DESIGNING A WEARABLE **GAIT ASSISTANT** FOR

PARKINSON'S PATIENTS

João Paulo Lammoglia | Final Master Project | **Industrial Design** | Jan 2016

TU/e

Designing a Wearable Gait Assistant for Parkinson's Patients

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ABSTRACT

The project revolves around the Freezing of Gait (FOG) phenomenon occurring among elderly patients with Parkinson's disease (PD). FOG is the temporary, involuntary inability to move and it can be experienced on turning, in narrow spaces, whilst reaching a destination, and in stressful situations. FOG is one of the most disabling and common mobility disorder in PD, and is usually observed in the advanced stages of the disease (Nieuwboer, 2013). Gait impairment and FOG seriously affect the quality of life of patients as it can lead to an unpredictable loss of control over movement and can result into falls.

The effectiveness of the Sensory cueing in improving gait in PD patients has been established by different researchers (Bagley, 1991) (Freedland, 2002). Sensory cueing can be defined as the use of external temporal or spatial stimuli to facilitate movement, gait initiation and continuation (Nieuwboer, 2007). It can be divided into three modalities: visual cueing; auditory cueing; and tactile cueing. Visual cues help to enlarge the stride length and generate sufficient amplitude movement (Azulay, 1999), while auditory cues help to stabilize the gait timing (Freedland, 2002).

The goal for this project is to combine the established scientific knowledge on FOG and Sensory cueing with an in-depth User Research into the design of an intelligent product/service for the assistance of a more independent lifestyle for PD patients with FOG symptoms.

In this document it is described my design vision and connected to it motivation for my Final Master Project. After, information about the context and project can be found. It is illustrated the project development, design approach, outcomes and future steps.

FROM VISION TO PROJECT

I design for Healthcare. I am interested in the mergence of the Physical, the Digital and the Sensory Experiences.

Good design is more than just making something look pretty, but is a key element in making products and services better, useful, and ultimately helpful to solving small as well as big problems in the world. Designers have a responsibility. To turn conflict into a new opportunity is what makes a design great.

I have a long concern for health problems among elderly people and I believe that design can present smart ways of managing them in an improved manner. User Centred Design and Inclusive Design; I strive to design technologies and solutions for those who need it most. In my vision, Designer is, by definition, an activist:

"An activist is someone who cannot help but fight for something. That person is not usually motivated by a need for power or money or fame, but in fact is driven slightly mad by some injustice some cruelty, some unfairness, so much so that he or she is compelled by some internal moral engine to act to make it better." Eve Ensler (2013).

MOTIVATION

The inspiration for this project comes from a close relative who suffers from Parkinson's disease (PD). I have been following the disease progression for several years, and have been surprised on countless occasions by the lack of assistance available. Taking drugs may come with side effects and in many occasions it is not completely efficient. This seems less than optimal, and I started wondering what can be done using less invasive methods.

As the elderly population increases and live longer, more people will require help with aspects of daily living and disease management. Design can play an important role in this scenario by implementing new methods, technologies and solutions in elderly health care and simultaneously making the lives of older adults easier and safer.

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INTRODUCTION

1. INTRODUCTION

According to the United Nations (UN, 2002), the older population is growing at a considerably fast rate. In absolute terms, the number of older persons has tripled over the last 50 years and will more than triple again over the next 50 years.

Overall, people are living longer and better than ever before. Nevertheless, the likelihood of a person developing a disability or chronic illness increases with age. Many older adults are disabled in one or more aspects of self-care and, in general, the elderly require more health care services. As the elderly population increases and people live longer, more people will require help with aspects of daily living and disease management.

Chronic conditions such as Parkinson's disease (PD) are usually progressive, gradually worsening the physical and cognitive state of the patient, until one comes to the stage where constant attention is necessary. Caregivers are amongst the most costly resources in healthcare (Takac, 2014). With limited resources in terms of personnel and infrastructure, the healthcare sector is challenged to develop novel instrumentation and therapy methodologies to cope with an increasing number of people with PD (Dorsey, 2007). The first contribution of this work addresses this problem and aims to deliver a wearable computing-based solution for independent motor training and assistance.

There is a clear need for strategies to help healthy older people remain productive and independent and to ensure that those who are disabled receive care and support so that they can live in their communities for as long as possible.

Age-related changes have great influence in the design of products, environments, and activities. The application of human centered methods for the design and development of assistive technologies can improve the lives of older adults in the areas of e-health, warnings and instructions, home safety, and the design of assistive devices (Czaja, 2009).

1.1 BACKGROUND

Parkinson's Disease (PD)

Parkinson's disease is a medical condition that progressively affects the neurological system, especially the region of a brain responsible for movement and that consequently causes difficulty of movements for a patient with PD. Degeneration of neurons that occurs in the brain causes insufficiency of dopamine which is a signalling chemical (neurotransmitter) crucial for efficient movements of a human body.

