback messages:** The older adults get stimulated and enjoy performing the exercises more when providing feedback using the gamification method. Older adults experience positive feedback messages as stimulating and pleasant, however the system needs to stay honest towards the user. So, when the older adult has to improve his or her performance, the system should give slightly more negative feedback.

8.2 Recommendations

The prototype made for this project is not yet finished. As explained in Chapter 7.5 the prototype has some bugs that needs to be fixed. These bugs confused many test participants and therefore had a negative influence on the interaction between user and system. Chapter 7.5 also describes that the prototype lacked some explanatory text. This also led to many confused participants, because of the lack of information. Therefore more explanatory text should be added about what is going on in the game, what should be done, and what is going to happen.

Moreover, the game could be made a bit more dynamic. At the moment only the water in the bucket and the dropping waterdrops move in the game. Making the game more dynamic, by for example having the sponge on the screen being squeezed as well, would add the realistic value of the game.

Many participants were curious and interested in other games related to other exercises. Therefore, more games could be developed for other exercises of the Life program. When using the Myo as gesture / movement tracking device, only exercises related to arm and hand movement can be measured. Therefore, when using the Myo, it is suggested to focus on strength-exercise related to the upper body, as these involve arm movement and muscles.

All participant owned an iPad. Therefore it would be recommended to design the game to be played on an iPad. Most convenient will be that the older adults can download the game from the app-store / play-store.

At last, the effect of sound in the game and the effect of the vibration of the Myo could be tested in future research. The game has no sound or music included at the moment, therefore the effect of sound or music on the older adults would be interesting to do further research on. As explained in section 7.5, the older adult did not experience the Myo armband and its vibration function as disturbing or annoying, therefore the use of the vibration function of the Myo as a form of provide feedback would be interesting to research.

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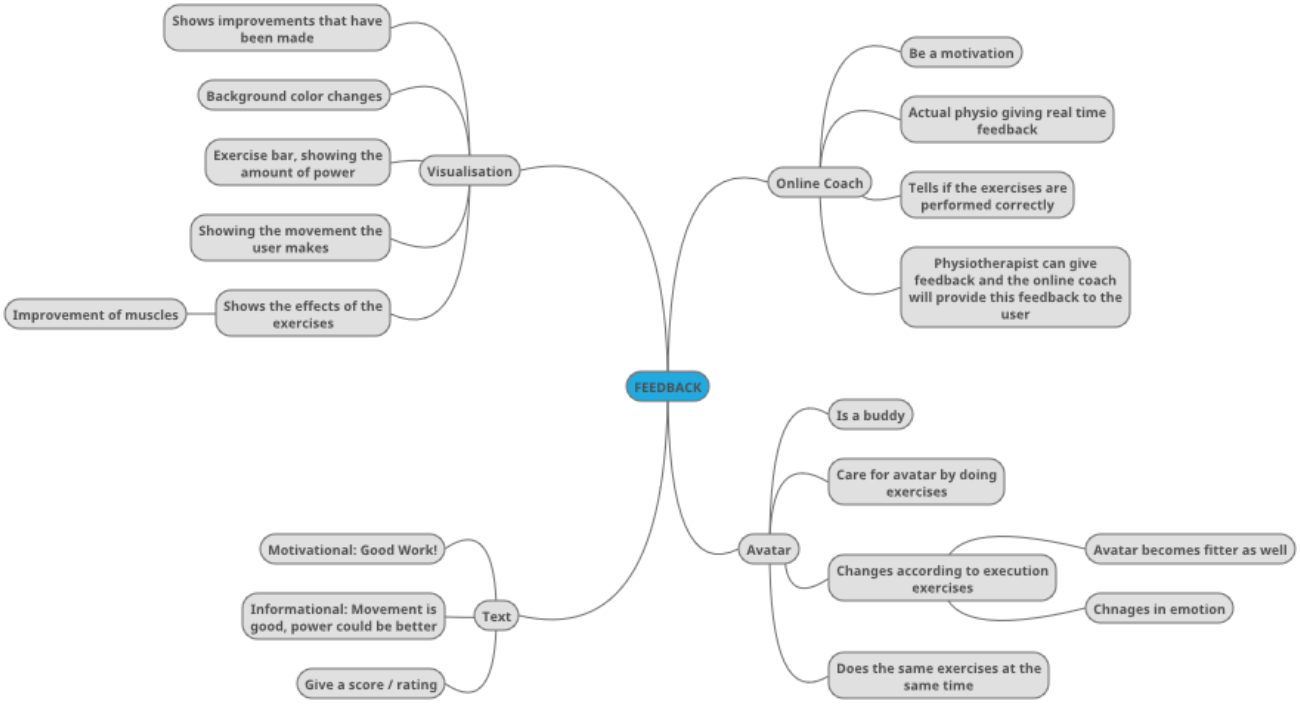
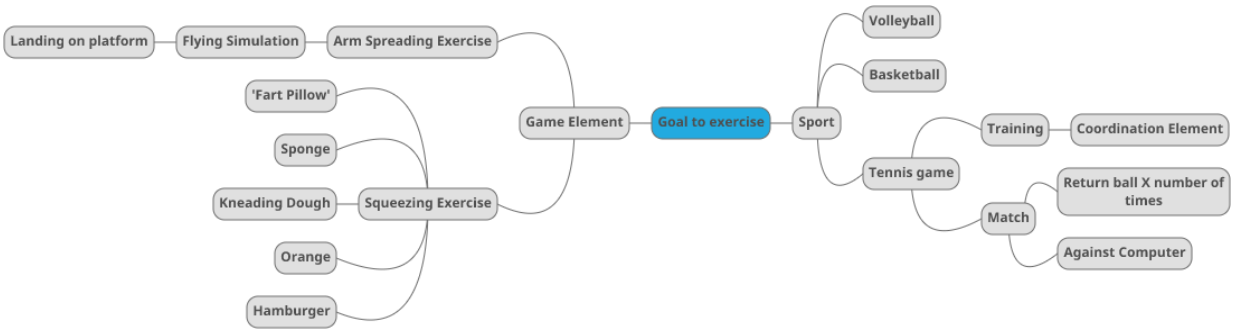
Appendix

Appendix A: Mind-Maps

A-1: Individual Brainstorm Session



A-2: Joint Brainstorm Session with Physiotherapist



Appendix B: Set-up Interviews / Brainstorm Sessions

B-1: Physiotherapist

Introduction

Welcome to this interview and brainstorm session. Thank you very much for joining. At first, is it allowed for me to record this conversation?

Explanation project

The goal of the project is to make it possible for elderly patients to do their regular physical exercises at home. Normally these patients would have to go to the physiotherapist or the physio would have to go to the patient's home, when executing the exercises. Already a website has been made, where patients can find videos explaining the exercises. In this way the patients could do the exercises at home. Only problem is that these patients now do not receive any feedback about the execution of the exercises and the physio does not know if the patient is doing the exercises correctly.
This project is focussed on solving this feedback problem. An electronic device will be used to give the feedback. This device can measure the arm-movement and rotation and the muscle tension.

Questions

General:

- What is your name and where do you work?
- Do you often work with elderly patients, in general?
- What does the normal treatment process for these elderly patients look like?
- What kind of exercises do you normally propose to those elderly patients?

Feedback:

- How can see if a patient is doing the exercise correctly?
- Is it possible for a patient to over exercise? If yes, how can you recognize this?
- How do you know if the patient is improving?
- What kind of feedback do you normally give, during the execution of the exercises, to elderly patients?
- What kind of feedback, about the execution of the exercises, do you as physio want to get from this project?

Brainstorm

Now we will brainstorm about the project. Goal of the brainstorm session is to find a way of giving the feedback to the patient. Everything is possible, do not think about limitations. Name everything what you can think of. All ideas are relevant, since they can include valuable information.

B-2: Older Adult (Dutch)

[Neem Informed consent door met de senior door.]

Introductie

Allereerst erg bedankt dat u mee wilt doen met dit interview / brainstorm sessie. Ik wilde u graag vragen of u het toestaat dat ik dit gesprek opneem (audio). Door het gesprek op te nemen kan ik het later terug luisteren en analyseren. Ik zal u eerst uitleggen waar dit project over gaat en wat het doel is van dit interview / brainstorm sessie.

Project**:**
Doel van dit project is om het mogelijk te maken voor senioren om thuis oefeningen te kunnen doen en daarbij feedback te kunnen ontvangen. Oefeningen doen is erg belangrijk voor senioren, want het zorgt ervoor dat ze fitter blijven en daarmee langer zelfstandig kunnen leven. Daarom heeft Roessingh Research and Development (RRD) een website ontwikkeld genaamd Life. Op deze website kunnen senioren oefenprogramma's doen en uitleg krijgen over hoe de oefening uitgevoerd moet worden. Met behulp van deze uitleg kunnen senioren thuis de oefeningen uitvoeren. Naast deze uitleg is feedback krijgen op de uitvoering van de oefeningen erg belangrijk, omdat men anders niet weet of de oefening correct word uitgevoerd. Normaal gesproken zou een fysiotherapeut deze feedback geven, maar als de oefeningen thuis worden uitgevoerd is dat niet mogelijk. Daarom is het doel van dit project om een systeem te ontwerpen dat feedback geeft aan senioren over de uitvoering van de oefeningen.

