
MIRRORCLE
watch and learn

Theme	Smart Health
Project	Smart Moves
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Year	B 2.1
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Client	University of Hasselt - dr. Annick Timmermans

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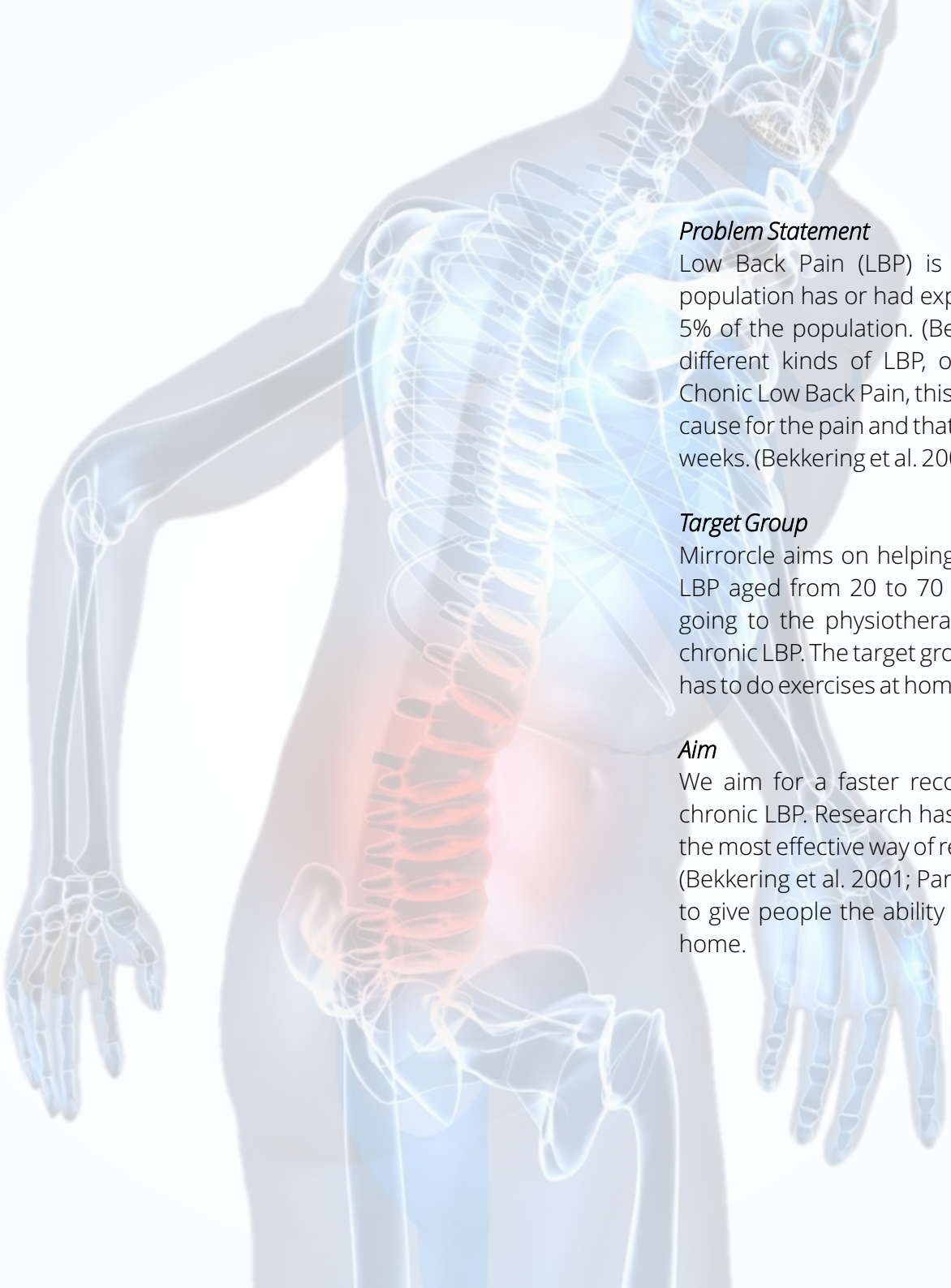
Introduction

We, Anne Wil Burghoorn, Emma Dhaeze, Jasper Faber and Jelle wories are a group of 4 students of the Technical University of Eindhoven from the project Smart Moves. Our project was about: Designing a product that will help people suffering from chronic aspecific low back pain. We chose to dive into the wearable proprioception aspect of this theme.

We wanted to create a product that could support the people with low back pain with performing their exercises at home. Therefore, we designed: The Mirrorcle. The objective, consisting and a detailed concept description can be read in the following pages.

Furthermore, this report contains a step by step analysis of the complete design procedure and the research behind the concept. All the research results, brainstorm out- comes, design alternations and received feedback will be discussed.



Objective

Problem Statement

Low Back Pain (LBP) is pain that 60 to 90% of the population has or had experienced, yearly this is around 5% of the population. (Bekkering et al. 2001) There are different kinds of LBP, our focus will be on Aspecific Chonic Low Back Pain, this means that there is no specific cause for the pain and that the pain lasts for more than 12 weeks. (Bekkering et al. 2001)

Target Group

Mirrorcle aims on helping people with aspecific chronic LBP aged from 20 to 70 years old. The target group is going to the physiotherapist to recover from aspecific chronic LBP. The target group is doing exercises there and has to do exercises at home as well.

Aim

We aim for a faster recovery of people with aspecific chronic LBP. Research has shown that doing exercises is the most effective way of revalidation for the target group. (Bekkering et al. 2001; Park et al. 2012) Therefore we aim to give people the ability to do their exercises better at home.

Concept

The Mirrorcle is an interactive mirror which helps you perform the exercises you got from the physiotherapist at home. After you paid your first visit at the physiotherapist you get the mirror home with you. The physiotherapist is provided with an editor which he can use to adapt exercises according to the patients needs. These exercises will be uploaded to a cloud which is connected to the mirror.

The design of the mirror is comparable to a that of a roll-up banner. This makes the mirror light and wieldy so it can easily be taken home and doesn't occupy any space at the living room.

The interface of the mirror is divided into 2 parts. The exercise part, and the progress part.
In the exercise part, the exercises from the cloud can be seen and executed. In the progress part, a overview can be seen concerning the progress of each exercise. The progress data from these exercises are uploaded to the cloud. The physiotherapist has acces to this data. In this way the physiotherapist can adapt the exercises in such a way that they match the current rehabilitation state of the patient. In addition the patient becomes motivated in performing the exercises because he or she knows an authority (the physiotherapist) is watching with them.

The mirrorcle isn't a normal mirror. It makes use of a one-way mirror. In this way it's possible to see yourself in the mirror, but also see light projections that are coming from behind. By using a short-throw beamer the interface is projected onto the mirror. A kinect on top of the mirror tracks the position of the spine of the user. This system works together to provide audiovisual feedback in order to support the patient in maintaining a correct posture.

We made a Scenario of use we made of this concept which you can see in appendix 1.

Research

At the beginning of our project we did a literature research in many different articles. We did not know anything about Chronic A-specific Low Back Pain and wanted to get more into depth knowledge before we should start designing and brainstorming on the project. To structure our research we stated four research topics:

1) Low Back Pain (LBP)
2) The target group (people with LBP)
3) Effective ways of revalidation
4) Extrinsic feedback

For each of the topics we made an overview of all the most important subjects and grouped the related subjects together. This was done so we could easily use the research in our brainstorm sessions. Below, summaries of the most relevant aspects we got out of the research are discussed. For the images of our overviews please see appendices 2.1, 2.2, 2.3, 2.4.

Low Back Pain (LBP)

General information

"Low back pain (LBP) is associated with dysfunction and local muscle systems, feedback and feedforward postural control mechanisms." (Ribeiro et al. 2011)

Aspecific LBP is pain without a specific cause, so there is no compression of a nerve root, a trauma, an inflammation or a tumor, this is the case for around 90% of the people with LBP (Bekkering et al. 2001). There are different types of LBP namely, acute (0 - 6 weeks), subacute (7 - 12 weeks) and chronic (>12 weeks). For (sub-)acute LBP exercises are not meaningful, though for chronic LBP exercises are.

Cause

LBP is the result of an interaction between biological, psychological and social factors (Bekkering et al. 2001). Psychological aspects that can play a role are: depression, anxiety, and low self-efficacy, which negatively affect quality of life (Park et al. 2013). Where depression is the most common sympton of Chronic LBP.

There is also a difference between men and women, because women are more affected by psychosocial factors and men are more affected by the physical strain of work (Taieb-Maimon et al. 2012).

Processes

There are two processes of LBP (Bekkering et al. 2001):

Normal process: in time activities and participation increase gradually. For most of the patients the complains decline during those activities, no physiotherapist is needed here.

Abnormal process: limitations and participation problems remain the same over time or increase, also increase of complains. We call a process abnormal if there is no increase of activities in three weeks. In this case a physiotherapist is needed.

Research

The target group (people with LBP)

Population

60 to 90% of the population will experience LBP once in their life, yearly this is around 5% of the population (Bekkering et al. 2001). The first episode of LBP mostly starts in the age of 20 to 55.

Characteristics people with LBP

There are different people with LBP who have different ways of dealing with complains (Bekkering et al. 2001). The way people deal with complains are determined by the characteristics of that person. Generally there are two ways of dealing with complains:

Adequate way: a person is capable of adjusting the load (activities and tasks) to the load capacity of the back. People strive for an active lifestyle or look for distraction when they feel pain.

Inadequate way: due to the LBP people move less, avoid certain acitivities or rest too much to reduce the pain.

Activities

Most of the time the mean activity level of patients with CLBP (chronic LBP) does not differ from that of healthy individuals. Though the distribution of activities over the day is different, patients with CLBP have higher activity levels in the morning and lower activity levels in the evening, if you compare them to the healthy individuals mentioned above (Dekker - van Weering et al. 2012).

Future

"A focus on (self-) management of physical condition will become increasingly important in future chronic care and in the support of the healthy elderly population." (Op den Akker et al. 2012)

Effective ways of revalidation

There are several aspects that are important when revalidating from aspecific chronic low back pain. These aspects will be discussed below.

Posture

Posture correction is an important component in the treatment of patients with low back pain. The starting point for an ideal posture is the preservation of the three curves (lumbale lordose, thoracale kyfose, cervicale lordose) (Matheve 2012).

There are some facilitation capabilities to learn a correct posture (Matheve 2012):

- Manual guidance
- Tactile feedback through patient
- Visual feedback
- Tape

Exercise

For chronic LBP exercises are a meaningful treatment (Bekkering et al. 2001; Park et al. 2012) but "repetitive exercise for strengthening has limitations in increasing motivation for exercise programs and for treating

psychosocial symptoms" (Park et al. 2012).

An exercise program starts with the determination of a baseline, this is the average of the current activity level (Bekkering et al. 2001). The program contains a build-up of activities in duration, frequency and intensity. The person has to practice at home and has to track his/her progress him/herself in a chart at home. When a person is scared to move, the initial level of the program has to be lower and the steps should be smaller. Besides if a patient is not familiar with an exercise or incapable of performing it, program feedback should be provided (Ribeiro et al. 2011).

"Compared to usual care, exercise therapy improved post-treatment pain intensity and disability, and long-term function. Behavioural treatment was found to be effective in reducing pain intensity at short-term follow-up compared to no treatment/waiting list controls. Finally, multidisciplinary treatment was found to reduce pain intensity and disability at short-term follow-up compared to no treatment/waiting list controls." (van Middelkoop et al. 2011)

Gaming

Gaming components (like Nintendo Wii sports) could encourage participants with doing their exercises, because this makes them more enjoyable. Besides gaming requires mental and cognitive function, this may be a possibile reason for improvement in the mental health composite (Park et al. 2012).