PD influences immeasurably everyday life of individuals afflicted with it. The disease manifests itself often by characteristic symptoms. There are four key motor symptoms of PD that are a definitive sign of onset of this condition. These symptoms can be grouped under the acronym TRAP (Jankovic, 2008):

Tremor

It is a characterized by rhythmic shaking of some body parts, especially limbs, that occurs completely unintentionally. There are two main types of tremor – the rest tremor that happens to 75% of cases (Hughes, 1993) and the postural tremor which is a bit less common. The former type can be showing itself when the muscles are resting whereas the later one appears during movement.

Rigidity

This symptom is appearing in muscles and causes a certain resistance to movement of limbs that are in a state of passive movement. This resistance occurs in the joints and is characterized by an enhancement of the muscle tone. Similarly to the tremor, there are two types of rigidity in PD: lead-pipe and cogwheel one. The names are connected to the feeling of a person attempting to bend a stiff limb. Moving a limb affected by the first type of rigidity feels like bending a lead-pipe whereas applying external force to the limb with second type of rigidity will result in unequal movement.

Akinesia (or bradykinesia)

Akinesia is a difficulty or even ineptness to start moving which results in freeze-moment of a patient unable to move. Bradykinesia has a similar basis but it can be described as a difficulty of moving in a normal speed therefore causing troubles with planning and executing any type of movement or with performing tasks (Berardelli, 2001).

Postural instability

As the name suggests this symptom is a connected to problems with keeping balance during movement. Together with FOG it is the cause of frequent falls of individuals with PD and therefore increases greatly risk of hip injuries. The simplest test for this symptom is performed by quickly pulling a patient to the back by his/her shoulders and observing the postural response. If a patient takes more than two steps backwards or the response is in any way abnormal it indicates the occurrence of postural instability.

PD has three general stages by which a doctor can recognize the progression of the illness. Those stages are judged and decided on by the severity of motor symptoms and the influence the disease has on the daily life of the patient. Sets of symptoms are used to validate the stage of this medical condition.

Early stage

Motor symptoms can be observed on one side of the body and although they might be unpleasant they do not yet affect daily activities. Changes is posture, ability to walk and facial expression are visible yet at this stage the medication for PD is working efficiently in suppressing the first symptoms. Often in this phase the mobility issues are less of a concern for a patient than the anxiety and often depression following the diagnosis.

Moderate stage

In this stage the mobility inabilities occur on both sides of the body and they are fully visible. Additionally challenges connected to balance and coordination might occur causing the postural instability and general feeling of lack of control. During this phase of the illness the so called freezing of gait, described by the patients as “the feeling of having your feet glued to the ground” (Giladi and Nieuwboer, 2008), may happen. Because the medication effectiveness is weaker some troubles with doses might be present. That means that symptoms might re-emerge between the doses as well as the high concentration of the medication in the beginning of a dosage can cause involuntary movements (Marconi, 1994).

Advanced stage

The influence of motor symptoms in the last stage is so strong that it cause difficulty in walking and moving. That causes the patient to live in a wheelchair or in a bed for most of the time. Assistance for daily activities is required and as the medications almost stop working their side effects can be very challenging to manage. All motor symptoms are present and combinations of non-motor symptoms are also possible.

PD is developed by individuals mostly older than 60 years old. Because of the general increase of life expectancy, the number of PD patients will also increase in the future. Although the illness is incurable, correct treatment enables the individuals affected by it to lead comfortable and productive lives for years after being diagnosed.

Freezing of Gait (FOG)

Freezing of gait (FOG) is a common symptom of PD, experienced mostly in the advanced stage, sometimes in the moderate stage of the disease. It is characterized by momentary and involuntary inability to move, either in the process of walking or during the initiation of a movement. It occurs in 50% of cases of patients with advanced PD (Macht, 2007). Giladi and Nieuwboer (2008) define it as "an episodic inability (lasting seconds) to generate effective stepping in the absence of any known cause other than parkinsonism or high-level gait disorders." In most cases an episode of FOG lasts few seconds, but in some case it can be up to 30 seconds. It is strongly influenced by the walking or moving situation. FOG is mostly triggered by turns, initiation of movement or in open spaces (Schaafsma, 2003). Additionally it can appear during passing through doors or crowded spaces (Giladi, 1992).

Because the symptom is involuntary it occurs unpredictably and influences the quality of lives for patients. Of course it causes the instability, both physical and mental due to lack of control over a body, and increases the risk of falls (Bloem, 2004). PD develops in elderly patients in most of the cases and it means that falls are dangerously enhancing the risk of hip fractures (Templeton, 1980). As mentioned the additional result of FOG can be the fear of future falls which causes anxiety and feeling of helplessness. (Wallhagen, 1997).