Doel Interview / Brainstorm Sessie:
Tijdens de ontwerp fase van dit project word er gebruik gemaakt van een 'co-design' methode. Dit betekent dat de eindgebruiker (u in dit geval) betrokken word in het ontwerp proces. Met dit interview / brainstorm sessie betrek ik u in het ontwerp proces. Met het interview word belangrijke informatie over de gebruiker (u) verzamelt. Tijdens de brainstorm sessie kunt u uw eigen ideeën over hoe dit feedback systeem ontworpen zou moeten worden inbrengen.

Interview
Tijdens dit interview worden u een aantal gesteld. Probeer altijd zo volledig mogelijk te antwoorden en uw antwoorden uit te leggen.

Administratief:
[Schrijf geslacht op]

- Wat is uw leeftijd?

Feedback:

- Wat zijn uw hobby's of dagelijkse activiteiten?
- Hoe gaat u met kritiek om? (stel het systeem zegt dat u de oefening niet goed uitvoert)
- Wat vind u een prettige manier van het krijgen van feedback?

Ervaringen Life project:

- Wat is uw ervaring met het gebruiken van Life?
- Voerde u de oefeningen vaak alleen uit of met anderen?
- Wat zijn uw redenen om oefeningen te doen?
- Wanneer gingen de oefeningen vervelen?

- Wat zou u willen verbeteren aan het Life programma?

Brainstorm

- Stelt u zich voor u de ontwerper bent, wat zou u dan maken?

[Samen ideeën bedenken over de manier van feedback geven. Hierin is alles mogelijk, laat de mensen niet in beperkingen denken]

B-3: Developer Life Project

Introduction

Welcome to this interview and brainstorm session. Thank you very much for joining. At first, is it allowed for me to record this conversation?

Explanation project

Goal of this project is to design a feedback system for the Life project. This feedback system will give direct feedback towards the older adult, regarding his or her performance. The older adult can use this feedback to improve their performance. The performance of the older adults will be measured using the Myo Armband.

[Show and explain the Myo Armband].

As you are the developer of the Life project, I would like to ask you a few questions, regarding the Life project. Furthermore I would like to have a joint-brainstorm session about how to design a feedback system for the Life project.

Questions

- What is the aim of the Life project?
- What is the Life project based on?
- What is the role of the physiotherapist in the Life project?
- What specific choices have been made wile designing the Life project?
- What are the test results of the Life project so far?
- Did you think about how to approach this user group (word choices, motivation wise)? If yes, how?
- Did you brainstorm before about ways to give feedback about the performance of the older adult? If yes, what were the resulting ideas?
- What of the Life project would you like to improve?
- Do you have tips for me on how to handle this project?

Brainstorm

- Imagine you are in my position and you have to design a feedback system for the Life project, how would you design it?

[Tell the developer how the brainstorm will work. Explain the developer not to think in limitations.]

Appendix C: Informed Consent Interview Older Adults (Dutch)

C-1: Information Letter

Geachte heer/mevrouw,
Zojuist bent u gevraagd om deel te nemen aan een interview / brainstorm sessie. De uitkomsten van dit interview / brainstorm sessie zullen gebruikt worden voor het ontwikkelen van een feedback systeem voor een oefenprogramma waarmee senioren thuis oefeningen kunnen doen om fit te blijven.
Het gehele onderzoek zal ongeveer 30 minuten duren. Uw beslissing over uw deelname, moet u kunnen baseren op goede informatie van onze kant. Daarom ontvangt u deze schriftelijke informatie, die u rustig kunt (her)lezen. Binnenkort zal door de onderzoeker contact met u worden opgenomen en zal aan u worden gevraagd of u aan het onderzoek wilt deelnemen. Tijdens dit contact moment kunt u de vragen die u over het onderzoek heeft voorleggen.

Doel en achtergrond van het onderzoek
Het ontwikkelen van een feedback systeem voor een oefenprogramma waarmee senioren thuis oefeningen kunnen doen om fit te blijven. Dit systeem zal de bewegingen van de gebruiker herkennen en op basis van deze informatie de gebruiker feedback geven over hoe de oefening was uitgevoerd. De wijze van feedback geven zal op basis van de informatie verkregen met dit interview / brainstorm sessie ontworpen worden.

Wat houdt deelname aan het onderzoek voor u in?
U zult meewerken in de ontwerp fase voor het systeem. Dit houd in dat u een aantal scenario's voorgelegd zult krijgen en hierover een aantal vragen zult krijgen. Verder zult u meedoen in een brainstorm sessie. Dit houd in dat u samen met de onderzoeken actief gaat bedenken hoe de feedback eruit zou moeten zien.
Wanneer u besluit mee te doen aan dit onderzoek vragen wij u om een toestemmingsformulier in te vullen en dit te voorzien van uw handtekening.

Wanneer komt u in aanmerking voor het onderzoek?
U komt in aanmerking voor dit onderzoek als u boven de 65 jaar bent.

Mogelijke bijwerkingen / Risico's
Deelname aan dit onderzoek zal voor u geen risico's met zich meebrengen.

Mogelijke voordelen
Door deelname aan dit onderzoek draagt u bij aan de ontwikkeling van een oefensysteem waarmee thuis oefeningen kunnen doen. Hierdoor kunnen senioren fitter blijven, waardoor ze ook langer zelfstandig kunnen blijven leven.

Vertrouwelijkheid
De gegevens die gedurende het onderzoek over u verzameld worden, zullen vertrouwelijk behandeld worden volgens (inter)nationale regels en wetten, waaronder de Wet Bescherming Persoonsgegevens. De gegevens zullen zodanig gecodeerd worden dat ze niet tot u te herleiden zijn. Uw gegevens worden anoniem in een elektronische database van Roessingh Research and Development (RRD) opgeslagen en alleen gebruikt t.b.v. dit onderzoek.

Vrijwillige deelname
U bent vrij om deelname aan dit onderzoek toe te staan of te weigeren. Ook indien u nu toestemming geeft, kunt u te allen tijde zonder opgave van reden deze weer intrekken.

Ondertekening toestemmingsverklaring
Als u besluit om mee te werken aan dit onderzoek dan zullen wij u vragen een formulier te ondertekenen. Hiermee bevestigt u uw voornemen om aan dit onderzoek mee te werken. U blijft de vrijheid behouden om zonder opgave van redenen uw medewerking te stoppen.

Voor verder informatie
Mocht u na het lezen van deze brief nog nadere informatie willen ontvangen, of komen er voor of tijdens het onderzoek nog vragen bij u op, dan kunt u contact opnemen met Max Slutter via 06-83128272 / m.w.j.slutter@student.utwente.nl, of Jan-Willem van 't Klooster, 0880875727 / j.vantklooster@rrd.nl

C-2: Consent Form

Titel van het onderzoek

"Creating a feedback system for home exercises for older adults with the Myo"

Onderzoeker

Max Slutter

Ik bevestig dat ik de informatiebrief heb gelezen en ik begrijp de informatie. Ik heb voldoende tijd gehad om over mijn deelname na te denken en ik ben in de gelegenheid geweest om vragen te stellen. Deze vragen zijn naar tevredenheid beantwoord.
Ik geef toestemming voor deelname aan bovengenoemd medisch-wetenschappelijk onderzoek. Ik weet dat mijn deelname geheel vrijwillig is en dat ik mijn toestemming op ieder moment kan intrekken zonder dat ik daarvoor een reden hoef op te geven.
Ik geef toestemming dat bevoegde personen van Roessingh Research and Development en bevoegde autoriteiten inzage kunnen krijgen in mijn onderzoeksgegevens.
Ik geef toestemming om de gegevens te verwerken voor de doeleinden zoals beschreven in de informatiebrief.

Naam proefpersoon:

Handtekening: Datum:

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Naam onderzoeker:

Handtekening: Datum:

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Appendix D: Transcription Interviews / Brainstorm Sessions

D-1: Physiotherapist

P: Physiotherapist
I: Interviewer

Questions
General:

Do you often work with elderly patients, in general?	
P	"Yes I work often with elderly patients."
I	"Also with elderly patients that do the exercises for fitness and do not have a decease?"
P	"The patient will always come with a reason. If people only come to get fitter, they will be treated at a different department within Marl, namely medical fitness. The patients pay their own bills. This changes when patients is in therapy, then they really "got" something. For example pain in the shoulders or back, stroke or parkinson disease."
I	"However in general you do have experience with elderly patients?"
P	"Yes, however all patients have to recover from or need treatment for something."
What does the normal treatment process for these elderly patients look like?	
P	"First, as a physio you have to discover the problem. What are the problem of the patients in their daily life. Most important is connecting a goal to the treatment. For example a patient really wants to do the four-day hike, or wants to climb a mountain etc. I am trying to connect these kind of concrete goals to the therapy, since then the patients have more of a goal to work. This often motivates the patients. After finding a goal, the patient's disabilities that prevent the patient from achieving the goal, are defined. This can be low muscle strength or a lack of moving-ability.
What kind of exercises do you normally propose to those elderly patients?	
P	"It depends. For example when patients have back pain, then I will propose exercises that strengthen their back muscles. Or when patients have mobility issues, I will propose exercises that improve their mobility. So it depends on the patient's problem, what kind of exercise I propose to the patients."

Feedback:

How can you see if a patient is executing the exercise correctly?	
P	"Checking. So when I propose an exercise to the patient to do at home, I will ask them what kind of exercises they did the next time we see each other. And when the patient does not it know anymore, then this is an indication that the patient did not do the exercises. If they know what kind of exercises they did, but they do not execute the exercises properly, I will correct them."
I	"How can you see if somebody is executing the exercises properly?"