Extrinsic feedback

General

Extrinsic feedback is information provided from an external source (another person or instrument) (Ribeiro et al. 2010; Ribeiro et al. 2011). The feedback can be provided in two forms, namely knowledge of results, this is about informing the outcome of achieving the goal or target of a determined task. And the knowledge of performance which is about informing about the characteristics of a performed movement or task (Ribeiro et al. 2010).

With the use of extrinsic feedback, it is possible to enhance: the "central nervous system facilitation of optimal sensory-motor loops" (Ribeiro et al. 2010), the "patient awareness, confidence and volitional control over specific physiological processes" (Ribeiro et al. 2010), "motivation" (Ribeiro et al. 2010) and "reinforcement for repetition of successful actions" (Ribeiro et al. 2010).

The more novel the task and less experienced the participant; the more useful extrinsic feedback is likely to be (Ribeiro et al. 2010).

Different kinds of extrinsic feedback

In the research to feedback to stimulate patients with chronic low back pain was found that patients responded to both the encouraging and discouraging feedback

messages (Dekker- van Weering et al. 2012). Though when looking at the overall reaction on the encouraging and discouraging messages, the reaction on discouraging messages seems to be stronger than on the encouraging messages. It can be concluded that the personalized feedback messages have an additional value over the continuous visual feedback that patients receive during the day. (Ribeiro et al. 2010). Though we also found that visual information could increase patientns postural awareness (Ribeiro et al. 2011).

Two different forms of delivering extrinsic feedback are content and timing (Ribeiro et al. 2011). Where content refers to attributes of focus of intervention and timing refers to attributes related to when feedback is provided during motor training. It was found that concurrent and constant feedback should be avoided.

Involving care providers
"A system should provide feedback to both patients and care providers. In other words, such systems should provide continuous monitoring of health status, with the promise of coaching, or continuous motivational aid aimed at achieving behavioural change." (Op den akker et al. 2012)

Iteration 1

Meeting Physiotherapist Paul Truijens

After all the research we did, we still had some questions, especially about the treatment of people with LBP. Besides we wanted to see and hear about LBP from someone working in the field. To get other interesting insights as well. Therefore we planned a meeting with physiotherapist Paul Truijens. (fig. 1) The most important things we got out of these meeting were:

- The way of treatment differs per patient, the cause determines the way of treatment.
- The therapist lets people bend and stretch. He listens to their story and then he comes up with a treatment method and exercises.
- Removing the cause is difficult. Most people who suffer from lower back pain are sitting too much and for a long period of time. They have a passive lifestyle.
- When people experience many problems with their lower back they visit the therapist 2 times a week. After two weeks they only visit once a week. Then once per two weeks and then one per month.
- If you suffer from chronic lower back pain, pain is no indicator that something is wrong. Patients have to move although they feel pain. Movement will help them to recover even faster.

The conclusion of this meeting was the following. The exercises the patients get are very personalized. Each patient has pain on different places and therefore a different treatment is needed. Most chronic lower back pain is caused by lack of movement and sitting in a wrong position for too long. Promoting an active lifestyle is important, especially for the people who tend to have a passive lifestyle. People have to move, even if it hurts (this is the case for chronic lower back pain). Exercises help patients to reduce their symptoms. These exercises are given by the therapist.

fig. 1

Iteration 1

Ideation 1

After we did research on the topic of aspecific low back pain, we started the ideation phase. The first brainstorm we did was just a regular mindmap brainstorm where we would just write down everything that would came to mind when we thought of low back pain. This brainstorm was not very effective, because we got stuck at one moment and we could not connect a good idea to the words we wrote down. For the next day we prepared a brainstormsession in which we used different techniques. We got these techniques out of the book Thinkertoys (Michalko, 2006). Underneath you will find a list of the techniques we used and how they contributed to our project.
We started with some warming up exercises to get our brain clear from negative thoughts and to get in the mood of ideation.

Symbol
Each member of the group had to draw a symbol that represents creativity for them and had to explain why that was. This created a very relaxed atmosphere and helped us to think about creative things.

Space creature
As a follow up, warming up exercise each member had to draw a space creature. It could be anything. Most people will draw something that looks like something they already know. But the goal of this exercise was that we had to think out of the box, to go out of our comfort zone.

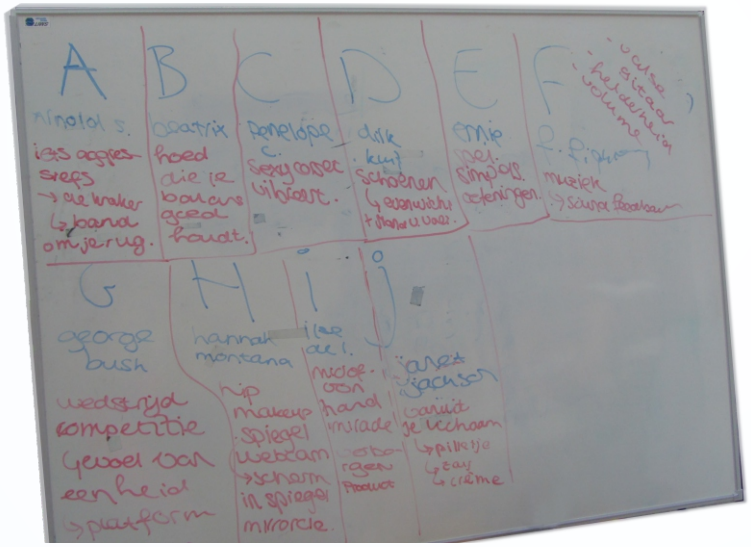
One + one = one (in a different way, but based on it)
This exercise is both individual and a group activity. First every member had to write down 10 random words. After everyone had done this each member summed up his/her words and we combined the words that formed good combinations. Unfortunately this exercise was not really interesting to do, but still it created a nice atmosphere which is good when you eventually want to come up with out of the box ideas.
After the warming up we actually started with brainstorming. We used 3 techniques which will be explained below.

Reverse assumptions
This technique gave us the opportunity to get rid of our premade assumptions about the subject and to turn them around into a new approach. So we wrote down our assumptions about a product that had to help people with low back pain. The problem was that we actually did not have very much premade assumptions and it just would not work for us this idea. The subject is to broad and too vague to use to apply this technique on.

Iteration 1

Taking a different perspective (fig. 2)
Using this technique we had to write down the alphabet and write down a famous person below each letter. Than we had to approach our subject from the point of view of the famous person and write down the aspect we thought the product should have if it was made for that person. We never thought that this would be an effective technique, but actually it turned out different. It was a very relaxed exercise and this created a flow of creativity.

fig. 2



Idea Box (fig. 3)
Using the idea box we had to set our challenge and to come up with 4 parameters that belong to this challenge. Underneath these parameters you have to write 5 options. Than you have to combine the options underneath each parameter and come up with an idea for each combination. We executed these steps and we gave ourselves the task that every member of the team had to come up with one idea per combination so we would have 20 ideas on the end of the week.

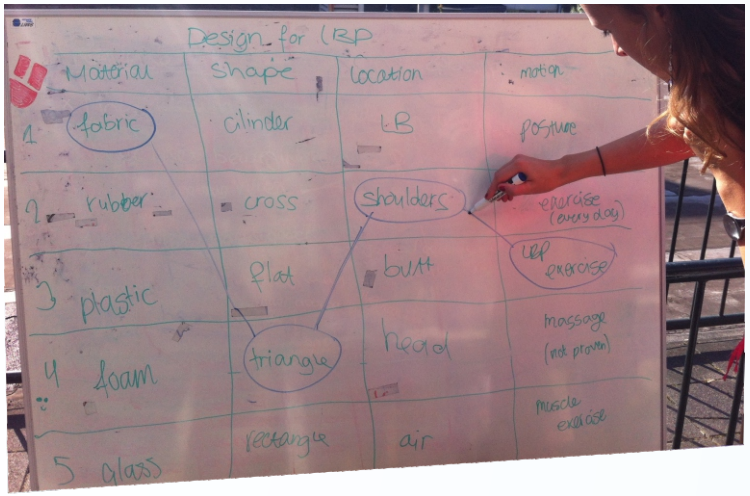


fig. 3

Sorting out and categorizing

After this week of coming up with ideas we wrote down every idea that came out of this week on post-its and we categorized them into three groups: Exercise therapy, Posture advice, Promoting Active lifestyle. Once we had these three boards with ideas we could started with choosing, combining and eventually conceptualizing. In appendix 3 you can see the sheets we made containing all the concepts.

Iteration 1

Conceptualization

After this ideation week we started with conceptualization. We took 4 ideas that were most appealing to us and we worked them out further. These four ideas were:

- Spine sticker: this sticker is placed on the spine of the patient. This sticker measures the posture of the patient and also gives feedbacek about it.
- Triangle of decision: this device reminds you to take the right decision everywhere you go. So to take the stairs instead of the elevator and to go by bike instead of by car. This will promote an active lifestyle.
- Mirrorcle: this interactive mirror will perform the exercises for the patient and the patient has to follow the outlines of the character on the mirror. When the person does not perform the exercise correctly the mirror will give feedback.
- Shoulder pads: these pads are placed on the shoulder of the patient and will remind the patient of a good posture. When the patient moves in the wrong direction with his/her spine the pads will pull the patient back in the right posture. At the end of the day the patient can see the data gathered by the pads.

We presented these 4 ideas to dr. Annick Timmermans in a Skype-meeting.

Meeting Annick Timmermans 1

Dr. Annick Timmermans of the University of Hasselt is our client for this project. After the conceptualization phase we arranged a Skype-meeting with her to propose our ideas we got out of the conceptualization phase to her. She found the idea of the Mirrorcle the most appealing because it is very innovative. The idea of the spine sticker she found quite risky, because people could be allergic for the material of the sticker. It was clear that she saw less potential in the other 2 ideas. Also she told us that it is proven that when people perform exercises in front of the mirror that they recover faster (Wand et al. 2012) This is because the patients get a higher feeling of control when they see themselves in the mirror. It takes away the fear and pain to exercise. When performing the exercise, the patient has to keep his low back stable, she told us.

Prototyping 1

After this meeting with Annick we decided to take the Mirrorcle as our main concept. There were a few reasons why we chose this idea:

- We thought this was the idea with a high potential and the most innovative one.
- There is nothing like this idea allready on the market for people with low back pain.

Iteration 1

- dr. Annick Timmermans send us an article which validated the idea of the Mirrorcle. A citation out of this article:

  > "In conclusion, patients reported significantly less increase in pain and recovered significantly faster when they were able to visualize their back during the performance of repeated spinal movements, than when they were not able to visualize their back." (Wand et al. 2012)

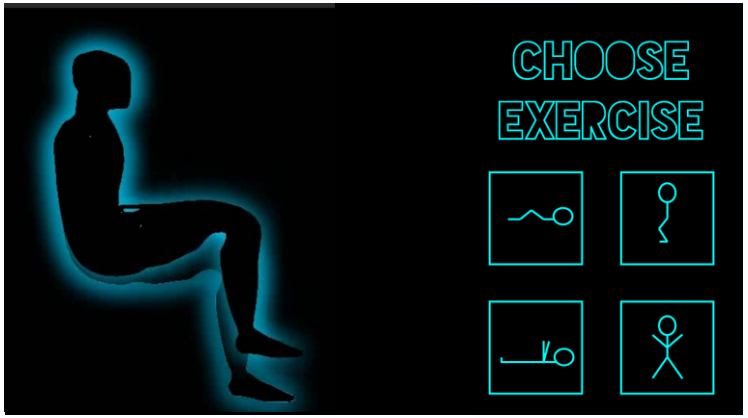
So due to these reasons we started with thinking how we could actual realize our idea with the Midterm-Demoday coming up. The prototype we made consists out of 2 parts: the hardware and the software.