Three types of manifestation originally introduced by Thompson and Marsden (2000) are distinguished:

Shuffling

Characterized by placing small steps with almost lack of lifting the feet from the ground. This causes slow movement.

Leg trembling

Shaking of legs can be observed in the knees, which move slightly while feet are on the ground. In some case heels can be lifted or only one leg is trembling.

Complete akinesia

Complete inability to move and can be sensed as a feeling of rigidity and immobility. It usually appears in the initiation of the walking movement.

Occurrence of FOG is strongly dependent on the situation of the patient. The external symptoms of FOG are a result of internal process triggered by pathophysiology of the human motor system and/or the surrounding environment.

Five types of specific potential situations are described in the literature (Schaafsma, 2003):

Start hesitation

Initiation of a process of walking that is preceded by a postural change, for example from sitting to standing.

Turn hesitation

Turning situation that occurs during walking, often caused by an obstacle (door, an object, etc.).

Tight quarter hesitation

Situation of walking in narrow spaces or approaching them.

Destination hesitation

When reaching a final goal, such as a chair or a bed.

Open space hesitation

When there is no obvious reason in the space for causing trouble.

In addition to five described situation that can cause FOG, it can also be triggered by an emotional or mental trigger. Well known internal factors are stress, depression and anxiety, all of which are common side effects of being diagnosed with PD (Moreau, 2008).

Treatment and therapy for FOG

Treatment for FOG is difficult and mostly ineffective. The most common medication is Levedopa but there are cases of worsening condition after dosage of it. (Giladi, 1992).

It is possible for a patient to develop individual techniques that will help with the hesitation of movement. Such techniques have proven to be successful and they involve lateral swaying, stepping over someone's foot, stepping over lines on the floor or moving in a rhythm of music. In consequence to observing such individual methods of patients, sensory cueing has been developed as efficient therapeutic method. Rehabilitation based on such methods has receiving a lot of attention in the last years (Nieuwboer, 2008).

Sensory cueing is defined as "the use of external temporal or spatial stimuli to facilitate movement, gait initiation and continuation" (Nieuwboer, 2007). There are three main types of sensory cueing and they are: visual cueing, auditory cueing and tactile cueing.

Sensory cueing can be a valuable method for overcoming FOG episodes if adapted in a correct way to an individual situation of a patient. The main challenge concerned with that is the ability to detect and react towards the real-time FOG episodes.

Image 1. Freezing of Gait Therapy, parallel stripes

1.2 PROJECT OBJECTIVES

The goal for this project is to combine the established scientific knowledge on FOG and Sensory cueing with an in-depth User Research into the design of an intelligent product/service that can assist in a more independent lifestyle of PD patients.

The development of the system for gait assistance in patients with FOG has been set as the main goal of the project. This goal is carried out through the following three research objectives:

Contextualization of FOG using Sensory Cueing

Contextualization to improve the knowledge about sensory cueing applications, especially in terms of the User Experience. This is carried out through the analysis of existing clinical and commercial solutions and by the use of UX methods and theories while investigating the efficiency of these solutions in real-life situations. This helps determining the most suitable cue systems for freezing of gait or recovering normal gait after freezing episodes occurred.

A secondary motivation is to evaluate these sensory cues with respect to the development of an assistive device for PD patients suffering from FOG to be used in daily life. It is relevant to understand the patients´ subjective perception of the effectiveness of those systems.

Design of the Sensory Cueing System

The main point towards the main goal is the development of an intelligent system capable of actuating in real-time episodes, helping patients to overcome the temporarily inability to move. The goal is to design for both Gait Rehabilitation platform at home and a Real-Time Assistive platform for unsupervised environments. The design of the system should include the best features of the previously developed FOG cueing systems in terms of usability and robustness, and offer the space for the sensory and usability upgrade. The everyday ease-of-use of the system is considered as the top priority.

Validation of the Sensory Cueing System

Validating the design in a real-life situation is essential for the outcome of this project taking in consideration the emergence of the subject and its implications in daily living of elders with PD. It is also crucial to confirm the assumptions of this research while collecting feedback from the Users and Experts involved in this project. This opens opportunities for improvements and future applications.