P	"Well.. I proposed the exercises to them, so I will see immediately, if they execute the exercise in front of me, if they execute it correctly or not. For example the patient has to first tighten their muscles before doing something else. Or their knees are not in the correct position. Can be anything."
I	"Allright. This project is mostly focussed on exercises that involve arm-movement and arm-muscles. Are there specific patterns that a patient has to do for these kind of exercises?"
P	"Important is, when strengthen the muscles you have to exhale and when relaxing again you have inhale. What I also do is handing over a piece of paper to the patient that explains the exercises. This includes drawings and text. This is so they know how to execute the exercises."
Is it possible for a patient to over-exercise? If yes, how can you recognize this?	
P	"Yes that is possible. You can see this from the reaction of the body of the patient. When patients do an exercise often, it can happen that the pain gets worse. It then can be possible that they did not execute the exercise correctly or it can be possible that they executed this exercise way too often. For that reason, I always say to the patient how often they have to execute a certain exercise. For example you have execute this exercise fifteen times and you have to take a break."
I	"And if they follow your instructions, then in principle nothing can go wrong?"
P	"No, however of course it can be possible that I my estimation is incorrectly. Then the patients will say that they experience pain during the execution of the exercises, the next time we see each other. And then I would delete this exercise for now and we have to see if some other exercise would be better. It can happen that a physiotherapist estimates things incorrectly."
How do you know if the patient is improving?	
P	"Subjectively, by the story that the patient tells. The patient can say things like: I feel less pain or I feel better. Objectively, by recognizing that a patient could in the beginning only walk 100 metres and he or she can now walk 300 metres. Or could in the beginning only cycle for 5 minutes and now for 30 minutes. Sometimes you can also measure the power of a muscle. For example in the beginning a patient could only push a weight of one kilo and it is now possible for the patient to push five kilos. You can also measure movement by looking at how the patient can bend its knee. So subjective and objective measurement moments."
What kind of feedback do you normally give to elderly patients, during the execution of the exercises?	
P	"This again depends on the patient. For some patients you need to be more strict, then you say things like you are doing this wrong. Where others need to be stimulated, so then you say 'well done, you're doing great, however you should improve this'. This is mostly the way to do it. First make a compliment and then afterwards tell the patient what to improve."
I	"So in that way the patient stays motivated?"
P	"Exactly. You have to make sure the patient stays motivated. At the moment you only tell the patients what they are doing wrong, the patients will get demotivated."
What kind of feedback, about the execution of the exercises, do you as a physio want to get from this project?	

P	"How often the exercise is executed. At the moment when you are working on building up the muscles-strength, especially when working with elderly patients, the maximum power' is very important. The maximum power' is a power that can only be executed once. So for example I am lifting a very heavy weight, that I can only lift once, then this the maximum power. This is something you can only do once. And especially for elderly patient this is useless. For elderly patients the amount of times the exercise is executed is more important. So using small weights and repeating the exercise often. Then you often use series of exercises, so for example a serie of fifteen times the same exercise. And the number of executions you are slowly going to increase. That is one. Second, the ROM range of motion is very important, especially for your project."
I	"Since a bigger range is better, right?"
P	"Yes, however it is also possible to go over a certain border. At Marl in the fitness centre, there are measurement equipments that show the range of motion. Then you, as a user, have to do three times an exercise and this measurement equipment can determine your range of motion. The equipment will determine both the speed and the range of motion, using LED lights. At the moment you go over the range of motion, the LEDs will turn red. This would be a nice method to show the range of movement, since this equipment also shows the user how far he or she can go."
I	"Does this range of motion stay the same for each individual? Or does it for example, change every day?"
P	"At Marl each patient or sporter gets a certain SD card that they have to plug in the exercise machines every time they use it. This SD card contains the range of motion of this person. In this way the machines know this range of motion of the person. So the range of motion stays the same for each person."

Brainstorm

Interviewer explains how the brainstorm is going to be and then the brainstorm starts.	
P	"As a just explained, you could use the range of motion of patients. And I don't know if it is possible but you could make it a bit entertaining. For example a tennis game or anything."
I	"In my state-of-the art research, I discovered that the Nintendo Wii is often used in rehabilitation. Especially the tennis-game is often used."
P	"Yes and if it would then be possible to program it in certain way that the patient has to return the tennis ball fifteen times for example. Or you could make it a real match against a computer. If you want to make a trainings application, you should make sure that is has a repeating element. So for example the tennis game should not stop after two hits, but after fifteen."
I	"It does not necessarily have to be a tennis-match. It could also be a tennis-training. Where you get fifteen times the same ball thrown at you and you have to return it fifteen times."
P	"Yes then it should be a tennis-training. Also you should hit the ball with a certain precision, for the coordination. This is also important, besides muscles strength."
I	"So coordination is also very important?"

P	“Yes coordination is important. You can strengthen a muscle a lot, however if your coordination is not good. Then you have a very strong muscle, however you cannot do anything with it.”
I	“For this project there are also other exercises. Like moving your arms to the side. Can you think of something to give feedback on this exercise”.
P	“Then you have to give the patient a goal, like for example grabbing something or basketball. Or doing a smash when playing volleyball.”
I	“So, you think when adding a game-element to the exercises, it will make the exercises more entertaining to do?”
P	“Yes, most certainly.”
I	“Do you also think, that this will work better in the end? Have a more positive effect on the end-result?”
P	“Yes, since patients are more stimulated when the exercises are more fun to do. And when you can connect a certain goal to it, it would work even better, For example when somebody has played tennis for a long while when he or she was young and when using this game, the patient can experience if he or she is still able to play tennis.”
I	“You can connect every exercise to a certain game with a goal. For example one of exercises is simply squeezing a ball. For example catching something on the screen.”
P	“Yes, maybe catching could be difficult. Since squeezing is really something different that catching. Maybe squeezing out a sponge (so all the water comes out) or squeezing a ‘Fart-pillow’.
I	“That is fun. That each time you get something different in your hand on the screen, since you have to repeat this exercise three times.”
P	“Yes, like squeezing a hamburger, so everything falls out. Or kneading dough. Everything is possible.”
I	“That makes the exercises definitely more fun to do. And in the interview you said that patients have a goal, like cycling from one place to another.”
P	“Yes and the patients have to determine this goal themselves. They really have to think, what do I really want to do again. Some people cannot think of such a specific goal and they just want to feel fitter or be more mobile. But if they really have a specific goal, they will be more stimulated and the treatment would work better. Additionally you can adjust your training program nicely around this specific goal.”
I	“Yes that is what I was thinking as well. When patients have a certain goal, you can say to them after executing this exercise you will be this much closer to achieving your goal.”
P	“Yes exactly. That is what we do at Marl as well. A patient can receive a print of the improvement they made so far. You can indeed also tell them that they are relatively closer to achieving their goal.”
I	“Great. It may only be difficult to include every personal goal in such a program”.

P	"I can imagine that you offer the patients multiple options to select their goal. For example being able to cycle for a longer period of time, or walking for a longer period of time etc. These kind of general goals. Maybe the patients can choose from this. Then you make it a bit more personal than just doing the exercises. Personal messages help as well. Simply saying 'hello [name], it is nice to see you again', for example."
I	"When looking at the other exercise (moving arm to the side), you can make a flying simulation for example."
P	"And then see for what time they keep doing the exercise. I already imagine you crash into the land, when you cannot keep up with the exercise. That they almost reached the landing platform."
I	"Maybe that will discourage the patient. But do you think it would be necessary to give the patient a goal in the game? Like fully squeezing out the orange or you need to land on the platform. Or do you think that the effect of seeing something happening on the screen is already enough (so without a clear goal)?"
P	"I think having a goal will always work better and have a more positive effect. At the moment you have a goal in the exercises, patients will go a step further. When the patient is getting tired, he or she will keep doing the exercise to get to the goal. This results in more training effort and this will increase the satisfaction of the patient. This will motivate to get over a certain horder."
I	"For this exercise, the patients need to keep their arms spread for one second. So this can be a clear goal."
P	"Yes, but you have to make it visual. The patients need to keep their arms spread until they see the landing platform."

D-2: Developer Life

What is the Life project?
We first started with the Persilla project some years ago. Goal was to offer seniors that are not vulnerable the possibility to stay fit. The project is based on the Otaga fall preventions program. This often used in Australia and the United States and we made a digital version of it. Goal of this project was to discover if seniors were able to do these kind of exercises by themselves at home. Conclusion was that seniors are able to do this. Also handling the technology was fine for them.
Have you made certain (design) choices related to the users?
Not certainly. Of course it has been tested, however we did not change anything after.
There we no difficulties for the seniors with using a website?
Finding the website was difficult, however once on the website everything was fine.
What kind of feedback is already included in Life?
When users stop with an exercise, they get a question why they stopped training. They can type in the answer on the website. After finishing the training you also get questions. This time about more general (comments on total training). After the first three times of executing an exercise the user can decide to go to the next level. […] We discovered that the users like to perform the exercises together with the instruction video. So when the user have to perform the exercise ten times and the instruction video only explains / performs the exercises three times, the users will also only perform the exercises three times. So counting the amount of times the exercise is performed would be a nice addition.
How would you give feedback to the users?