Hardware - Oneway-mirror (fig. 4)

fig. 4

Because it was out of our reach to prototype an actual digital mirror we decided to make use of an oneway-mirror and a beamer. This function of the oneway-mirror is that from the one side you can look through the Plexiglas and from the other side it acts like a mirror. We put some foil on Plexiglas to create such an oneway-mirror. It depends on the lighting which side acts like the mirror and which as the see through. We needed this oneway-mirror because we projected the animation of the exercise by means of the beamer. We projected this at the see through side so it was visible at the mirror side. This way the patient can see itself but also the animated character. To make this mirror more stable we put a frame around it, made out of wood.

fig.5



Software - Animated character & interface (fig. 5)

For the animated character we used the program Blender. With this program you can create 3D models and animate them. We created a 3D model of a person in Blender and animated one exercise with it. The problem was that this 3D model was not perfect so we used a downloaded character of a human in the end to make it look more decent. We only made the outlines of the character visible (using Adobe Aftereffects) so the patient was also able to see him/herself.

For the interface we wanted a clear and very simplistic

interface which would speak for itself. The patient can chose the exercise he/she wants to perform and after the exercise he/she can see the progress he/she made.
After making this prototype we made a movie of the mirror in use. We made this movie, because we wanted to explain our concept to people in a clear way without giving a live demo involving the actual prototype. We used this movie in the Pecha Kucha we presented. Here is the link to the movie:
https://www.youtube.com/watch?v=tb4p-FFMK2g

Meeting Annick Timmermans 2

In the week of the Midterm-Demoday we arranged a second meeting with Annick Timmermans. This time she came to the TU/e so we could actual show our mirror. (fig. 6) She was very enthusiastic about the concept and gave us qualitative good feedback. Underneath this feedback will be discussed.

fig. 6

- The spine has to be in the right position during the exercise. So when the patient performs a leg tilting exercise and tilts his leg quite high but his spine is not in the correct position, the exercise does not have any use. Therefore only give feedback on the position of the spine, not on the way the exercise is performed considered the height of the leg for instance. It would be best if the patient can see the whole exercise, like you have now, first, so it can learn for itself. And then the patient has to do the exercise again but then only the curve of the spine is visible on the mirror. Now you can give feedback. You also can give feedback by means of audio. Also give feedback on overall performance. Give the patient adjustments so they know what to do for the next exercise. Where they have to focus on. *Result:* At first the patient can see 5 times how the exercise has to be performed and then this animation will go to the bottom right. Then the curve of the spine appears and the patient has to get in position according to this curved line. Then the patient has to perform the exercise again and he will get feedback on how he did it.
- It would be nice if the physiotherapist could indicate the margin in which the spine can be during the exercise. A beginner can have a bigger margin than an advanced patient. Also the physiotherapist can adjust the exercise set for the patient when he sees the data per exercise.
- A beginner has to have continuous feedback, because he/she still has to learn it. A more advanced patient

has to have the opportunity to think, did I perform the exercise right or not, so he/she should get feedback less often. Also the exercises should become more difficult over time.
- Exercise should be explained very clearly.
- Change the name, lumbago is very negative. *Result:* we changed the name to Mirrorcle, which sound a lot more positive and motivating.

Midterm-Demoday

For the Midterm-Demoday we had to create a 'Pecha Kucha'. This is a presentation of 20 slides which each have a duration of 20 seconds. We decided to show the movie we made of the concept, using three slides, instead of showing the actual mirror, because this movie was also clear enough for the feedback we wanted to get. Unfortunately we did not get very much feedback on our concept by the people that were the audience at our presenation, only that people with low back pain cannot bend to control the interface of the mirror. So the mirror's interface has to be at arm height. Anne Wil and Emma presented this Pecha Kucha. After presenting this Pecha Kucha one time, we were asked to present again. We 'won' the prize of best presentation together with another student. The prize was that we could exhibit on the exhibition 'Domotica & Slim Wonen' in the Evoluon on 19 and 20 December. Later in this report more about this.

Reflection

When we reflect on this first iteration of our project we can conclude that we gained a lot of knowledge about our problem statement through papers about aspecific low back pain. We got those papers via our client dr. Annick Timmermans. The way we approached this iteration by dividing it into several phases we did not spend too much time on one part of the design process. Also the close connection with dr. Annick Timmermans made our design process very effective. Due to the professional feedback she gave us we dared to take decisions and go further.

For the next phase of this project we decided that we should focus more on the back than on the whole exercise. This is something dr. Annick Timmermans told us in a meeting. We also changed the name (as you can read in the next section) due to this iteration.

Iteration 2

Prototyping 2

After the midterm demo day and client meeting, we had quite some improvements to make to our concept, below is a summary of these points of feedback and things that we ourselves wanted to improve.

Scale

For the first prototype, we used a regular beamer to project on the back of the mirror. To achieve the right size of projection for the mirror, the beamer had to be four to five meters behind it. This meant that the prototype took up a large space to set up. After midterm demo day, we managed to purchase a short throw beamer from an elementary school in Arnhem, like the ones that are used on smartboards, so we could drastically decrease the size of the prototype, because the beamer could now be placed directly under the mirror. (fig. 7)

fig. 7

Improving looks

For the new prototype, we removed the foil that looked like wood, and painted the mirror and the placeholders white, which made it look a bit more like a health product, which is what we wanted to achieve.

Heigth

fig. 8

A great point of feedback we got from the midterm demo day was that people had to bend over to use the interface on the mirror, because the mirror was too low. Especially for people who experience low back pain, this is not optimal. Also, people could not see themselves completely in the mirror without tilting the mirror backwards slightly. We started to make some kind of elevated placeholders, which had the tilted angle in them. This way, people could see their entire body and did not have to bend over to use the interface. (fig.8)

Yet another foil

In the first prototype, we discovered that just the one-way mirror foil wasn't enough, because the light from the beamer passed straight through, not being visible from the other side. We experimented with some materials

behind the mirror, and found that akyprop did the job, but wasn't very practical. After the midterm demo day, we ordered a diffuse foil that we stuck on the other side of the perspex. This provided a surface for the beamer to project on, but also allow for the light to pass through.

Improving interface

We got the feedback/advice from our client that we should change the way we wanted the user to perform the exercise. Our previous concept was that people could simply follow the outline presented in the mirror, this could be improved by first displaying the exercise a couple of times, but after that let the users do it themselves. This way, people would be more aware of their posture, instead of merely copying the outline in the mirror. When the user is somewhat inexperienced, the mirror should still give direct feedback on whether they had the right posture, but it might be worth researching whether the more advanced users should only be corrected after they have done the exercise, to further increase the motivation to correct your posture on your own ability.

Other

Furthermore, our client correctly pointed out that Lumbago means back pain, and that having a name for your concept that means and involves pain is not preferable. We had an informal brainstorm session where we came up with humorous names as 'El Spieguel' and 'Mirrorcle', and decided to stick with the latter for the time being. Eventually we even decided to stick with it altogether.

Testing 1 Domotica en Slim Wonen

As mentioned before, because our team had the best presentation during midterm demo day, we were selected to present our project on the Domotica & Slim Wonen exhibition in the Evoluon in Eindhoven. This was an amazing experience, and a great opportunity which we are very thankful for. Not only were visitors very enthusiastic about the concept, we got an enormous amount of feedback and advice. Below is a picture of our stand at the exhibition (fig. 9)

fig. 9

Visitors at the exhibition came from all sorts of different backgrounds, which allowed for a lot of different perspectives and segments of expertise to get feedback

Iteration 2

from. Below is a summary of most points of feedback we received. Everything has been minuted and eventually processed into this section. The feedback has been categorised by subject of our concept it refers to.

Exercise

Matters we could adjust about the exercise itself.
Include a counter for the amount of exercises done right.

- The amount of times the exercise has to be done before the cycle is ended.
- Make the goal of the exercise adjustable, in this way it stays a challenge.
- Exercise isn't clear (e.g. should I be using 1 or 2 legs?)
- Turning your head 90 degrees sideways during the exercise so you can see yourself isn't preferable for correct posture.

Interface

Remarks about the looks and the control of the interface.

- Lacks interaction
- Audio information could improve a lot
- Interface has to be brighter (visibility)
- Interface is too granular (too low resolution)

Design

Comments about the looks and feel of the mirror. Also the functional design comes to question.

- Mirror is very unwieldy, we need to make it more portable.
- Ways to fix this: foil for on a normal mirror, using a tv in exchange for the mirror, a shutter, a strip above a normal mirror.

Application

Instances and target group we could also dive into using our mirror.

- Mentally disabled facilities
- Gyms
- Wellness centre
- Post-Surgery application

Users

Remarks we got according the user group and usefulness of our product.

- Can have a negative effect on the physiotherapist because the patients won't come as frequent as before,
- Users will perform better when they know their physiotherapist is watching their performance online.
- We can also focus on bigger groups of physiotherapists. They have more money to invest.
- The physiotherapist can visit you at home except of you going to the physiotherapist.

Products to take a look at for inspiration/technology:

During the Slim Wonen en Domotica beurs we also had a lot of suggestions of products to take a look at for inspiration. Namely:

- Flexichair: http://www.flexchair.nl
- e-health: http://www.zorgvisie.nl/Home/Dossiers/E-

health/

- Unity 3D software: http://unity3d.com
- EGT lab fontys: k.nieboer@fontys.nl
- Silverfit: http://www.silverfit.nl/index.php
- Oculus Rift: https://www.oculus.com
- Technogym: http://www.technogym.com/nl/producten/wellness-at-home/producten-voor-thuisgebruik/16721

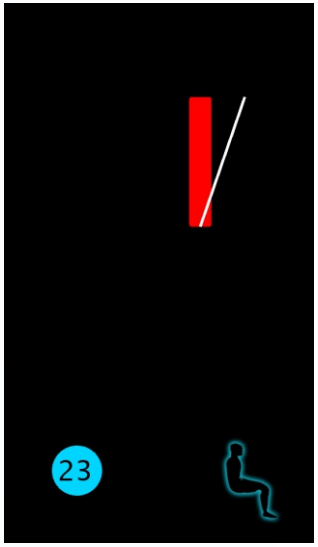
Iteration 3

Prototyping 3

During the domotica exhibition we received a lot of feedback. The things we changed in our prototype according to the feedback were the last changes we made till the final demoday.
The following aspects are the things we improved in our third iteration:

1. *Kinect integrated & improved exercise interface (fig. 10)*
From the beginning of the project on, we wanted to integrate a kinect sensor into our prototype in order to make our mirror interactive. After the domotica exhibition we stated ourselves a goal that we wanted our mirror to be interactive at the final demoday. We contacted an expert Peter Peters, who's expertise lies in programming and electronics. We asked him to give us advice and support about creating our interaction model.

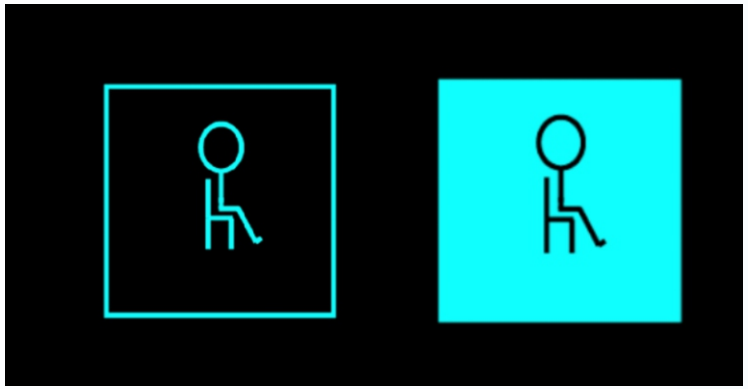
fig. 10



After 2 weeks of working on programming we managed to connect the Kinect to processing the way we wanted it to work. We've managed to set up an animation which tracks the angle between torso and bottom. Around this animation we've set up a square that illustrates the boundaries of the maximum angle. Together creating the feedback model. Besides this, we also created a mistake counter, adding up the times you cross a boundary. And a demonstration animation which first demonstrates the exercise several times, and then moves to the right bottom of the screen. See appendix 4.1 and 4.2 for the most important part of the Processing code.