1.3 APPROACH

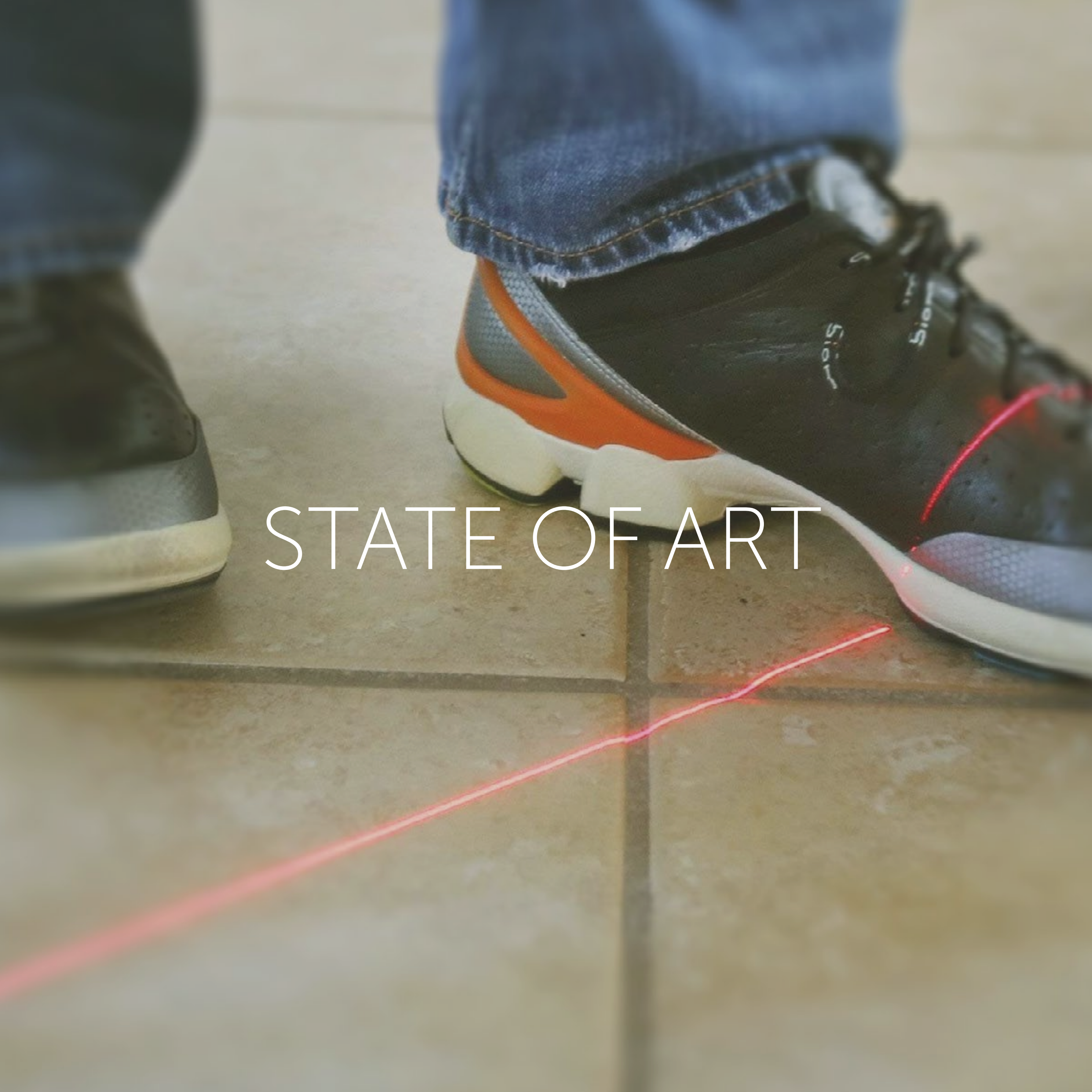
The project will consist out of two main phases. The initial phase will be explorative. It is about understanding the context, the user and design opportunities. The second, design oriented phase is about integrating the found design notions into an intelligent design.

Explorative phase

This phase is about exploring project's scope. Performed through interviews, observations, literature research, and by using UX methods and theories. At the end of this phase the first concept and a first prototype will be presented. After that, the artefact will be explored in a contextualized setting.

Design oriented phase

In contrast to the explorative phase, this design oriented phase is about putting the gained knowledge into the further development of the final concept. This will be performed by an iterative process, where a number of artefacts and solutions will be tested in the real context. The result of this process will be a refined final prototype, combining specific requirements and characteristics identified during the user research and validation.


STATE OF ART

2. STATE OF ART

FOG Detection

The active monitoring technology has a potential to objectively assess FOG on a long-term scale and to alleviate the episodes that happen in daily living, by using a timely detection and the context-aware sensory cueing. The usual approach to the assessment of motor related symptoms is to use wearable inertial sensors in order to measure the kinematic parameters of the movements of body segments (Takac, 2014).

The literature review has shown that there does not yet exist a mature FOG detection system (available on the market), although a few research groups might be close to the required solution. Currently, it is hard to directly compare the results between the groups and pick the best approach due to the difference in the datasets and the measurements they used in evaluation.

As this project is not focusing on the development of a detection system for FOG episodes, rather in the sensorial feedback system, a general review was made to assure that there exist feasible technologies in order to detect these episodes. This knowledge will be used as input for the product development.