Show them what the goal is, not only how often they performed the exercise, but also how close they are to reaching the amount of times the exercise should be executed. Be aware that if an exercise is meant to be executed fifteen times, that is also fine that the user executes it ten times. As long as they are improving it is fine. Furthermore keep the design simple, do not give them too much input, because then they can be distracted.
[Explains gamification example of squeezing sponge]
That is a really fun and nice idea. […] Be aware, that you do not give too much negative feedback, since this can discourage the users. Also age can make a difference. Users between 65 and 75 years old are mostly fitter and can handle computers better, where users above 75 years old have difficulties with both issues.
Are the exercises normally performed at home or in neighbourhood centres?
Mostly at home.

D-3: Older Adults

U1: Woman

U2: Man

What are your experiences with the Life Beweegportaal?	
U1	At first, we have to mention that we exercise for one hour every day. These are intensive exercises, therefore the Life Beweegportaal exercises were easy compared to our normal exercises. After a week we stopped using Life, because we felt it had no use for us.
So the exercises offered by Life were not intensive enough?	
U2	No. You must consider us as exceptions. Almost no one else in our age category will do this intensive exercises this often.
Image you are a senior that doesn't exercise, would Life then be useful?	
U1 & U2	Then I would say yes. For a lot people this could be very useful.
What kind of sports have you done?	
U1	Gymnastics. I like to do sports.
U2	Ice skating, cycling, soccer and gymnastics.
Do you think that other people in age category need a little push in the right direction before they start doing sports / exercises?	
U1	A little push? I think they need a big push in the right direction. Often other people in our age category are really surprised when we tell them that we exercise every day.
U2	In 2006 I had almost no stamina or endurance at all. Then I saw U1 exercising every day and I started doing that as well. I wanted to be as fit as U1 and this form of competition was a great motivation for me.
U1	I would like to say that when people just start doing exercises (and they are not used to exercise at all) you have to stimulate them by giving them a lot of compliments. However you also have to be strict for those people, to make sure that they keep doing their exercises. A physiotherapist could help those people with this. When those people experience that they feel fitter because of the performing the exercise, then the help of the physio can decrease.
U2	Do not expect too much of these people in the beginning. They have to build up slowly.
You also stimulate other people to do exercises, how do you exactly stimulate them?	
U2	Other people can see me as an example that it is possible for people in our age category to build up stamina and feel fitter by doing exercises.
U1	Also I keep asking people if they did there exercises. This reminds them to constantly do their exercises. Also I give a lot of compliments: "You are doing great" or "You are looking more in shape". I will say this if it is the truth. I will not lie to them. […] Also

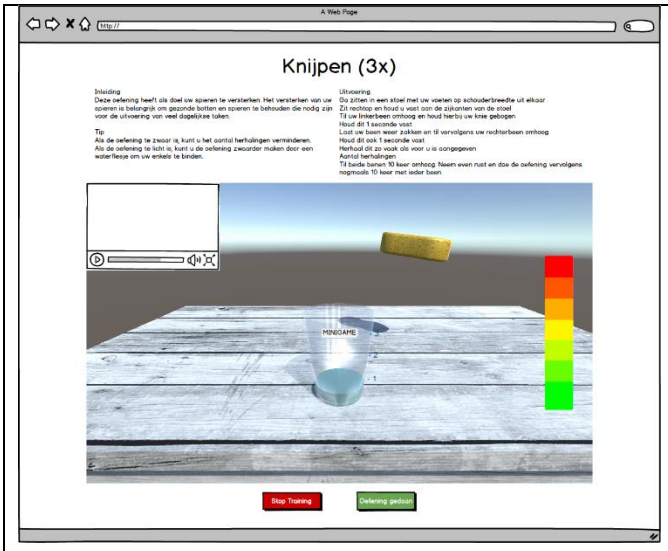
	I think it is important to do the exercises at a similar time every day. We prefer to do the exercises in the morning, however the time itself does not matter. Important is that it is the same time every day.
If people are not performing the exercises correctly, the system I am going to make has to tell them. How would do this?	
U1	I would like to see which muscles or parts of the body I have to focus on during the exercise. For example an exercise that involves a lot of arm movements, tell me what arm-muscles I am training and why this is important for me in my normal life. When people are performing an exercise wrong, there is not much you can do about it, since you are working from a screen.
[Interviewer shows Myo Armband to the users and explains the use of it]	
U1	Using this armband you could show graphs or blocks. And then stimulate then to get to the next block. […] Playing music during executing the exercises also stimulates me.
U2	When I see Tom Dumoulin cycling on TV, I will also cycle faster. You have to distract people when they perform exercises. Then you won't feel the pain.
U1	After a month the system should tell the user to step on a scale. Not in the beginning, but after a while. The people using Life surely have the goal to become fitter or to lose weight, therefore they sometimes have to check if they made progress.
Did you have problems finding the website?	
U1	We often use a computer, therefore it was easy for us to reach the website. But people that are not very familiar with computers can have difficulties. A message on the screen that directs to the Life program when people click on it and a password that is used once to login will make it easier for people to start. […] I was a gymnastic teacher once and people got motivated by me because they could see I was enjoying it. Also constructive criticism works very well. Do not be too strict, however tell them when they execute the exercises wrong. […] Sometimes the woman in the instruction videos only executed the exercise two times, where we had to execute the exercise five times. It would be better if the woman in the instruction videos also executes the exercise five times.
[Explains idea about gamification (squeezing sponge)]	
U2	That will work stimulated. When you get half a litre of water out of sponge and you want to get every water drop out of sponge, that can work stimulating. That is a very efficient example you just said.
U1	I also think this can work. When people see visual result of their efforts, then I think they get stimulated. Then want to do more effort, I think. That is a really nice and fun idea.
U2	These kind of ideas, that can stimulate people a lot.
Do you think I have to approach men and women differently?	
U1	Not in the beginning. Maybe later you can separate the amount of effort that they have to do.

U3: Man (68)
U4: Man (70)

What are your experiences with the Life Beweegportaal?	
U3	First of all I want to announce that of us are doing sports already. We go to the gym three times a week. Therefore when we saw the Life Beweegportaal we were both wondering if this program was designed for us. However after a while (when we were able to choose the level of difficulty), we both experienced that the exercises were getting quiet tough. Also there were exercises that were very useful and we did not execute these exercises in the gym. And we can imagine that this program can be very useful for people that do not exercise regularly. Warming was not very useful, we expected to have to work-out a bit more. Also it would be nice if necessary tools

	related to the exercises are announced in advance. Performing the exercises with others could work stimulating. Finding the website was difficult. Only the second time we totally understood the website. When performing the exercises while watching the instruction videos our tempo and frequency were good, therefore the instruction videos should have the same frequency as the amount of time I have to perform the exercises.
So the exercises offered by Life were not intensive enough?	
U3	Yes this was not intensive enough for me.
Did you have the feeling that you lacked feedback while performing the exercises?	
U3	Sometimes the program told me I had to exercise more often. For example the system reminded me when to exercise three times a week when I only did this two times a week. [..] The movement done besides the exercises is not taken into account. When I work in the garden for example (related to step-counters used before for Life). This is not fair. Life also wants to improve the social life of seniors. Therefore it should be possible to also enter this in the system. At the moment this is not included.
Suppose an user is not performing the exercises correctly, how should I give this kind of feedback?	
U3	At least do not punish them. Simply point out what they did wrong. You have to say it when the exercise is not performed correctly. […] I did not perform the exercises at the same time every day.
Would it be nice if the system reminded you to do the exercises?	
U3	Yes that would be nice, however then I would want to be able to decide when I want to perform the exercises. I would like to enter a time that suits me into the system and that the system reminds me at this time to do the exercises.
Did you enjoy performing the exercises?	
U3	Once I started performing the exercises, it was no problem. Some exercises were better than others. Mostly the warming felt unnecessary. And the warming-up was the same as the cooling-down, which felt conflicting.
What changes would you make to the Life Beweegportaal?	
U3	Inform the users what objects or tools they need before they start performing the exercises. The information did sometimes not fit on one page. And make it possible to enter your social and outside activity. And a reminder to do your exercises would also be nice. [..] If your improvement could be measured, that could work stimulating.
How would you give feedback to the user?	
U3	You could use a red line. The better the performance of the user the further he is located on the line. Or the use of blocks, where more blocks mean more effort.
[U4 joins the conversation and the interviewer and U3 explain him what was discussed beforehand.]	
U4	That is a nice and useful idea. Then you see the improvements you have made.

Appendix E: Design Sketches



Design 1

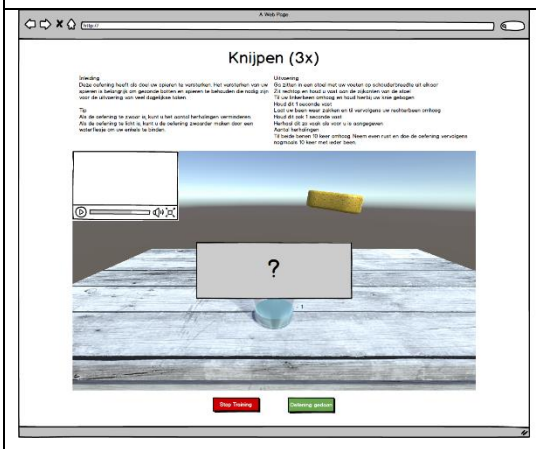
Design 1 consists of one webpage, where from top to bottom the header, instruction text, window combining instruction video and minigame and the navigation buttons are shown. Design 1 also has an live effortbar, showing the amount of effort the older adult is putting into the exercise.