2. *Improved user interface (fig. 11)*
During several runnings of our program we noticed the interface being hardly readable. Because we did not have

fig. 11



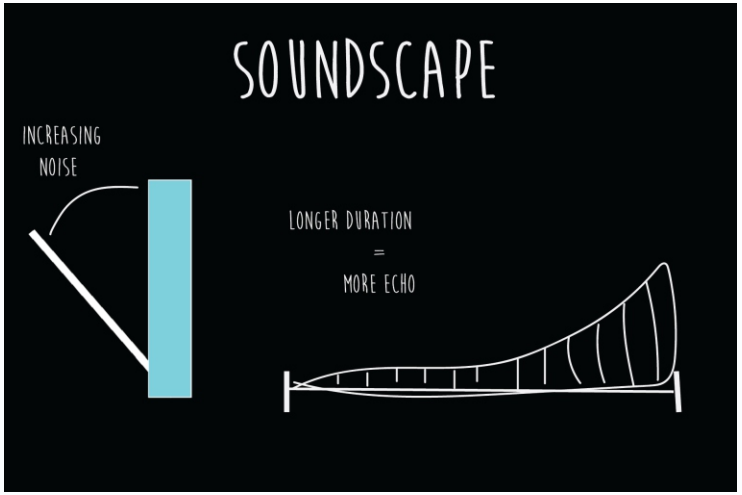
the resources in hand to use a technology like a way more brighter laser beamer, we decided to do whatever we could to improve the visibility of the interface. One thing we did was inverting the colours. We found out that a dark line in a bright background is better visible then a bright line disappearing in a big black background.

3. *Added Exercises*
For our exposition in evolution we only had 1 exercise to choose from. When interacting with the mirror the users

could only choose 1 of the 4 exercises. In this way the full usability of the mirror couldn't be tested. In order to get valuable feedback at the final demoday, we needed to integrate at least the 4 exercises into the mirror. Again we used the blender after effects collaboration in order to create the other 3 exercises.

4. *Sound Design (fig. 12)*
As solution for the 90 degree neck turning problem we decided to go and create a sound sketch during the exercise. With this sound sketch integrated in the mirror it isn't necessary anymore for the user to have his sight pointed at the mirror all the time. The sound is designed to create a sound display that will inform the user about the orientation of his spine. We decided to not integrate the sound design in our prototype for the final demoday.

fig. 12



This because the moment of designing this sound design was around the end of our project process. We did not user test the sound and did not had a good reason yet to implement it. In future processes this sound can be tested, tuned and eventually be present at later iterations of our prototype.

Testing 2

For this user test we wanted to use a more valid way of testing, we did not just want to look and see what happened without using any techniques. Therefore we prepared a user test beforehand using the overt observational research method and PUEU, a usability test.

When using the overt observational research method, the observer should introduce him/herself but should state the purpose of the research less clearly (Marshall 1998). No details are told, unless asked by the participant. Also it is important to let the user sign a consent form, for the use of the material made at the user test, in our case we made a video so we could observate the user after the user test. For our consent form see appendix 5.1. For our overt observational document please see appendix 5.2.

We made a list of things we wanted to observe, to see if the mirror was working correctly and if it was easy to use. The things we found from this observation were:

- Due to lighting conditions the interface was not really

visible. We had to explain the user which choices he could make.
- The interface is not intuitive, the user did not know that he could touch the button for exercises, extern explanation was needed.
- The user does not sit right, he sits faced to the mirror but he should turn 90 degrees, extern explanation is needed to get him in the right position.
- Extern explanation needed for the recognition, also explanation needed that he should do the exercise. Besides extern explanation needed that it is important to focus on the back and that the back should be in the right position.
- The user told us that the exercise was going too fast.
- The user also told that he could not keep his back in the right position because he had to turn his neck to see if he was doing it right or wrong.

After we did the overt observational research we asked the user to fill in a questionnaire about the usability of Mirrorcle. For this usability test we used the validated questionnaire: Perceived Usefulness and Ease of Use (PUEU) (Davis, 1989). Part of the PUEU questionnaire we did was the CBUQ questionnaire. (Brinkman et al. 2009) To see the whole questionnaire please see appendix 5.3 and 5.4. The outcomes of this questionnaire will be discussed below.

Our foundings, regarding perceived usefulness:
- The user found it quite likely that using the Mirrorcle will help him to accomplish his exercises faster.
- The user found it extremely likely that the Mirrorcle would help him to improve his exercise performance
- The user found it quite likely that using the Mirrorcle would increase his productivity
- The user found it slightly likely that he could do his exercises more effective when using the Mirrorcle
- The user found it quite likely that the Mirrorcle would make it easier for him to perform his exercises
- The user found it quite likely that the Mirrorcle would be useful when doing his exercises

Our foundings, regarding perceived ease of use:
- The user found it quite likely that it would be easy to learn how to use the Mirrorcle
- The user found it quite likely that he could easily make the Mirrorcle act the way he wanted
- The user found it quite likely that the interaction with the Mirrorcle is clear and understandable
- The user found it slightly likely that the Mirrorcle is flexible to work with
- The user found it quite likely that it would be easy to become skillful in using the Mirrorcle
- The user found it slightly likely that the Mirrorcle would be easy to use

All in all we got quite positive feedback of this user in our PUEU questionnaire. Although he was not really sure

about the ease of use of the Mirrorcle. He is more positive about the perceived usefulness than the perceived ease of use.

Pecha Kucha Studium Generale

fig. 13

During the domotica exhibition we got invited by Jeanette Schoumacher to come to the gaslab and give another pecha kucha about our project. We happily invited this offer. For the pecha kucha we used our old pecha kucha and added the aspects on which we improved since last time. Like a business model, the cloud, our future plans and of course the improved prototype. It was nice to present our project in between all other presentations which did not have anything to do with smart health. Before this presentation we always presented our project at the same time other smarth health projects were explainend/presented. It was nice to see our project as an individuel project and not a project which is part of the theme. Emma and Anne Wil presented the pecha kucha (fig. 13), while Jelle and Jasper where sitting in the crowd. They noticed that during the presentation, a lot of people were reacting very positively about our concept. This was something which motivated us even more to finish our concept before the final demodays.

Final Demoday

fig. 14

At the final demo days we chose to have four separate objects telling their own story. (fig. 14) We had our prototype, explaining the functionality of our project. The scale model, explaining the design of our future iteration. The scenario of use, explaining our concept and the application. And a timeline explaining our project process from begin to end. We decided to divide our concept into different sections. This because we thought this would strengthen the message of our concept. People can focus on the different parts and just 'see' where our concept is

Iteration 3

about. The demoday is an exhibition where people want to see and not have to listen to stories every time.

During the demoday we talked with a lot of students. Most of them mentioned the problems we already were aware of which exaggerated the importance of those aspects. In addition to this, we invited Annick Timemrmans to have a look at our final concept. She provided us with new feedback for future processes. The most important thing she pointed out was the fact that it wasn't beneficial to incorporate sound in our design. This because it takes away the feel of control we generate with the strong visual message of the mirror. Another thing we could look into was a collaboration between 2 mirrors. Also annick mentioned that we should reverse the mistake counter and make it into a correct counter. The mistake counter could work demotivating. All with all we could say that it has proven to be nice to eventually see that our third iteration of the prototype was working and ready at the time of the demoday. Which gave us a satisfied feeling.

Evaluation

Analysis of Interaction Smart Mirror using Frogger Framework

We used the Frogger Framework to evaluate our interaction. In this analysis the different kinds of feedforward and feedback of the mirror will be discussed.

Inherent feedforward

Analysis current state:
If the mirror is shut down it is not really visible what kind of actions are possible. When looking at the mirror at it's state now there is no on/off button or anything related to the possible actions.

When the mirror is on and the interface is visible, the interface communicates what kind of actions are possible. The way the interface is designed now only pushing actions are possible. Though, as also experienced in user research, it is not really clear that the images can be touched to make a decision. The images of the exercises in the interface communicate the possible exercises (thus actions), though this is another kind of action.

Points of improvement:
To improve, or make the interface more interesting, we could explore different kind of actions, like rotating or sliding. Besides we think we could make the exercise “buttons” more looking like buttons, to make the interaction more intuitive. Also we should think about the mirror's off mode, how do people know what to do to turn it on?

Functional feedforward

Analysis current state:
When you see the mirror (shut off) and you do not know this project, it is hard to see what you can do with this mirror. It could be that a person thinks that it is just a mirror. A little bit of explanation is needed before people will understand what the purpose of the mirror is.

Though when the mirror is turned on and the exercises are shown a lot more becomes clear. The interface tells the user more about the function of the product. In the interface the possibilities of 'doing exercises' and 'seeing progress' are shown. In this state of the interface the purpose of doing exercises with the mirror becomes clear. Though it is not clear that these exercises are especially for people with lower back pain. When the exercise starts it gives feedback on the back so this is the moment that it becomes clear for which target group the mirror is designed.

Points of improvement:
We could make the function of the mirror clearer at the beginning by changing the product semantics of the mirror. This is something we could brainstorm about, though it will be very heard to make the function more intuitively clear when the mirror is shut off. We could also

make the interface more intuitive regarding the function of the mirror.

Augmented feedforward

Analysis of current state:
Currently there is no augmented feedforward in the mirror.

Points of improvement:
We are thinking about involving audio more in the mirror. For example a voice audio that explains the purpose of a certain exercise. This way we would also have some augmented feedforward.

Inherent feedback

Analysis of current state:
There is no inherent feedback incorporated in the current mirror. There is no button which you feel when pressed, mainly because it is an interface and there are no actual buttons.

Points of improvement:
We could involve inherent feedback more in the mirror, by making the button feel like it is a button. For example by a little vibration when touched.

Functional feedback

Analysis of current state:
Different kinds of functional feedback are incorporated in the mirror.

Performing exercise
Direct feedback people get from the mirror when they are performing the exercise. This is the line that changes from blue to red if the back is in a wrong position. Also a little sound of wrong and good is involved in this feedback.

Using interface
When they 'push a button' on the interface the interface will change to the selected option.

Augmented feedback

Analysis of current state:
It is not really from an additional source but it is feedback the user receives after the exercised and appeals more to the cognitive skills of the user.

After the user did several exercises the mirror makes a graph of the progress of the user. Is the exercise going better and better? This is visible in this graph. The feedback the user receives is after the exercise, not directly and the user has to use it's cognitive skills a little more.

Reflection & Future

So, what to improve on the project in future? What would we do if we were to continue with this project? There are two main segments we would have to be working on. The first one is concept wise; improving the functionality and making sure it works properly. The second is marketing wise; thinking about how to implement the concept into our market and maybe already start doing so. Let's start with the first one.

Concept wise

Big and Unwieldy

Probably the biggest issue at the moment is that our prototype mirror is very big and heavy, because it is made out of wood, a big sheet of perspex, and quite a large projector behind it. All in all, you definitely need at least three or four people to move it. Given the fact that our concept is meant to be taken home after visiting the physiotherapist, combined with our current customer segment of people with chronic low back pain, this leaves tremendous room for improvement.

We have already been thinking about alternatives. The most likely option at the moment is to integrate the technology in a roll up system, like the roll up banners used at expositions. On top of this roll up system would be a wide-angle micro beamer, projecting from behind. The two foils that are now on the plate of perspex would be stuck on a thinner plastic that can be rolled up. We will have to do research on whether this is possible or not, because the foil on one of the two sides of the plastic will be stretched and the foil on the other side will be cramped.