A table with a chronological review can be found in the appendix A.

Sensory Cueing

People with PD can improve motor functions and decrease FOG severity by performing rehabilitation exercises (Tomlinson. 2012). In the same direction, clinical research in motor training in PD shows that sensory cueing while walking helps to decrease FOG severity (Nieuwboer, 2007).

Sensory cueing is defined as "the use of external temporal or spatial stimuli to facilitate movement, gait initiation and continuation" (Nieuwboer, 2007). There are three main modalities of cueing: visual cueing; auditory cueing; and tactile cueing. Continuous cueing has a positive impact on the gait but wears off over time [Nieuwboer, 2008], as users get used to the stimuli. A solution to mitigate this effect is to give the cue only in the case of a FOG event for a limited period of time.

Stern (Stern, 1980) earlier described methods for overcoming FOG. The most frequently used methods were verbal or auditory stimuli such as giving a marching command similar to that given to a soldier. Visual stimuli such as stepping over objects, including inverted walking sticks, another person's foot, and carpet patterns, were also helpful. The effectiveness of these tricks has been reported many times by other investigators (Takac, 2014; Cubo, 2004; Dietz, 1990; Ferrarin, 2004; Jiang, 2006).

The theory behind the sensory cueing predicts that improvements in walking speed, stride length and cadence should be observed when external stimuli are applied during the gait of a PD patient. However, not all sensory modalities act equally on all gait parameters. Visual cues, which are spatial in nature, help more to enlarge the stride length and generate sufficient amplitude movement (Bagley, 1991), while rhythmical auditory (temporal) cues target to stabilize the gait timing (Freedland, 2002).

A brief literature review of work so far performed in the field of Sensory Cueing is given below.

Visual Cueing

Examples of visual cueing include perpendicular stripes on the floor (Azulay, 1999), walking sticks (Dietz, 1990), rhythmic flashing light (Wegen., 2006), a beam mounted in a treadmill (LMU, 2012)(Image 2.), etc.

Image 2. Beam mounted in a treadmill

Auditory Cueing

The most used solution for rhythmic auditory cueing (RAC) is metronome. It has been used in a variety of applications such as a bluetooth headphone connected to an Smartphone App, etc. (Freedland, 2002; Ledger, 2008).

Image 3. (https://en.wikipedia.org/wiki/Metronome#/)

Tactile Cueing

Tactile cueing via tapping on patient's shoulder or a vibrotactile anklet and wristlet has been successfully used (Suteerawattananon, 2004)(Image 4.).

Image 4. Vibrotactile Anklet

2.1 BENCHMARKING

To find out which products designed for PD patients with FOG are available on the market, a benchmark research was performed. As can be seen from this overview, solutions for PD patients with mobility issues are not widely available in the market. On the one hand this allows for open exploration, but it also gives a limited frame to work with.

These existing devices can take several different forms: a cane that emits a laser light from its base, or an attachment that can be affixed to the handles of a walker, emitting a beam at the user's feet, etc. Some of these products are presented as follow.

Image 5. Agilitas, Visual Cueing device. (www.agilitas.com.au)

Image 6. Laser projector mounted in a walking cane (www.accessibleconstruction.com)

Image 7. Laser projector mounted in a walker. (www.eas.pt)

Image 8. Visual cueing glasses for PD patients.
(www.youtube.com/watch?v=izaGU_khU1Y)

Image 9. Visual cueing glasses for PD patients.
(http://medigait.com/pd/)

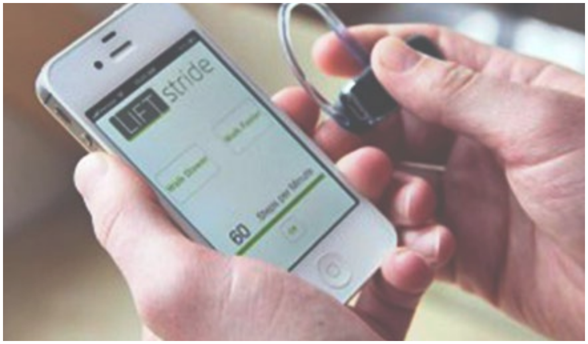


Image 10. Metronome based headphone and App.
(http://www.liftware.com/)

Image 11. Auditive and vibrotactile device.
(http://www.vitamove.nl/products/parkinson-buddy/)

Image 12. Wristlet vibrotactile device.
(http://mcl.open.ac.uk/MusicLab/86)

2.2 CRITICAL INSIGHTS

The assessment of FOG is a difficult task due to the variability of its manifestation in each patient. An additional aggravating circumstance is that FOG happens more often during daily life at the home and much less often during observations at the doctor's office or in a research laboratory. A completely robust, clinically proven solution for the automatic detection of FOG still does not exist, but there are several research groups that have been making the advancements towards the final goal.