Pros

- Window for minigame is large
- Live effortbar
- Possible to read instruction text while performing the exercise
- All fits on one webpage

Cons

- Minigame can distract older adult, causing the older adult not to read the instruction text
- Instruction video, minigame and effortbar in one window can be too much information for the older adult



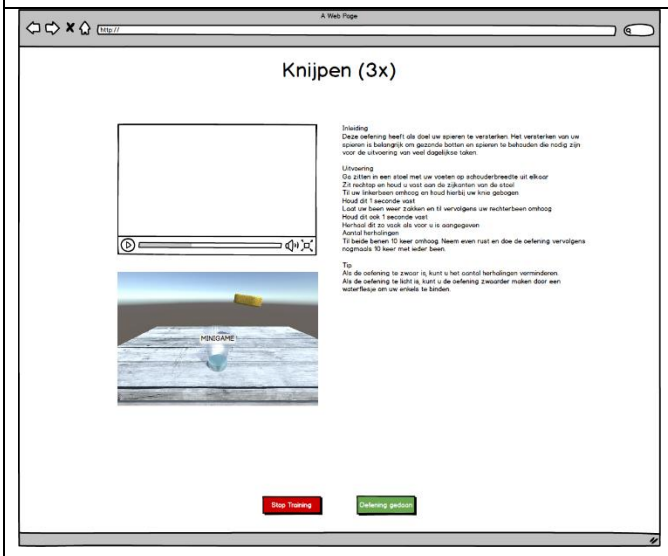
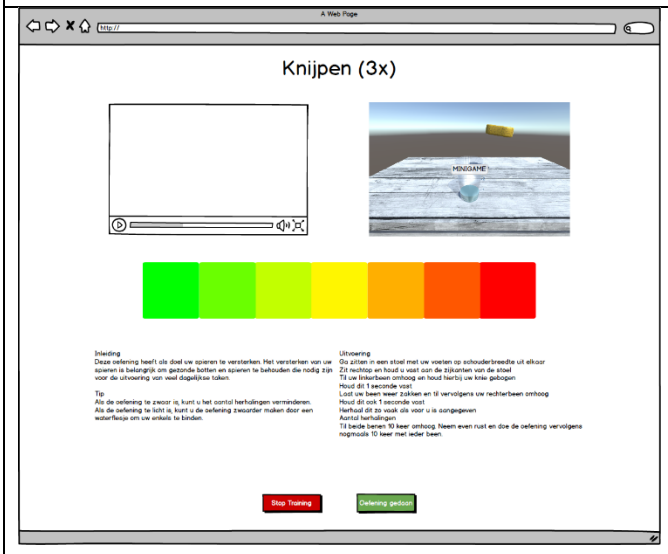
Design 2

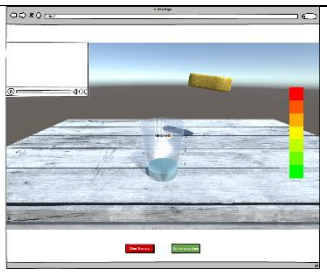
Design 2 consists of one webpage, where from top to bottom the header, instruction text, window combining instruction video and minigame and the navigation buttons are shown. Design 2 uses a pop-up message (?) to give feedback to the user. The given feedback can be in the form of an effortbar (when older adult is not putting in enough effort), timer (when user has to do something for a certain time), textual feedback or an animation (showing the older adult how to perform the exercise).

Pros

- Window for minigame is large
- Pop-up message will get attention from the user
- Possible to read instruction text while performing the exercise
- All fits on one webpage

Cons

	▪ Minigame can distract older adult, causing the older adult not to read the instruction text ▪ No live effortbar ▪ Pop-up message can confuse older adult
	**Design 3** Design 3 consists of one webpage, where on top the header, at the bottom the navigation buttons and from left to right, the instruction video, minigame and the instruction text are shown. **Pros** ▪ Very similar to current Life webpage design ▪ Possible to read instruction text while performing the exercise ▪ All fits on one webpage **Cons** ▪ Window for minigame is small ▪ No live effortbar ▪ Instruction video and minigame are not in the same window
	**Design 4** Design 4 consists of one webpage, where from top to bottom the header, the instruction video and minigame, the effortbar, the instruction text and the navigation buttons are shown. Design 4 has a large effortbar displayed from left to right. **Pros** ▪ Live effortbar ▪ Effortbar very clearly visible ▪ Possible to read instruction text while performing the exercise ▪ All fits on one webpage **Cons** ▪ Instruction video, minigame and effortbar are above the instruction text, causing the older adult not to read the instruction text ▪ Window for minigame is small



Design 5

Design 5 consists of two webpages. On the first webpage from top to bottom, the header, the instruction text and the navigation buttons are shown. On the second webpage a window with the minigame, the instruction video, the effortbar and navigation buttons are maximized on the display.

Pros

- Live effortbar
- Window for minigame is very large
- The older adults will not skip the instruction text

Cons

- Consists of two webpages
- Second webpage has a lot of information to handle
- Not possible to read instruction text while performing the exercise

Appendix F: List of Requirements

1. User has to be able to perform the exercises together with the instruction video (Interview users 1, 2, 3, 4 and developer Life).
2. Show how close the users are to reaching the amount of times the exercise should be performed and keep track of the amount of times the exercise has been executed (Interview developer Life).
3. Show real-time effort put in by the user (Interview user 3 and 4).
4. User must always be able to stop the training. Then the system should stop the exercise (Analysis of Life project).
5. System should not force users to complete the total number of executions, as long as they make progress it is fine (Interview developer Life).
6. Mostly give positive feedback in the form of compliments (Interview user 1, 2, 3, 4, physiotherapist and developer Life).
7. Stay honest towards the user, tell if the exercises are not performed correctly (Interview user 1, 2, 3, 4).
8. Must be possible to read the instruction text, while performing the exercises (Analysis Life Project).
9. Show the progress the users have made every month (Interview user 1 and 2).
10. Make it possible to perform the exercises together with others (Interview user 3 and 4).
11. Keep design simple, not a lot of input for the user to handle (Interview developer Life).
12. Provide a clear instruction of the use of the Myo Armband to the user (Interview developer Life).
13. Remind users to do their exercises (Interview user 1, 2, 3 and 4).
14. Show what muscles to focus on for the exercise (Interview user 1 and 2).
15. Announce in advance what tools or objects are needed for the exercises (Interview user 3 and 4).
16. User has to be able to enter the time he or she wants to perform the exercises (Interview user 3 and 4).
17. In a later stage, separate the amount of effort men and women have to do (Interview user 1 and 2).
18. Movement done by the user outside of exercises should be registered as well (Interview user 3 and 4).
19. Make it possible for the user to also enter their social activities into the systems (Interview user 3 and 4).
20. Warming up should be more intensive than it currently is (Interview user 1, 2, 3 and 4).
21. A calibration step should be added before loading the actual minigame, to make sure the performance of the exercises is measured correctly at any case (Functional system architecture).
22. The exercise should be performed sufficiently for the system to count it (Functional system architecture).
23. The instructions on how to wear the Myo should be before the warming-up, to make sure the Myo is warmed-up while performing the exercises (Activity Diagram).
24. Only display feedback messages after performing an exercise insufficiently for three times in a row (Functional system architecture).
25. System must not consists any bugs, negatively influencing the user experience (Evaluation).

26. System should have much explanatory text, on what is happening and what will happen in the game (Evaluation).
27. System should explain the link between the minigame and the result scene to the user (Evaluation).
28. System could automatically play the instruction video (Evaluation).
29. Effortbar could be more clear / visible (Evaluation).

Appendix G: EMG Data Squeezing and Resting

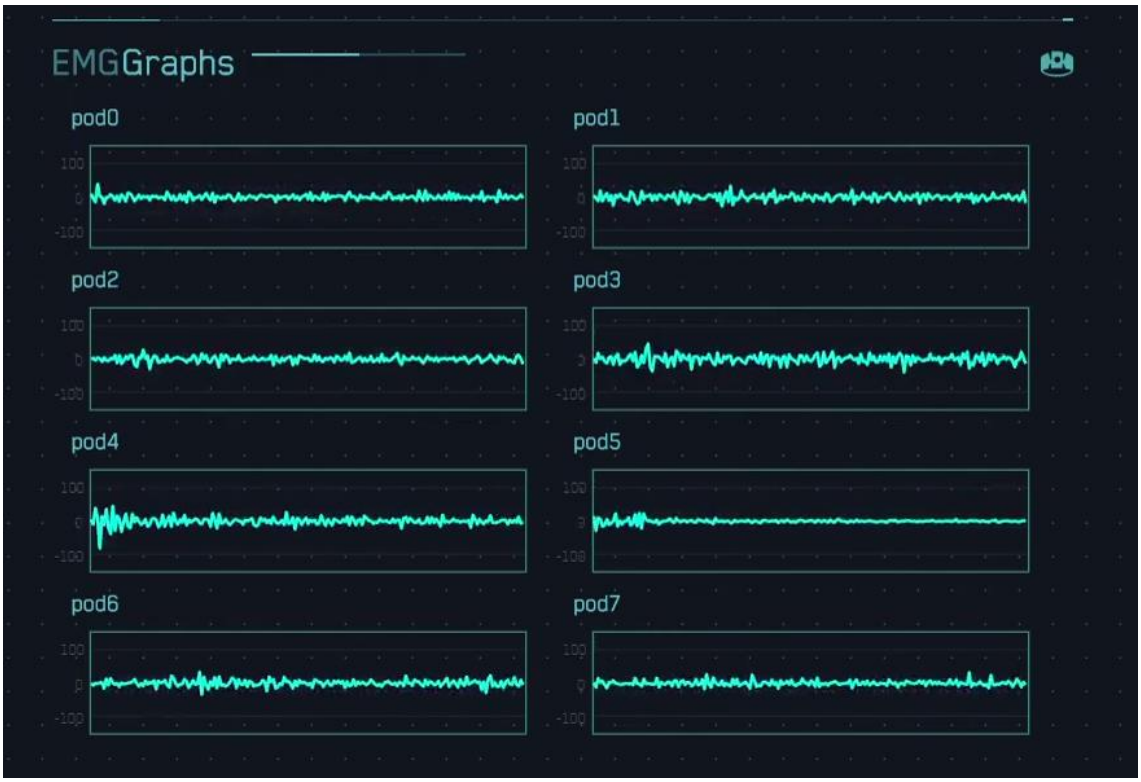


Figure G.1 EMG data of eight different sensors of Myo, at rest [65]