Another alternative was projecting it directly on an existing mirror in peoples homes, but there are two problems with this. Firstly, and the simplest reason, not everyone has a mirror of the appropriate size in their homes. Secondly, the basic idea of a mirror is that it reflects light, which makes it possible to see yourself. This does however mean that, with a normal mirror, the light emitted from a beamer will be directly reflected via the mirror onto the ground, when projecting from above. If it would be possible to find/make some kind of foil that people can stick onto their existing mirrors so the beamer can project onto it, but you can also still see yourself, it might be worth considering this option.

Visibility of Interface

Another major point that we will have to improve on is visibility of interface on the mirror. At the moment, everything is barely visible, even in perfect lighting conditions. There are several options to improve this.
One of the options is to use different foils to the ones that we are using now. The diffuse foil on the back of the perspex might be too diffuse not allowing enough light to pass through it. We could experiment with different densities of this foil, to find the perfect balance between allowing enough light through the foil, but also blocking enough so that you can still see it in the mirror, instead of all the light just passing through.

Reflection & Future

Another option is using a laser beamer instead of a normal beamer. Laser beamers have a relatively wide angle so it can be close to the mirror as well, but use a laser as light source instead of a normal lamp. Laser beamers are on average fifteen times brighter as a normal beamer, which could drastically increase visibility.

A far more innovative and futuristic approach might also be a viable option, using the new OLED technology. OLED technology could enable us to have the interface integrated into a foil, so a beamer would not be necessary. This would make our mirror a lot lighter, and way more compact. Of course, this technology is also a lot more expensive than using a beamer, but it is definitely with taking a look at in future and weighing up the positive and negative factors.

Interface and Sound Design

After having done the user tests, we realised that we were so into the projects that we looked at every part of our concept as a logical process, whereas the user might not understand things at all. In future, we should continue to test whether our interface is self-explanatory, because we ourselves are not able to give an objective opinion on that. One way to further improve the interface, making it more intuitive, is to add audible feedback. We have already explored this area a bit, but have not tested it yet, so this is something for future.

Information cycle (fig. 15)

At the moment, the basics of the concept are functioning; the mirror can correct the user during his or her exercises. The part where the physiotherapist can upload exercises to the mirror and download data gathered by the mirror, we still have to make. Below you can see a simple model of what the information cycle would look like. Our task would be to design the 'cloud', in other words, a website that interacts as medium between a physiotherapist and the mirror.

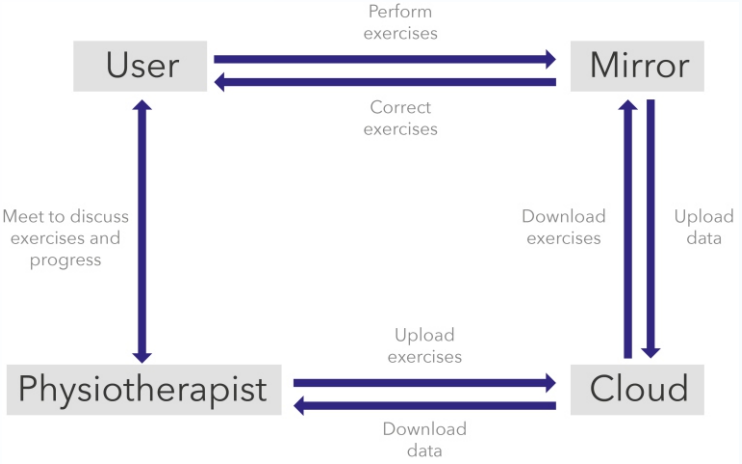


fig. 15

Marketing wise

If we were to continue with our project, we would be entering a new phase of the design process. During last semester, we went from a problem statement to a concept, whereas next semester we would be focussing on making the concept into a product, ready to hit the market. This would mean having to think more about how

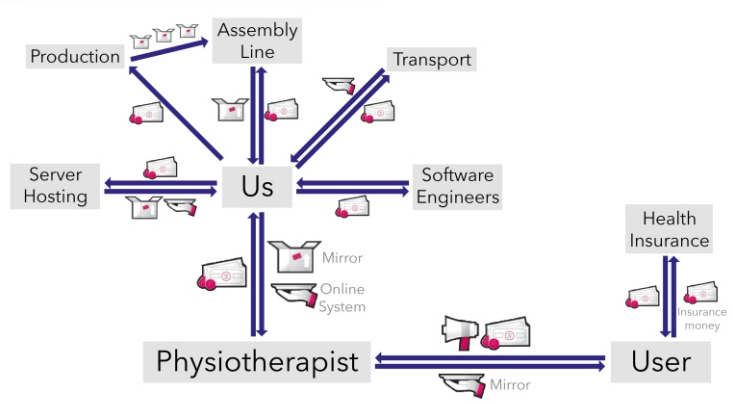
Reflection & Future

to implement our product into a certain market.
We have already started to make several business models for our concept, but there are also a lot of business related activities that we still have to do or improve on. (fig. 16)

fig. 16

Value Flow (fig. 17)

fig. 17



Something we have already done is making a basic value flow, which you can see below. Let's start at the bottom half of the model. We deliver the mirror as a product to the physiotherapist, and offer him the service of the online system, in exchange for money. The physiotherapist delivers the mirror to the user as additional service, in exchange for additional money, covered by either the users themselves or health insurance companies. We pay for server hosting, to put our interface for the physiotherapist online. We pay software engineers for developing software for on the mirror and the online interface, but we might do this ourselves. Furthermore, we pay for production and assembly, and for transport from the factory to us, and to from us to the physiotherapist. For a bigger picture please see appendix 6.1

Business Model Canvas (fig. 18)
We also already have a first version of the business model canvas, this is however only a start. A lot has to be improved on this, and we have to make this for more situations, with different target groups and different possible channels to promote and sell our mirror. A future activity would definitely be to arrange meetings with experts to receive feedback and advice on this. For a bigger picture please see appendix 6.2

fig. 18

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Physiotherapists Beamer company Kinect Foil Company Assembly Transport	Marketing & Exposure Coordinating Developing Software (inhouse) Delivering mirror and giving instructions to physiotherapist **Key Resources** Hardware and software	Faster recovery through structured feedback on exercises Exercise and recover in your own home, with the expertise of your physio-therapist Motivational Physiotherapist can offer extra service on top of their treatment	Marketing & Exposure Coordinating Developing Software (inhouse) Delivering mirror and giving instructions to physiotherapist **Channels** Website Exhibitions and Fairs Physiotherapist Physio equipment stores	People with lower back pain
Cost Structure Production costs of mirror Software development Transportation Server hosting			**Revenue Streams** Physiotherapists buy our product (Monthly fees?)	

Reflection & Future

Market research

Another thing we have to do is market research. Looking at the market and where we could implement our concept. Of course, we started from the target group involving people with low back pain, but we have already seen that the mirror can also be used in a lot of other areas, like fitness centres, dancing schools, rowing associations, etcetera. This was also something that was pointed out to us during the Domotica & Slim Wonen exhibition. Looking at all the possible markets will give us insights into where we should be focussing our concept on, before applying to other areas. It might be wise to start with this in future.

Division of tasks

Working on this project, we sometimes did things together but we also worked individually on something or in a duo. Underneath you can see a list of all the main activities of the project and who worked on it. The activities are listed in chronological order.

- Research phase - All
- Preparation brainstorm session - Emma
- Ideation and Conceptualization phase - All
- Prototyping mirror - Anne Wil & Jelle
- Blender modeling - Emma & Jasper
- Blender animation in After Effects - Jasper
- Interface design - Anne Wil
- Shooting movie - All
- Editing movie - Jasper & Jelle
- Pecha Kucha Mid-term demoday - Anne Wil & Emma
- Business model canvas first version - Emma
- Flyers and poster Domotica beurs - Anne Wil & Emma
- Improving prototype - All
- Switching movies processing (Wizard of Oz) Domotica beurs - Anne Wil & Emma
- Presenting at domotica beurs - All
- Programming final design (including kinect) - Emma
- Analysing interaction with Frogger Framework - Anne Wil
- Information model and value flow - Jelle
- Business model canvas final version - Jelle
- SysML models - Anne Wil
- Pecha Kucha Studium Generale - Anne Wil & Emma
- Photoshoot prototype - Jasper & Jelle
- Preparation overt observational research - Anne Wil & Emma
- Preparation PUEU questionnaire - Anne Wil
- User test - All
- Analysing user test -Anne Wil & Emma
- Sound design - Jasper
- Scale model final design - Anne Wil & Emma
- Sketching storyboard - Anne Wil & Emma
- Preparation Final Demo Day - All
- Timeline process - Jelle
- Final Demoday - All
- Writing report - All
- Lay out report - Emma

Reflection Anne Wil

I choose to do this 'Smart Moves' project within the theme 'Smart Health' because I was focusing on health care in my vision and I wanted to explore this more. My previous project was also healthcare related, namely designing an activity for people with dementia. Though this was more the social side of the healthcare theme. For this project I wanted to try a project that was more solution oriented within healthcare, so revalidation of people with LBP fitted very good. I wanted to explore if this was the direction I really wanted to go in. All in all I really liked this part of healthcare and the fact that I was able to improve peoples life with providing a solution for their problems.

At the end of this project I am very proud of what we were able to make. The fact that we got invited for the 'Slim Wonen en Domotica' fair and a Pecha Kucha for Studium Generale confirmed that we were on the right track and that our project interested people. Those activities also helped me to get even better in communicating our concept.

Part of our success within this project was also due to the structured design process we choose at the beginning of the semester. In my previous project we also had a structured process but we sometimes were a step ahead of our process. We started with the next steps while we did not finish the previous, I feel that this went a lot better in this project.

Within this project I mainly wanted to develop the competencies: Form and Senses, User Focus and Perspective, as stated in my PDP. Although I also had some smaller goals regarding the competencies: Design and Research Processes, Integrating Technology, Ideas and Concepts, Descriptive and Mathematical Modeling and Communication. I am content about the development I have gone through and that I reached the goals I set in my PDP. Full reflections about my competency development can be found in my showcase. I will discuss my main learning points within the project below.

Form and Senses

I decided to focus more on the form and senses part of designing in this semester. Also because my assessor of B1.2 gave me the following feedback:

"I think that next semester you should focus on further development of your hands-on designing skills like sketching, model building, designing and giving form to 3D objects." Flip Ziedses des Plantes (Assessor B1.2)

Within the project I have been doing different activities to develop myself regarding this competency. Starting with making the prototype of Mirrorcle, designing the interface of Mirrorcle, making scale models of the final design and ending with sketching a scenario of use. These helped me developing my hands-on designing skills. Mainly the making of the scale models of the final design were helpful. With the use of little materials Emma and I

Reflection Anne Wil

made a small mirror model. After we finished the first model we saw that the dimensions were not right yet and we made a new one where the dimensions did fit better to our purpose (making Mirrorcle better transportable). I experienced how useful making a scale model can be since you can actually see and feel how it looks, but you did not spend too much time on a final prototype yet. It enabled us to make iterations in the final design.

User Focus and Perspective

This semester I wanted to conduct more official user tests within the project. In my previous projects I did a lot of user testing but I was not using official methods. During my assignment in the first quartile I learned more about doing user tests, here I also learned about validated questionnaires. I wanted to apply this knowledge within the project, therefore I prepared a user test at the end of the semester. For this user test I used a usability questionnaire (PUEU) and together with Emma I prepared the overt observational research method. These methods helped me to get more insights regarding the things we could improve. And it prevented from forgetting any feedback or missing feedback because you are too focused on one thing of the concept.