Sensory Cueing has shown numerous benefits for patients with PD, yet it is not possible to determine its effectiveness in every situation due to diverse factors such the use of medication, mental state, etc. It is important to combine the user's habits and needs with a coherent concept for each patient. Thus, is essential to create customizable products that can be upgraded or easily changed, adapting to the user, its characteristics and context.

Automated devices have proven to be effective under testing. According to different researchers, a wide number of users indicated that sensory cueing was beneficial.

Through analysis of literature research and state of art it was also possible to gain detailed knowledge about Parkinson Disease (FOG) and solutions to help overcoming the hurdles that it causes to individuals suffering from it. Although existing projects are innovative they could have additional benefits, especially related to the User Experience of such products.

There exists an opportunity to create a valuable and effective product that can bring a new light on current developments. The opportunity of this project is to develop a more interactive and responsive design to improve the user experience of Parkinson's patients suffering from gait and mobility issues.


STAKEHOLDER
archipel
archipel

3. STAKEHOLDER

Client Involvement

For this project I am collaborating with Archipel, a Dutch based company that manages a diverse number of Nursing Homes across the Netherlands. Archipel has its own Parkinson's expert team. It consists of Parkinson's practitioners, including doctors, psychologists, physiotherapists, occupational therapists, speech therapists, nutritionists, nurses, social workers and sexologists. The expert team focuses on clients with Parkinson's disease, their families and caregivers.

Archipel has showed a great interest in collaborating with the project by providing clinical knowledge and access to professionals and patients. They are interested in the development of innovative solutions for Parkinson's patients, especially those related with mobility issues. Therefore, an appropriate case for this project.

Expert collaboration

Image 13. Han Vissers at Archipel Landrijt

Han Vissers is a Senior Physiotherapist specialized in the treatment of older adults with chronic diseases such as Parkinson's. He is a Specialist at Archipel Landrijt and Archipel Domelhoef.

The professional collaboration and guidance during the project allows to elucidate the main areas in which physiotherapists can assist people with Parkinson's Disease. These areas are: posture, range of movement, walking and turning, balance and transfers.

3.1 CLIENT ANALYSIS

Understanding the stakeholder's point of view is a important step towards an effective design process. In order to get acquainted with the client's needs, requirements and perspectives a number of UX tools will be adopted during this process. The following methods are applied: Contextual interviews, Field of Study (observation), Co-constructing Stories and Video Recording.

Contextual Interviews

The contextual interview took place at Archipel Landrijt. It was video recorded and transcribed (Appendix).

Image 14. Contextual interview at Archipel Landrijt

From the contextual interview it was possible to outline some specific requirements for Freezing of Gait and Parkinson's rehabilitation. It was stated few points for exploration. The first point was related to comfort and ergonomics, especially when the patient has to use devices and equipment for an extended period of time. The second point was related to usability (ease of use), as the Physiotherapist mentioned that some of the patients usually have an impaired cognitive skill. The main requirements was that the system should be easy to use, comfortable, discreet and above all to be safe to use in any situation.

During the interview some of the assumptions about methods for overcoming mobility issues episodes (FOG) have been clarified. It was stated some of the solutions already investigated such as using visual, auditory and tactile cueing. He agreed that some of these approaches can certainly help patients to overcome the freezing of gait as well as balance and posture. Although, he also mentioned that the efficiency of such approach is conditioned to certain occasions, such as the health and emotional condition of the patient.

Field of Study (Observation)

While observing and following the experts during their work hours, it was possible to identify specific requirements for gait training in Parkison's disease.

The observation took place at Archipel Landrijt and started with a analysis of the methods and tools used by the physiotherapists in gait and balance training sessions. The tools range from simple fabric stripes (image 14) and plastic bricks (image 15) to an Interactive game system that uses a depth camera and a TV screen (image 16). Subsequently, a observation of the interaction between patients and physician was addressed. It was possible to briefly understand some of the methods and needs.