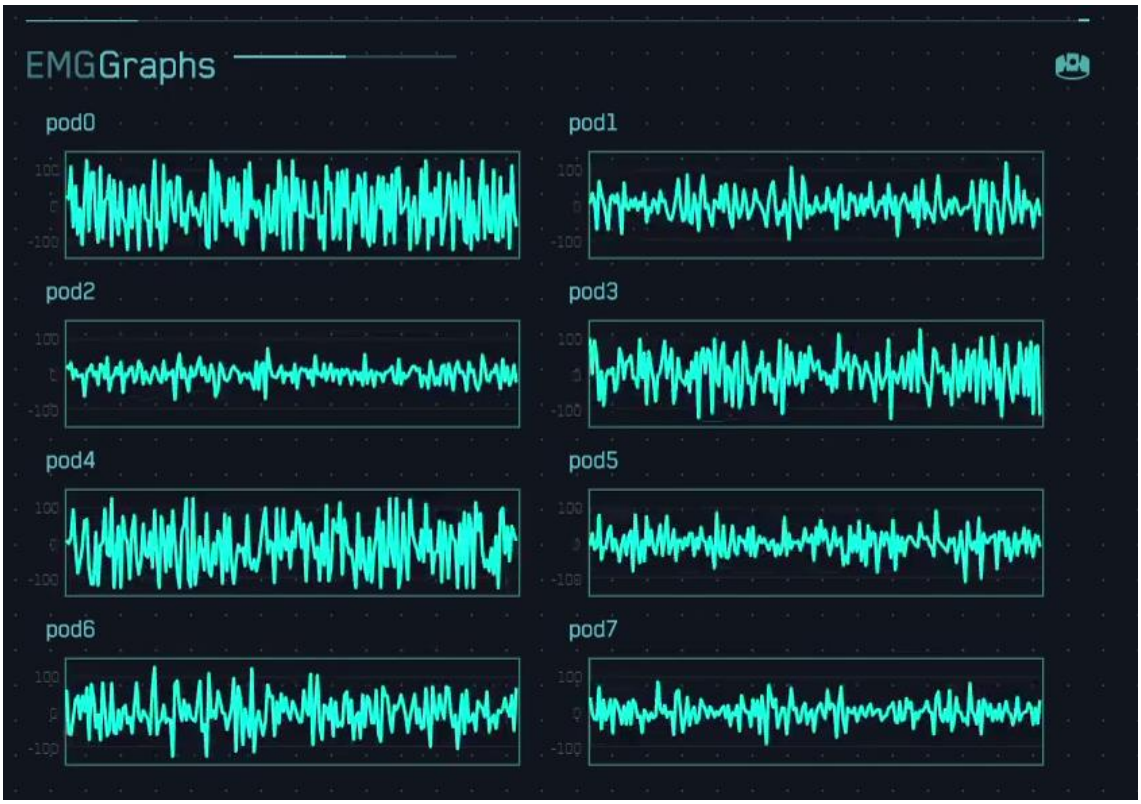


Figure G.2 EMG data of eight different sensors of Myo, when squeezing [65]

Appendix H: Images of minigame

Figure H.1 Look of minigame scene, displaying "Try to use more strength" feedback message

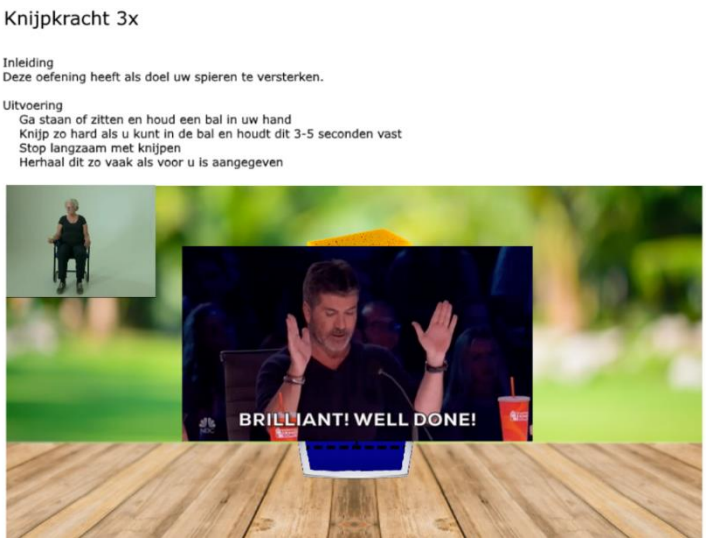


Figure H.2 Look of minigame scene, displaying positive feedback message

Appendix I: Informed Consent User Tests (Dutch)

I-1: Information Letter

Geachte heer/mevrouw,

Zojuist bent u gevraagd om deel te nemen aan een wetenschappelijk onderzoek. De uitkomsten van dit onderzoek zullen gebruikt worden voor het ontwikkelen van een feedback systeem voor een oefenprogramma waarmee senioren thuis oefeningen kunnen doen om fit te blijven.

Het gehele onderzoek zal ongeveer 20 minuten duren. Uw beslissing over uw deelname, moet u kunnen baseren op goede informatie van onze kant. Daarom ontvangt u deze schriftelijke informatie, die u rustig kunt (her)lezen. Binnenkort zal door de onderzoeker contact met u worden opgenomen en zal aan u worden gevraagd of u aan het onderzoek wilt deelnemen. Tijdens dit contact moment kunt u de vragen die u over het onderzoek heeft voorleggen.

Doel en achtergrond van het onderzoek
Het ontwikkelen van een feedback systeem voor een oefenprogramma waarmee senioren thuis oefeningen kunnen doen om fit te blijven. Dit systeem zal de bewegingen van de gebruiker herkennen en op basis van deze informatie de gebruiker feedback geven over hoe de oefening was uitgevoerd. De wijze van feedback geven zal getest worden tijdens het onderzoek.

Wat houdt deelname aan het onderzoek voor u in?
U zult een aantal keer een knijp oefening uitvoeren. Deze oefening houd in dat u simpelweg een aantal keer stevig in een bal zult moeten knijpen. Uw handelingen worden gedetecteerd door een Myo armband. Deze armband doet u om uw onderarm en deze kan dan uw spieractiviteit en armbewegingen detecteren. Het uitvoeren van de oefeningen zal ongeveer 10 minuten duren. Daarna zal de onderzoeker u een aantal vragen stellen over uw ervaringen. Dit zal ook ongeveer 10 minuten duren.

Wanneer u besluit mee te doen aan dit onderzoek vragen wij u om een toestemmingsformulier in te vullen en dit te voorzien van uw handtekening.

Wanneer komt u in aanmerking voor het onderzoek
U komt in aanmerking voor dit onderzoek als u boven de 65 jaar bent.

Mogelijke bijwerkingen / Risico's
Deelname aan dit onderzoek zal voor u geen risico's met zich meebrengen.

Mogelijke voordelen
Door deelname aan dit onderzoek draagt u bij aan de ontwikkeling van een oefensysteem waarmee thuis oefeningen kunnen doen. Hierdoor kunnen senioren fitter blijven, waardoor ze ook langer zelfstandig kunnen blijven leven.

Vertrouwelijkheid
Tijdens het onderzoek zullen er audio en video opnamen gemaakt worden van u. Deze opnames worden gebruikt de interactie tussen u en het systeem te kunnen analyseren.

De gegevens die gedurende het onderzoek over u verzameld worden, zullen vertrouwelijk behandeld worden volgens (inter)nationale regels en wetten, waaronder de Wet Bescherming Persoonsgegevens. De gegevens zullen zodanig gecodeerd worden dat ze niet tot u te herleiden

zijn. Uw gegevens worden anoniem in een elektronische database van Roessingh Research and Development (RRD) opgeslagen en alleen gebruikt t.b.v. dit onderzoek.

Vrijwillige deelname
U bent vrij om deelname aan dit onderzoek toe te staan of te weigeren. Ook indien u nu toestemming geeft, kunt u te allen tijde zonder opgave van reden deze weer intrekken.