Teamwork

Within this team we did not really have an actual leader. All members of the team were really communicative and a lot went well by itself due to team dynamics. If I reflect on my role in the team I feel like I was the person who kept everyone on track of the planning, and motivated others throughout the process. Though I experienced that I sometimes was, together with Emma, more driven and critical than others in the team. Which sometimes leaded to different expectations, workload and stress from my side. Within the group there were different perspectives of how to work. Though it sometimes gave tension, it is also a positive thing because I learned that I could sometimes be less strict and more relaxed. I realized that different perspectives complement each other within a team.

All in all I am very satisfied with this project and my development throughout this project. I learned lots of new things that I will definitely take with me to my future projects.

Reflection Emma

When I look back at this semester I think when looking at the end result this is my best project of 3 semesters. The way I went through the design process was far more structured and efficient than ever before and this resulted in three iterations. Setting up a project planning in phases helped to achieve this. Because of this structure I had more inner rest, which I did not have in the other two projects I did before. I had less stress and more faith that it would become a good project. Because of this faith and rest I could focus better on and had more fun in the project. So now I saw that stressing does not always help and when you take a step back and look at the whole can help you to see things clear again. So for the next project I am going to do I will certainly use this phase technique again.

Regarding my personal goals this project was very useful; especially the goal in ideas and concepts. I set the goal that I wanted to use techniques of the book 'Thinkertoys' to go through the ideation phase. I chose some maybe weird techniques when you first look at them, but the outcomes were very valuable. Due to the technique 'from a different perspective' we actually came to the idea of the Mirrocle. So this goal was very good applicable in this project.

The goal I set in integrating technology was that I wanted to deepen my knowledge in Processing was also very useful. Programming the Kinect and creating the smart system the Mirrorcle has in it was quite a challenge for me, because it was a lot different than the previous things I did with Processing. Reaching out to experts like Peter Peters helped me in with programming and this resulted in the end result I wanted. Due to the struggles I had with this the end result was even more satisfying for myself.

Together with Anne Wil I worked on the competency User Focus & Perspective. She did an assignment in this area so she had more knowledge than I had. We worked together preparing and analyzing the user test in which she showed me which techniques there were available and how to ask the right questions. Now we only did a user test in the end of the design process, but for the next time I want to involve users earlier in the design process.

Standing at the exhibition Domotica & Slim Wonen was for me a key point in the whole semester. It was new for me that other people besides students and coached gave feedback on the concept we designed and it turned out to be really valuable. It would be nice if I had such an opportunity every semester from now on!

Looking at the teamwork this semester I think until the Midterm-Demoday we did a lot together and there was a good vibe. We are all quite communicative persons so that worked well together. After the Midterm-Demoday we divided the tasks more to our own interests. For me this was very nice that I could focus on the things that I wanted to develop. The programming I did all on my own, but making things like the scale model and the scenario of use I worked together with Anne Wil. We are very much at the same thought level so our cooperation went very

Reflection Emma

smooth and efficient. Sometimes I felt this was not the case with the boys in our group. They were also at the same thought level but this was not the same level Anne Wil and I were on. So this resulted in a not always efficient way of working.

At last I want to mention the close and good cooperation with the client was something that I liked very much. Dr. Annick Timmermans was very open to us and very willing to help. Due to the scientific papers that she sent us we got a validation for our project and we went through a good research phase. Also the enthusiasm she showed about our project gave me a really positive vibe.

All in all this was a good project and I am very satisfied with the end result; not only of the Mirrorcle itself but also regarding my personal goals.

Reflection Jasper

When comparing this project to my previous project (B1.2), I see a high contrast in the design processes. In my previous project it took a very long time before we all agreed on the final concept. Endless discussions about different ideas and design choices led to a very long conceptual phase. This resulted in having to little time for actually developing the product. This semester we had our concept rather clear in the first 2 weeks which left us with plenty of time to work out the concept through a prototype. Having a physical prototype provided us with the ability to test the functionality of our concept. Which is, in my opinion, very valuable for further development of the concept.

In my view this way of having a design process works out really well. Having several iterations of your concept gives you the ability to test, gather feedback, reflect and improve. Which eventually lead to having a strong concept. Furthermore I want to mention that this theme worked out really well for me. In my previous theme, next nature, you were given the freedom to design simply everything for every problem you could imagine. Whether in this project you were given a problem statement from the start. We could immediately start ahead with doing research and generating ideas.

In addition what, in my opinion, made this semester really special is the moment we got invited for the domotica exhibition at evoluon. From that moment there could be seen that the whole group got motivated like never before in the project. I think this is because suddenly, a project that has been 'just' a study project before, turns into something more serious.

The weeks before the domotica days we worked really hard to create a strong prototype that was able to explain our concept. Because of this 'sprint' we saw ourselves being ahead of all the project groups because we basically had another iteration to work towards. In my opinion this was really helpful in keeping everyone sharp and motivated to work on the project.

Furthermore, another motivational factor was due to all the positive reactions we collected throughout the design process. On the Midterm-Demodays we got elected as best project presentation, and after that on the domotica exhibition, we also collected loads of positive reactions. These factors together resulted in us being very motivated on working on the project.

When talking about the teamwork I must say that the collaboration went really good. There were small amounts of discussion points because most of time we all were at the same line. We had a very nice and structured way of task division. After every iteration we summarised the feedback points, reflected on these and converted them into long-term tasks. These tasks were divided along one or more team members according their goals and expertise. Besides that, we also made short-term tasks lists to keep everyone sharp. In my opinion, making tasks lists for long and short-term worked out really well.

Often you see project groups being lazy the first weeks and work really hard at the end before the demodays. By using iteration based long term task lists and daily short tasks lists we managed to keep on track most of the time.

Reflection Jasper

Concluding I can say that this project was totally different for me then my previous projects. I learned a new way of going through a design process, how to keep your team sharp and motivated and i got insight in how the serious side of a project in the open world looks like. This semester and this project motivated me in such a way, that i'd really like to continue with this project. I would like to explore more about the phase between your worked out concept and the final product. I see a lot of opportunities to use these experiences to work on my learning goals. Also because of all the positive reactions I really see this project work, also by expanding it with another semester.

Reflection Jelle

In contradiction to my previous projects, this time, we had a clear problem statement; design for people with chronic aspecific low back pain. Both previous projects were very open ended and had broad design statements. The fact that we were given a clear problem and target group meant that we could immediately start researching the subject and investigating in what products already exist, which I found to be very positive. I'm not great at the abstract beginning where, in other projects, we had to look for a problem, so I thought it was great to be able to skip this part.

Another positive thing I experienced for the first time in this project was that we started our semester by making a rough weekly planning of different stages in our design process, like research, prototyping, etcetera. This way, we could plan ahead how many iterations we would be able to do and it gave us a clear indication of how far we should be with our progress.

Throughout the whole project, we maintained contact with our client, which was also new for me. We were lucky to have a client, Annick Timmermans, who was very much willing to help us with everything, she gave us tremendous research to base our design choices on, helped us with subjects that needed an expert view, and I would like to thank her for that. Involving an expert client helped us in validating choices, which is quite important in the health sector of design.

Participating in the 'Domotica & Slim Wonen' beurs also helped me change my attitude towards the project. When we heard that we were allowed to have a stand with our concept in the Evoluon, our project started to change from a regular project that I had done before, into something that felt more like our own product which I wanted to expose to others, which made my intentions for the project a lot more professional. At these moments of exposure, people from all sorts of backgrounds (i.e. physiotherapists, ergo-therapists, technicians, etc.) were all very enthusiastic, which helped my motivation even further, ultimately up to the point where Jasper and I decided to continue with the Mirrorcle.

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Acknowledgements

Working on this project we worked together with several people and we want to thank them in this section.

Bas van den Boogaard - He gave us the first code we needed to connect the Kinect to the laptop.

prof.dr.ir. L.M.G. (Loe) Feijs - He was our coach during this project. Every week he helped us going through the design process asking critical questions and giving us advice.

Chris Jansen - He lend us his Kinect for this whole semester so we could work with it.

Teun Jaspers - He also helped with part of the programming of the Mirrorcle.

ir. P.J.F. (Peter) Peters - Since his expertise lays in programming and electronics we reached out to him when we had trouble programming the Mirrorcle. He was of great help solving these problems and he spent a lot of time helping us.

J.A. (Jeanette) Schoumacher - She gave us the opportunity to stand at the exhibition Domotica & Slim Wonen. She also invited us to the Pecha Kucha night in the GasLab.

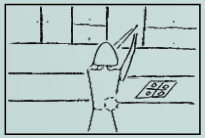
Prof. dr. Annick Timmermans - She was our client for this project and helped us a lot with the research papers that she send us. Also her openness and willingness to help us gave us a bigger the motivation for this project.

Physiotherapist Paul Truijens - He helped us with our usertest by providing a patient with the diagnose which we designed for. Also he was very open to us for coming into his practice and asking him questions.

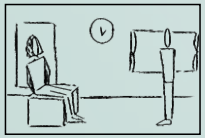
Appendix 1

Please zoom in on your computer if you want to read the text underneath the sketches.

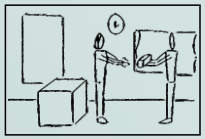
Scenario of Use



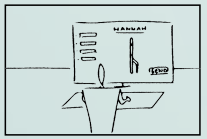
Hannah is doing the dishes and she has been suffering from aspecific chronic lower back pain (LBP) for 12 weeks now. She went to the doctor but there was no specific reason for her LBP. He said she should go the physiotherapist, so tomorrow is her first appointment.



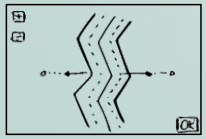
During her first meeting with her physiotherapist she is doing exercises for her lower back with him.



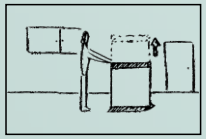
She also has to practice these exercises at home, because this will fasten her recovery process. The physiotherapist gives her the 'Mirrorcle', an interactive mirror that helps her perform the exercises the right way at home.



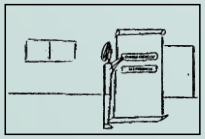
Her physiotherapist has an exercise editor for the 'Mirrorcle' where he can upload the right and personalized exercises for Hannah to the mirror she is taking with her.



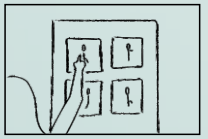
In this system the physiotherapist can also change the margin of error for Hannah. Since she is just a beginner she can make little more mistakes than more advanced users.



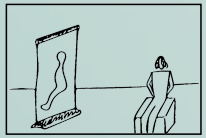
Hannah goes home and puts the package on the ground; her physiotherapist explained that she should roll up the mirror and press the on/off button on the top of the mirror.



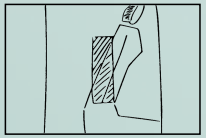
The menu opens up, she can choose between 'doing an exercise' or 'seeing progress'. Because it is the first time Hannah uses 'Mirrorcle' she chooses to do an exercise.



Following up there are four different exercises she can choose from, today she wants to perform a sitting exercise.

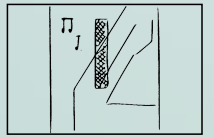


First the animation of the exercise appears and Hannah can watch how she should do it. She already tries to do the exercise in the right way.

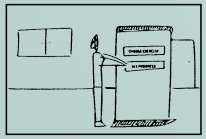


The animation of the person showing the exercise moves to the lower right and the spine of Hannah appears. She starts performing the exercise and suddenly the blue spine changes to orange, this means her back is in a slightly wrong position.

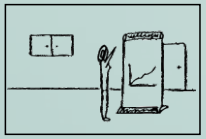
She changes the position of her back while doing the exercise and the spine on the screen becomes blue again; also a sound is played which confirms Hannah she is back in the right position.



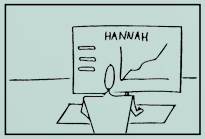
Continuing the exercise the spine changes to red and a sound appears that she is doing it wrong. Again she changes her back and the spine changes to orange and blue after.