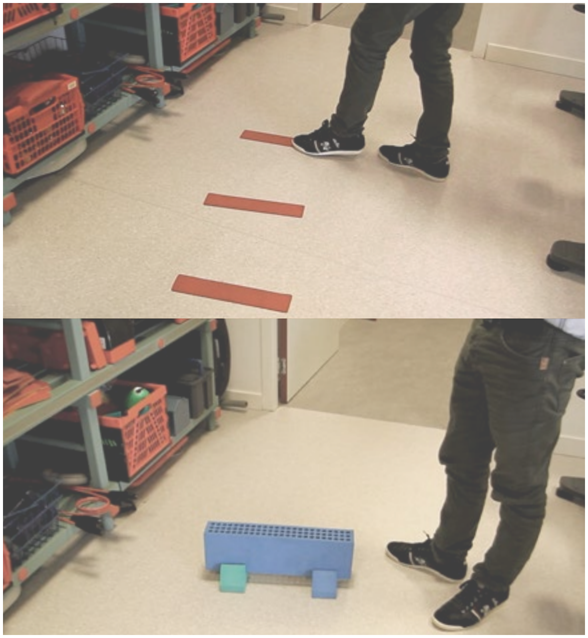


Image 15. Tools for gait training at Archipel Landrijt

Co-constructing Stories

Co-constructing Stories provided with feedback both useful, as it was inspiring, and usable, as it was specific to the context and structured. The technique elicits stories from the experts, thus it reveals grounded feedback as stories indicate reasoning. Moreover, stories were easily remembered, communicated and they established a shared vision among the team members. This technique helped eliciting in-depth feedback that was specific to the context, in relatively little time. It gave validation over multiple points of the project to assure that it is on the right track, from the user's (physicians and patients) perspective.

Tools for discussion were created. These tools included interviews, a map of their facilities (Rehabilitation Centre) and some figures and post-its with which they could physically illustrate movements (Appendix). The result of this interaction was the understanding of a coherent scenario, in order to elucidate some of the patient's needs and guide the design process and first iterations.

Image 16. Co-constructing Stories with experts at Archipel


Image 17. Interactive Game System

3.2 CRITICAL INSIGHTS

From the Client Analysis it was possible to determine the initial requirements and needs for the project. Some of these requirements are summarized below.

Safety

Products should be designed to hope a wide variety of physical and sensory impairments, supplying safe, supporting features before they may be needed. Such products should be free from danger, injury, or damage under reasonable conditions by all who may be expected to handle, use, or operate them.

Comfort

Products should be free from disturbing, painful, or distressing forms or features. In many cases, comfort for all can be achieved with simple adjustments of type size, contrast, colour, proportion, or dimension.

Convenience

Products should be designed to provide convenient, handy, and appropriate use for all who would operate them. This means such things as convenient storing, repair, cleaning, packaging, and carrying.

Ease of Use

Products should be designed for simple, easy, and uncomplicated use, regardless of age or limitation. Understandable instructions, simple operations, and logical controls that do not confuse them, tire their muscles, or defy their dexterity.

Embodiement

Products should be designed to accommodate and fit the widest possible range of appropriate human dimensions. Eye glasses, hearing aids, crutches, canes, walkers, and seeing-eye dogs become extensions of one's body and should be considered along with the person who must use them.

It was also possible to identify different parameters that PD patients with Freezing episodes have to deal with when using Sensory cues. These parameters are related to cognitive and motor skills:

Perception

Patients, generally, rely on sensory cues to perceive the various forms of information demonstrated. Perceiving information communicated by a product's form, components, controls, displays, instructions (visual, auditory, tactile), etc.

Interpretation

Easily understanding the information communicated, displayed, transmitted, or symbolized (clarity, readability, comprehension).

Failure to understand messages causes to diminish the competence and safety, and prevents patients from responding appropriately. People with one or more sensory impairments or disabilities must rely on their remaining senses to complete the tasks.

Response

Reacting to the information received (human motor response, machine reaction).

Most products that patients use need some form of response from the user. Many people with physical and sensory limitations are prevented from responding to the dictates of a product's functional demands.

The client analysis helped to validate the perceived design opportunity from the expert's perspective. This result is open for discussion as the experts are part of a big community of Parkinson's physicians. Despite that, the design opportunity showed potential to design for and the initial discussions will help to concretize the project. Retrieving the expert's opinion upon these initial ideas and assumptions helped me to find a direction for the next steps.


USER RESEARCH

4. USER RESEARCH

Effective user experience starts with a good understanding of the users perspectives. Not only who they are, but to dive deeper into understanding their motivations, behaviour and needs. This deep insight into the users will help keep the project focused on delivering a great experience.

4.1 USER PERSPECTIVE

The first step in the user requirements analysis is to gather background information about the users and the processes that currently take place. The following methods will be adopted: Contextual Interviews, Field of Study (observation), Storyply and Video Recording.

Contextual interviews

The contextual interview with patients took place at Archipel Landrijt and home environment. From this session it was possible to identify specific user´s behaviour and needs. The interviews were video recorded. The User target group is composed by three older adults, from 70 years and above, with PD and FOG symptoms.

Analysing the data from the interviews was a difficult task. Identifying each patient needs and trying to create a pattern proved to be very challenging. Each patient brings different characteristics related to physical condition, motor skills, motivation, needs, etc.

Some of the insights collected during the interviews are summarized below.

There is mounting evidence to suggest that the patients constitute a stigmatized group. Products should be discreet and safe while using in public.

Designing for usability is essential while designing for the User group. Motor skills have a great influence on how the patient will use the product. Easy to use products, good grip, clear interface, simple information, adequate materials and mono-tasking.