Ondertekening toestemmingsverklaring
Als u besluit om mee te werken aan dit onderzoek dan zullen wij u vragen een formulier te ondertekenen. Hiermee bevestigt u uw voornemen om aan dit onderzoek mee te werken.
U blijft de vrijheid behouden om zonder opgave van redenen uw medewerking te stoppen.

Voor verder informatie
Mocht u na het lezen van deze brief nog nadere informatie willen ontvangen, of komen er voor of tijdens het onderzoek nog vragen bij u op, dan kunt u contact opnemen met Max Slutter via 06-83128272 / m.w.j.slutter@student.utwente.nl, of Jan-Willem van 't Klooster, 0880875727 / j.vantklooster@rrd.nl

I-2: Consent Form

Titel van het onderzoek
"Creating a feedback system for home exercises for older adults with the Myo"

Onderzoeker
Max Slutter

Ik bevestig dat ik de informatiebrief heb gelezen en ik begrijp de informatie. Ik heb voldoende tijd gehad om over mijn deelname na te denken en ik ben in de gelegenheid geweest om vragen te stellen. Deze vragen zijn naar tevredenheid beantwoord.

Ik geef toestemming voor deelname aan bovengenoemd medisch-wetenschappelijk onderzoek. Ik weet dat mijn deelname geheel vrijwillig is en dat ik mijn toestemming op ieder moment kan intrekken zonder dat ik daarvoor een reden hoef op te geven.

Ik geef toestemming dat bevoegde personen van Roessingh Research and Development en bevoegde autoriteiten inzage kunnen krijgen in mijn onderzoeksgegevens.

Ik geef toestemming om de gegevens te verwerken voor de doeleinden zoals beschreven in de informatiebrief.

Naam proefpersoon:

Handtekening: Datum:

--- ---

Naam onderzoeker:

Handtekening: Datum:

--- ---

Appendix J: Administrative Questions User Test (Dutch)

Administrative data Test person nr. [ ]

Geslacht	M / V
Leeftijd	.....
Doet u al regelmatig oefeningen? Zo ja, hoe vaak per week? Gebruikt u daar een oefenprogramma voor? Doet u de oefeningen samen met anderen?	
Heeft u al ervaringen met het Life programma?	JA / NEE
Welke technologische apparaten heeft u allemaal in huis?	
□ iPad / Tablet □ Smartphone □ Laptop □ Desktop Computer	□ Spel-computer □ Smart-TV □ Anders, namelijk .....
Hoeveel waarde hecht u aan lichamelijke oefening? (1-5)	.....
Speelt u vaak spelletjes? En zo ja, welke spelletjes? (Bordspellen / Apps)	

Appendix K: Questions of Questionnaire User Test (Dutch)

K-1: Questionnaire Questions System 1 (without Feedback / Game)

Systeem 1 (Zonder feedback / game)

Ik denk dat ik dit systeem graag vaak zou gebruiken.

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het systeem onnodig complex

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik dacht dat het systeem makkelijk te gebruiken was.

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik denk dat ik de hulp van een technisch persoon nodig heb om dit systeem te gebruiken.

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond de verschillende functies van het systeem erg goed geïntegreerd

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik dacht dat er te veel inconsistentie in dit systeem was

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik kan me goed voorstellen dat de meeste mensen dit systeem erg snel onder de knie hebben.

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het systeem erg lastig om te gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik voelde me zeer zelfverzekerd toen ik het systeem gebruikte

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik moest een hoop dingen leren voordat ik het systeem goed kon gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik werd gestimuleerd door het systeem

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik was onzeker of ik de oefening goed uitvoerde toen ik dit systeem gebruikte

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het leuk om met dit systeem te werken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

K-2: Questionnaire Questions System 2 (with Feedback / Game)

Systeem 2 (met feedback en game)

Ik denk dat ik dit systeem graag vaak zou gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het systeem onnodig complex

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik dacht dat het systeem makkelijk te gebruiken was

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik denk dat ik de hulp van een technisch persoon nodig heb om dit systeem te gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond de verschillende functies van het systeem erg goed geïntegreerd

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik dacht dat er te veel inconsistentie in dit systeem was

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik kan me goed voorstellen dat de meeste mensen dit systeem erg snel onder de knie hebben

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het systeem erg lastig om te gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik voelde me zeer zelfverzekerd toen ik het systeem gebruikte

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik moest een hoop dingen leren voordat ik het systeem goed kon gebruiken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik werd gestimuleerd door het systeem

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik was onzeker of ik de oefening goed uitvoerde toen ik dit systeem gebruikte

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Ik vond het leuk om met dit systeem te werken

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Appendix L: Questions of Structured Interview User Test

Question Prototype with Feedback nr.

Deze vragen gaan alleen over het systeem met de feedback en de minigame.

Wat waren de beste aspecten van dit prototype en waarom?
Wat waren de mist goed aspecten van dit prototype en waarom?
Hoe vond u het om de Myo Armband om te hebben?
Hoe vond u de feedback die gegeven werd aan u?

Wat vond u van het spelletje? Wat voor effect had dit op u?
Wat zou u nog graag verbeterd zien worden aan het prototype?
Zou u dit product thuis willen gebruiken? Waarom wel / niet?
Heeft u nog laatste tips/ opmerkingen / verbeterpunten over de test, het prototype of de vragen?

Appendix M: Administrative Data Participants

Legend:

- **Nr:** Participant number
- **M/W:** Man / Woman
- **Age:** in years
- **Exercising**
  - **More than one time a week:** X = Yes, empty = No
  - **Using a program for performing exercises:** X = Yes, empty = No
  - **Performing exercises alone:** X = Yes, empty = No
- **Experience with Life program:** Y = Yes, N = No
- **Devices:** What technological devices does the participant have:
  - **IP** = iPad
  - **SP** = Smartphone
  - **LP** = Laptop
  - **ST** = Smart-TV
  - **DC** = Desktop Computer
- **How important is physical movement for the participant, according to the participants themselves:** Participants gave rating between 1 and 5
- **Playing Games Regularly**
  - **Board-games:** X = Yes, empty = No
  - **Computer Games / Apps:** X = Yes, empty = No

Nr	M/W	Age	Exercising			Experience with Life	Devices	Importance of physical movement (1-5)	Playing Game	
			More than 1x a week	Using program	Alone	Y/N			Board	Computer/ Apps
1	W	70				N	IP, SP, LP	2	X	
2	M	70	X		X	Y	IP, LP, ST	4	X	
3	W	67	X			N	IP, LP	5		X
4	W	82	X		X	N	IP, LP	5		X
5	W	75	X		X	Y	IP, DC	5	X	
6	M	76	X		X	Y	IP, DC	5	X	
7	M	71	X		X	N	IP, SP, DC	5	X	X
8	W	70	X			N	IP, SP	5		

Appendix N: Transcription Recordings

Test Person 1

Time	Happening
2:28	Starts performing squeeze exercises, using system 1 (without feedback).
2:32	Starts reading instruction text out loud.
2:48	Squeezes in ball with both hands.
2:59	Counts in her head and continues squeezing the ball with both hands.
3:24	Stops squeezing the ball and starts squeezing ball with right hand.
4:03	Starts squeezing the ball with the left hand.
4:16	Finished the exercise.
4:30	Starts performing squeeze exercise using system 2 (with feedback).
4:32	Reads text in game out loud and performs calibration step. Does not read the instruction text above the gameplay.
4:35	Spots the instruction text and starts reading it. Stops performing calibration step.
4:51	Performs calibration step and the game starts.
4:55	Listens to instruction video.
5:21	Starts squeezing the ball with the right hand.
5:36	Because of flaw in game, the game finishes after the test person only squeezes two times.
5:37	Laughs at "well done" message.
5:38	Is confused if she already performed the exercise three times.
5:42	Finished the exercise and sees results.

Time to complete the exercise using system 1: 1:52
Time to complete the exercise using system 2: 1:12

Test person 2

Time	Happening
4:11	Starts performing squeeze exercise, using system 2 (with feedback)
4:18	Reads instruction text out loud.
4:29	Starts squeezing in the ball before reading the text in the game play. Calibration step is done.
4:31	Is confused the game starts.
4:43	Starts squeezing in the ball.
4:53	Because of flaw in game, the game finishes after the test person only squeezes one time.
4:55	Result screen is shown. Test person keeps squeezing in the ball, to complete the exercise.
5:10	Finished the exercise.
5:16	Test person asks: "There is no further feedback. The fact that the results are displayed in this way means I performed the exercise correctly? Or what does this mean?"
5:39	Reads the feedback message (which says: "Well done, but try to use a bit more strength next time", and wonders if he can squeeze again and show his strength right now.
5:53	Test person wants to try system 2 again to see if he understands the system better this time.
6:00	Explains he does not fully understand the calibration step and that this calibration step should be explained a bit more.

6:25	Test person does not understand how he can derive his performance from the result screen.
6:59	"I do not understand the order of the effortbars. I cannot derive any information from this result screen."
7:39	Starts performing squeeze exercise using system 1 (without feedback).
8:19	Performs exercise three times with right hand.
8:36	"And what can I see right now? Because I can learn nothing from this. I cannot see if I succeeded or not."
9:01	Finishes exercise.