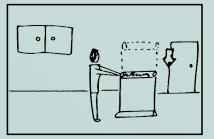
After doing the exercise for a while Hannah is finished, the screen goes to the main menu. Hannah can choose whether she will do another exercise or see her progress.



Hannah chooses to see her progress, since she has done the exercise more often her progress is shown for each exercise. Hannah sees that she is performing the exercise better and better which makes her confident and motivates her to continue doing these exercises.



The progress of Hannah is also sent to the physiotherapist. This makes it easier for the physiotherapist to create a set of exercises which he should practice more during the hour Hannah visits him.



After performing some exercises Hannah calls it a day. She rolls the mirror back in the case and stores it in the closet. Tomorrow she will practice again.

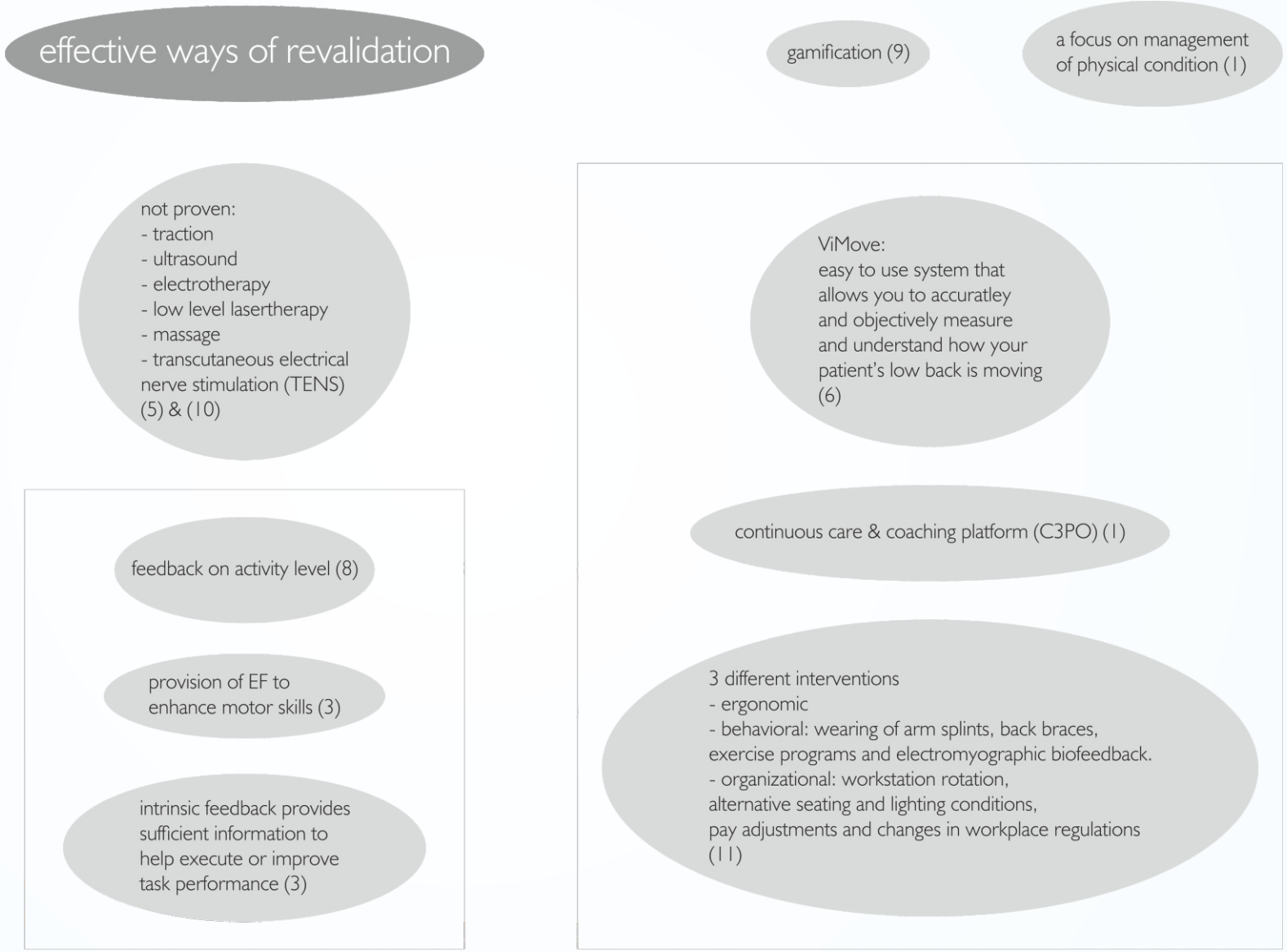
Appendix 2.1


LBP
LBP highest cost regarding occupational disablity (5)
Exercise is the main component in treating chronic LBP, but repetitive exercise for strengthening has limitations in increasing motivation for exercise programs and for treating psycho-socio symptoms (9)
chronic LBP reduces muscle strength, endurence, flexibillity and balance ability (9)
repetitive movements:
- lifting
- bending
- wrong posture
difference between men and women:
- men moslty due to physical work
- women mostly due to phycho-socio reasons
(12)
patients should always try to continue right posture and movement even if they experience pain (5)
- (sub)acute LBP exercise therapy not meaningful
- chronic LBP exercise meaningful (5)
result of interaction between biological, psychological and social factors (5)
Musculoskeletal movement syndromes, such as non-specific LBP, present with dysfunction of muscle systems (global and local) and feedforward postural control mechanisms. While the local muscle system tends to have diminished activity thereby potentially exposing vertebral joints to increased instability, the global muscle system tends to present with increased muscular activity, increasing intervertebal compressive force. Furthermore, patients with LBP are likely to present with reduced lumbo sacral position sense (disrupted feedback) and delayed contraction of transversus abdominis (altered feedforward postural control) (7)
psycholigical aspects:
- depressions
- anxiety
- low self afficacy
(9)
Normal progress:
In time activities and participation increase gradually. For most of the patients the complains decline during those activities, no physiotherapist needed (5)
Abnormal progress:
Limitations and participation problems remain the same over time or increase. Also increase of complains. Abnormal progress when there is no increase of activities in 3 weeks. Physiotherapist needed. (5)
acute 0-6 weeks
subactue 7-12 weeks
chronic > 12 weeks
(5)

Appendix 2.2


target group
90% of the patients with back pain has a specific lower back pain (5)
60-90% of the population has had lower back pain in their lives and 5% anually (5)
The prevalence of MSS among persons with frequent computer use (3-5 h a day) ranges from 40% among college students, 50% among new workers in the first year on the job to over 70% of university staff and students (11)
age between 18 - 65 continuous or recurrent episodes of pain in the lower back lasting for more then 12 weeks (8)
the first episode mostly starts when people are within the range of 20 - 55 years (5)
effective coaching (1)
broad user involvement throughout all stages of development (1)
subacute and/or chronic aspecific lower back pain
more active in the morning than in the evenings (1)
inadequate way of reacting, passive lifestyle, take rest to lower the pain (5)
adequate way of reacting on complains, strive for active lifestyle (5)
lower back pain disappears spontaneously in 4 to 6 weeks (5)

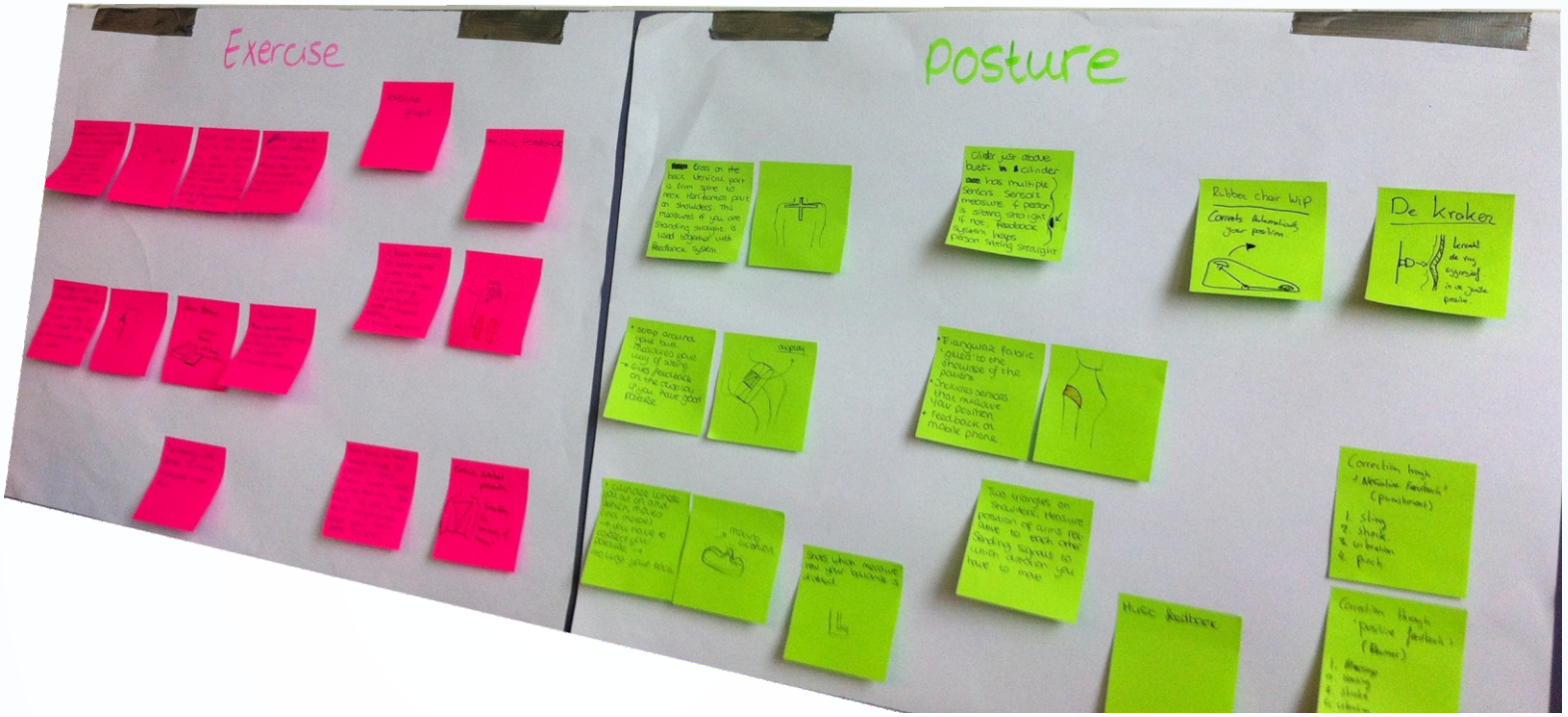
Appendix 2.3


effective ways of revalidation
gamification (9)
a focus on management of physical condition (1)
not proven:
- traction
- ultrasound
- electrotherapy
- low level lasertherapy
- massage
- transcutaneous electrical nerve stimulation (TENS)
(5) & (10)
ViMove:
easy to use system that allows you to accuratley and objectively measure and understand how your patient's low back is moving (6)
feedback on activity level (8)
continuous care & coaching platform (C3PO) (1)
provision of EF to enhance motor skills (3)
3 different interventions
- ergonomic
- behavioral: wearing of arm splints, back braces, exercise programs and electromyographic biofeedback.
- organizational: workstation rotation, alternative seating and lighting conditions, pay adjustments and changes in workplace regulations
(11)
intrinsic feedback provides sufficient information to help execute or improve task performance (3)