Time to complete the exercise using system 1: 1:22
Time to complete the exercise using system 2: 0:59

Test Person 3

Time	Happening
1:11	Starts performing squeeze exercise, using system 1 (without feedback).
1:16	Difficult to read the text.
1:39	Starts squeezing in the ball with the right hand.
2:19	Starts squeezing in the ball with the left hand.
2:40	Finishes the exercise.
3:08	Starts performing squeeze exercise, using system 2 (with feedback).
3:15	Performs calibration step.
3:23	Stands up.
3:34	Stops squeezing when explanation video says her to do this.
3:46	Because of flaw in game, the game finishes after the test person only squeezes two times.
3:56	Keeps performing exercise. Also squeezes the ball three times with the left hand (while the MYO armband is worn on the right arm).
4:11	Finishes the exercise.

Time to complete the exercise using system 1: 1:29
Time to complete the exercise using system 2: 1:03

Test person 4

Time	Happening
2:50	Starts performing squeeze exercise, using system 1 (without feedback).
2:55	Reads instruction text.
3:12	Starts squeezing in the ball with the right hand.
3:33	Starts squeezing in the ball with the left hand.
3:58	Finishes the exercise.
4:15	Starts performing squeeze exercise, using system 2 (with feedback).
4:19	Reads the text: "Squeeze with most power as possible" and squeezes with maximum power.
4:26	Calibration step failed and test person has to try again.
4:35	Researcher had to restart the system.
4:45	Calibration step succeeded.
5:08	Because of flaw in game, the game finishes after the test person only squeezes two times.
5:16	Finishes the exercise.

Time to complete the exercise using system 1: 1:08
Time to complete the exercise using system 2: 1:01

Test person 5

Time	Happening
2:15	Starts performing squeeze exercise, using system 2 (with feedback).
2:19	Performs calibration step.
2:24	Because of bug in game, the researcher has to restart the system.
2:36	Performs calibration step again.
2:58	Squeezes in the ball with the right hand.
3:05	The "Try to use more strength" message pops up. The test person reads this out loud. "The system thinks I am not strong enough".
3:10	Squeezes again in the ball.
3:26	"I squeeze and then I see a bucket getting filled with water, however I cannot know when I perform the exercise correctly or not. It says I do not use enough strength, however this will probably pop up every time. I difference in squeezing with more or less power is not really visible on the screen."
3:56	Finishes the exercise.
4:17	Starts performing squeeze exercise, using system 1 (without feedback).
4:22	"It does not do anything."
4:44	Finishes the exercise.

Time to complete the exercise using system 1: 0:27
Time to complete the exercise using system 2: 1:41

Test person 6

Time	Happening
20:10	Starts performing squeeze exercise, using system 2 (with feedback).
20:13	Performs calibration step.
20:39	Squeezes three times, using right hand.
20:40	"That's it?"
20:44	Squeezes again.
20:45	"That's it?"
20:46	Finishes the exercise.
21:07	Test person already has experience with original Life project (system 1), so this system is skipped.

Time to complete the exercise using system 1: No Data
Time to complete the exercise using system 2: 0:36

Test person 7

Time	Happening
2:39	Starts performing squeeze exercise, using system 1 (without feedback).
2:42	Reads instruction text carefully.
3:34	Squeezes three times in the ball, with the right hand.
4:21	Squeezes three times in the ball, with the left hand.
4:58	Finishes the exercise.
5:10	Starts performing squeeze exercise, using system 2 (with feedback).
5:12	Reads instruction text quickly.

5:18	Performs calibration step.
5:43	System crashes, researcher has to restart the system.
6:19	Performs calibration step again, this time it succeeds.
6:40	Squeezes with right hand in the ball.
6:55	Because of flaw in game, the game finishes after the test person only squeezes two times.
7:07	"It says 'perfectly done, keep this going'". Test persons laughs.
7:09	Finishes the exercise.

Time to complete the exercise using system 1: 2:19
Time to complete the exercise using system 2: 1:59

Test person 8

Time	Happening
0:51	Starts performing squeeze exercise, using system 1 (without feedback).
0:53	Reads instruction text carefully.
1:04	Stands up.
1:08	Squeezes very hard in the ball with the right hand. Instead of stretching the arm in front of the body, she holds her arm next to her body.
2:21	Checks again how often the exercise should be performed.
2:34	Squeezes three times with the left hand.
3:05	Finishes the exercise.
3:15	Starts performing squeeze exercise, using system 2 (with feedback).
3:30	Reads instruction text again.
3:38	"It is almost the same, right?"
3:41	Performs calibration step.
3:47	Stands up. Still keeps squeezing the ball.
3:55	Because of flaw in game, the game finishes after the test person only squeezes two times.
4:02	Keeps performing the exercise, while the result screen is shown.
4:29	Finishes the exercise.

Time to complete the exercise using system 1: 2:14
Time to complete the exercise using system 2: 1:14

Appendix O: Calculation of SUS Ratings

Statement	System without feedback or game		System with feedback and game	
	Avg. Rating Participants	Corresponding SUS Rating	Avg. Rating Participants	Corresponding SUS Rating
I think that I would like to use this system frequently.	2,75	1,75	4	3
I found the system unnecessarily complex.	1,125	3,875	1,125	3,875
I thought the system was easy to use.	4,75	3,75	4,625	3,625
I think that I would need the support of a technical person to be able to use this system.	1,375	3,625	1,375	3,625
I found the various functions in this system were well integrated.	3,625	2,625	4,375	3,375
I thought there was too much inconsistency in this system.	2,25	2,75	2	3
I would imagine that most people would learn to use this system very quickly.	4,875	3,875	4,875	3,875
I found the system very cumbersome to use.	1	4	1,125	3,875
I felt very confident using the system.	4,75	3,75	4,75	3,75
I needed to learn a lot of things before I could get going with this system.	1,25	3,75	1,25	3,75
Resulting SUS Rating		84,375		89,375

Appendix P: Structured Interview Results

Best aspects of system:

- "Nice game. Muscle strength was needed to squeeze the sponge. It is possible to vary with the minigame (for example turn the top of a bottle). This would be fun exercises".
- "It is visible what I am doing on the screen. There is a competition element in the game, which works stimulating. The bucket and sponge were a lot of fun."
- "It visualises the strength and the results were visible."
- "Directly visible result of your actions, which stimulates."
- "It was simple. It shows the result."

Worst aspects of system:

- "When someone does not like working with computer, this system will not work. Also privacy is very important, I do not want my performance to be shared with anyone."
- "The order in which the performance were shown. The result screen confused me. The live effortbar was not visible during the gameplay."
- "There was only one exercise."
- "Game did not respond to my actions."

What was it like to wear the Myo Armband:

- "Not annoying."
- "Fine, it was no problem."
- "The armband and it vibrating were not disturbing."
- "Absolutely no problem."
- "No problem".
- "Does not bother me."
- "Not annoying at all."
- "No problem."

How was the feedback towards the user:

- "Also fun, no angry smileys. It is good that no negative feedback was given to me. Older adults already know that they have to exercise, so there is no need to punish them when they do not exercise or perform the exercises incorrectly. They already get punished, because they do not exercise."
- "There was not a lot of feedback, except for the images. On the result screen there should be text explaining what is shown. At the moment I did not understand the results."
- "The strength I put in was shown."
- "Good. Although I already knew how to perform the exercise."
- "Good. Although the first time I had to search for the effortbar."
- "Good. It was a direct reaction on my actions."

What was the game like and what the effect of the game on the participant:

- "The bucket and sponge were fun. There are a lot of variations possible. I would like to have five different games every two days."
- "Fun. However the goal / aim of the exercise was not described."
- "Funny, because every time there was more water in the bucket. This however had no effect on me."

- "It was nice. It made me happy. The raising water stimulated me to use more strength / power."
- "It was a little challenging. It also made me think of washing the windows, which is not fun to do. Furthermore it was nice that I could squeeze in the ball."
- "It was a nice game."
- "It did not have much effect. It is nicer to see the game than to see nothing."

Improvements for system:

- "Add different levels. If the older adult is performing good, he or she could go to the next level. This would give the idea that I can get to a next level and therefore improve."
- "System should invite user more to read the text and system should know that reading the text does take some time. The pace in which the exercises should be performed should be made more clear. At last, the results should be made more clear, by making the connection between the game and the results more clear."
- "Add more different exercises. Would be fun if there were also games for neck and back related exercises."
- "Add more exercises and the exercises were not challenging enough. I am curious to what other games you could think of."
- "Use a firmer ball."

Would participants like to use this system at home:

- "Yes. But I would like to use it alone, not together with others. However it must be possible to use the system with others, because many people would like that."
- "Yes, if the aim of the exercise is more clear and if the effect of a certain exercise on certain complaints is described."
- "If I had this at home I would use it every day."
- "Yes. Especially if there were exercises meant for neck and back complaints."
- "No. I am not the kind of person for using exercise programs."
- "Yes maybe I would. For non-sportive people this would be very useful."
- "Not yet."
- "No, maybe if I suffer from something."

Last comments / tips:

- "Add more exercises. Make sure it is offline, for privacy reasons. Make a game for every exercise. I exercise more often when I could play these kind of games."
- "The text and rating buttons in the online questionnaire were too far separated from each other."
- "Offer different size balls. Besides that, I was satisfied with everything."
- "You could use the ball for various exercises. Using the ball challenges you to put in a lot of power."
- "Offer two different balls. Different in size and different in firmness."
- "It was a very simple test, it do not understand the purpose of it."