Appendix 2.4


extrinsic feedback
Clinicians should also consider the provision of summary or average feedback whereby a number of trials should be conducted without feedback, followed by the patient receiving overall feedback comparatively related to previous performance(s). An example might include providing visual feedback of muscle contraction associated with increased muscle thickening. (7)
self-modeling photo-training (12)
If the patient is not familiar with the exercise or incapable of performing it program feedback should be provided. (7)
provided from an external source (physiotherapist or a biofeedback device) (7)
The visual information increased patients postural awareness compared to the control group. This study showed that adding feedback to the rehabilitation program was related to better clinical outcomes. (7)
-
Thus when using rehabilitative ultrasound imaging, feedback should not be provided immediately after the abdominal hallowing exercise was executed. By providing delayed feedback (e.g. verbal instruction or visual feedback after a few seconds of movement execution), patients are encouraged to better use and organize intrinsic feedback (somaosensory) information. Clinicians should also consider the provision of EF when requested by the patient. (7)
Similarly, Wong and Wong found that the provision of an audio feedback by means of a spinal monitor device, reduced the amount of time spent in trunk flexion by healthy s ubjects during daily activities.
In order to improve sitting posture, audio feedback could be used to help patients to improve spinal sense of position. (7)
Different forms of EF could focus on different neuromuscular impairments of these patients There are diverse forms of delivering EF and the different characteristics can be divided into two main domains: content and timing. Content characteristics refer to attributes of focus of intervention of the EF. Timing characteristics refer to all attributes related to when feedback is provided during motor training. (7)
Timing feedback attributes, there is evidence that concurrent and constant feedback should be avoided (7)

Appendix 3



Appendix 4.1

This is the code to draw the back of the user of the Mirrorcle:

```
void drawLimb(int userId, int jointType1, int jointType2)
{
  PVector jointPos1 = new PVector();
  PVector jointPos2 = new PVector();
  float  confidence;

  // draw the joint position
  confidence = context.getJointPositionSkeleton(userId, jointType1, jointPos1);
  confidence = context.getJointPositionSkeleton(userId, jointType2, jointPos2);

  strokeWeight(5);
  strokeCap(ROUND);
  stroke(255, 255, 255, confidence * 200 + 55);
  line(jointPos1.x, jointPos1.y, 0,
  jointPos2.x, jointPos2.y, 0);

}
```

Appendix 4.2

This is the code to check if the back of the user of the Mirrorcle is in or out of the boundaries set:

```
void checkLimb(int userId, int jointType1, int jointType2)
{
  PVector jointPos1 = new PVector();
  PVector jointPos2 = new PVector();
  float  confidence;

  // draw the joint position
  confidence = context.getJointPositionSkeleton(userId, jointType1, jointPos1);
  confidence = context.getJointPositionSkeleton(userId, jointType2, jointPos2);

  if ((jointPos2.x > jointPos1.x + deltaX) || (jointPos2.x < jointPos1.x - deltaX)) {
    fill(255, 0, 0);
    player2.pause();
    //pause goodposition sound
    player.play();
    //play wrongposition sound

    // nummer 1 meer
    if(correct)
    {
      txt ++;
      correct = false;
    }
  }

  else {
    fill(0, 213, 255);
    player.pause();
    //pause wrongposition sound
    player2.play();
    //start goodposition sound

    correct = true;
  }
```

Appendix 5.1

Smart Moves | Anne wil Burghoorn | Emma Dhaeze | Jelle Wories| Jasper Faber

Toestemmings Formulier

Ik sta toe mee te doen in het onderzoek aangaande 'De Mirrorcle' afgenomen door Anne Wil Burghoorn, Emma Dhaeze, Jelle Wories en Jasper Faber, studenten van de Technische Universiteit in Eindhoven.

Ik sta toe dat er opnames worden gemaakt tijdens het onderzoek en dat deze opnames gebruikt mogen worden voor studiegerelateerde doeleinden. Ik begrijp dat meedoen met dit onderzoek vrijwillig is en dat ik gelijk laat weten wanneer ik me oncomfortabel voel. Ik begrijp dat terugtrekken uit dit onderzoek mogelijk is op elk gewenst moment zonder enige consequenties. Ik mag me beroepen op de mogelijkheid om mijn data te verwijderen uit het onderzoek. Het team mag mij uit het onderzoek halen als de omstandigheden naar enige vorm van gevaar wijzen. Vul alstublieft uw data hieronder in wanneer u de informatie heeft gelezen en geaccepteerd, en dat eventuele vragen zijn beantwoord.

Datum: _____

Uw naam: _____

Handtekening: _____

Dankuwel!

We waarderen uw medewerking

Appendix 5.2

Overt observational questions

What is being observated?

Is the choice between the choose exercise and the see progress clear?

- Is the user choosing the right option?
- Is the user asking questions about which button to press?

Is it clear for the user that there are no consequences the first few times the animation is played?

- Is the user already acting like there are consequences?
- Is the user doubting, does not know what to do?

Is it clear at first sight what the person has to do for the exercise?

- Are there questions asked by the user about the purpose of the exercise?
- Are there no questions asked, but is the exercise performed wrong.
- Does the user needs more information about the focus of the exercise?

When the spine appears, does the user get that he should stay in the box?

- Is it clear that the box stands for the marges the spine has to be in
- Does the user really pay attention to the hight and frequency of his leg exercise
- Is it clear for the user that the focus of the exercise is not on the hight of the knee but on the position of the back?

Design Choice: If the user focusses to much on the execution of the exercise itself and needs to be assisted by one of us we maybe need to find a way to make this clear.

Does the user interpret the feedback in the right way?

- If the spine appears red, does the user understand that he/she has to readjust his/her spine?

Is the feedback from the mirror enough?

- Is the user asking for extra feedback from the physiotherapist?

When the exercise is done and the interface in shown again, does the user automatically clicks on the see progress button?

- Does the user asks what to do now?

What is the overall reaction of the user on the mirror?

- Is the user enthusiastic?
- Is the user frightened of the whole interface and interaction?

Appendix 5.3

PUEU

Ervaarde nuttigheid

1. Door Mirrorcle te gebruiken zal ik mijn oefeningen sneller kunnen volbrengen.

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

2. Mirrorcle zal mij helpen om beter te presteren bij mijn oefeningen

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

3. Door het gebruik van Mirrorcle voor mijn oefeningen zal mijn productiviteit toenemen

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

4. Door het gebruik van Mirrorcle zal ik mijn oefeningen effectiever kunnen doen

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

5. Mirrorcle zal het makkelijker maken om mijn oefeningen te doen

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

6. Mirrorcle zal nuttig zijn bij het doen van mijn oefeningen

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

Appendix 5.4

Gebruiksgemak

1. Het zal makkelijk zijn om te leren hoe ik Mirrorcle moet gebruiken

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

2. Ik vind het makkelijk om Mirrorcle te laten doen wat ik wil dat hij doet

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

3. Mijn interactie met Mirrorcle is duidelijk en begrijpelijk

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

4. Ik vind Mirrorcle flexibel om mee te werken

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

5. Het zal makkelijk worden om behendig te worden in het gebruik van Mirrorcle

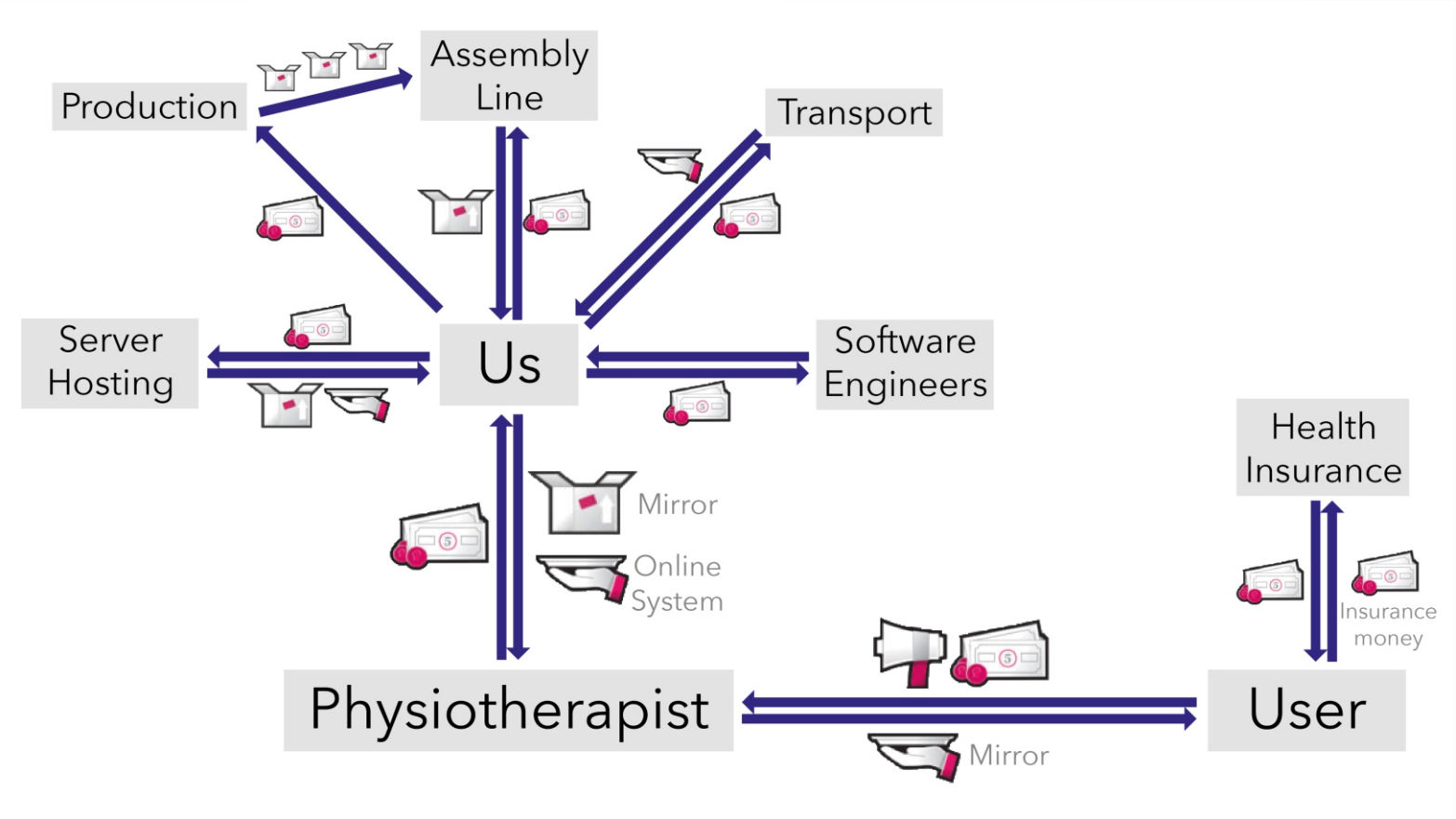
extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

6. Ik vind Mirrorcle makkelijk om te gebruiken

extreem redelijk licht niet licht redelijk extreem
Onwaarschijnlijk Waarschijnlijk

Appendix 6.1

Value flow



Appendix 6.2

Business Model Canvas

Key Partners
Physiotherapists

Beamer company

Kinect

Foil Company

Assembly

Transport

Key Activities
Marketing & Exposure

Coordinating

Developing Software (inhouse)

Delivering mirror and giving instructions to physiotherapist

Key Resources
Hardware and software

Value Proposition
Faster recovery through structured feedback on exercises

Exercise and recover in your own home, with the expertise of your physio-therapist

Motivational

Physiotherapist can offer extra service on top of their treatment

Customer Relationships
Marketing & Exposure

Coordinating

Developing Software (inhouse)

Delivering mirror and giving instructions to physiotherapist

Channels
Website

Exhibitions and Fairs

Physiotherapist

Physio equipment stores

Customer Segments
People with lower back pain

Cost Structure
Production costs of mirror

Software development

Transportation

Server hosting

Revenue Streams
Physiotherapists buy our product

(Monthly fees?)