Products designed for independent use are essential for this patient´s quality of life. Products that are reliable and safe to use independently at indoor environments can bring comfort and freedom for the patients.

People with Parkinson's often need more time to perform activities because of changes in hand coordination, muscle stiffness or slowness.

While analysing the data collected it was also possible to map some of the emotional stages of the patients. In addition to motor symptoms, Parkinson's disease is characterized by emotional dysfunction. Depression can affects a high percentage of Parkinson patients and other psychiatric conditions include anxiety and apathy.

As Parkinson's progresses, bringing new challenges, the patient goes through many of the emotions and stages of adjustment. Each person will experience the stages in their own order and at their own pace. Emotional disorders associated with PD are increasingly recognized as equally disabling.

Focus on abilities rather than inabilities. Each person's experience of PD is unique.

The emphasis in providing health care to the elderly should be on maintaining functional capabilities.

Clear information helps the patients to feel more confident while using a product. Anxiety can occur when the patient can not perform a task properly.

The patients agree that a clear communicational channels between them and the physicians create a sense of safety and confidence.

Field of Study (Observation)

Image 18. Gait training session

While observing a rehabilitation session, it was possible to identify general User requirements for gait training in Parkison's disease.

The observation took place at Archipel Landrijt and started with a analysis of the behaviour of the patients before and whilst training. Some of the insights from the analysis are summarized below.

Motor fluctuations. When PD patients are moving well, they say they are 'on'. When they are stiff and bradykinetic, they say they are 'off'.

Patients experienced involuntary movements whilst 'on'. These are dyskinesias.

Patients experienced shuffling gait. Gait is characterized by short steps, with feet barely leaving the ground. Small obstacles can cause the patient to trip.

Decreased arm-swing.

Rather than the usual twisting of the neck and trunk, PD patients tend to keep their neck and trunk rigid, it is required multiple small steps to accomplish a turn.

Forward-flexed posture. In severe forms, the head and upper shoulders are bent at a right angle relative to the trunk.

A combination of stooped posture, imbalance, and short steps. It leads to a gait that gets progressively faster and faster, it can end in a fall.

The training session used visual cues consisted in coloured stripes placed on the floor perpendicularly to the walking direction. The interstripe distance was personalized and optimized by the physical therapist during the first rehabilitative session. The physical therapist tested each subject with different distances between the stripes, The therapist asked the patients to walk over the stripes trying to step over the next stripe and avoiding trampling on them.

The outcome measures were gait speed, stride length and cadence. After the training period, gait speed and stride length had clearly increased in the group.

During the visual cueing training some requirements were identified. They are summarized below.

The therapist moved the visual setting several times. This means that portability and modularity are interesting point for improvement.

Patients trying to make a turn often try to look at the closest visual cue and give small steps toward the direction. This opens opportunities to explore guided walking through the use of directional visual cues.

Some patients tend to respond better to a specific type of cue (geometric lines, plastic bricks, coloured squares, etc). This prompts the idea that cues may have a different profile of effect.

Although the observation resulted in several insights, It is still necessary to develop a better understanding of the user group. Creating a persona and scenarios that can guide the design process and summarize common characteristics (patients) is essential for the outcome of the project.

Storyply

Storyply presented an organized way to create coherent personas, scenarios and its developments. Story Thinking is a new approach that helps creating open-ended stories and to envision the possible conflicts and consequences that the User could face in an earlier stage of the design process. It is important to take into consideration the behaviour of the users in each phase of the process. Storyply helped to organize these scenarios while providing visual aids that supported the design process in an efficient manner.

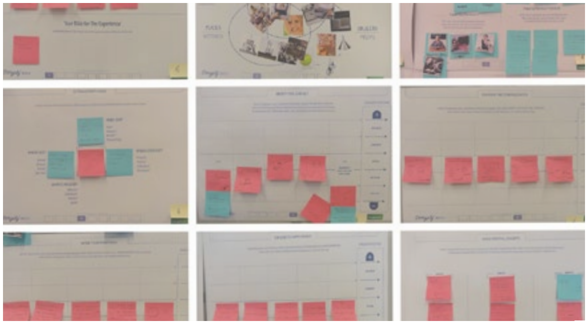


Image 19. Storyply workshop

The result was the development of a persona and scenario to guide the design process. This is especially due to the fact that the patients share many characteristics but as well as differences. It will be important to summarize the data collected into a coherent representation of the patients. The persona and scenario are presented next.

Persona and scenario

Image 20. Patient training at Archipel Dommelhoef

Angela, Female
Age at interview: 86
Age at diagnosis: 78
Background: Retired
Brief outline: Diagnosed in 2007. She experiences tremor, freezing and rigidity and problems sleeping at night.

Eight years ago, Angela noticed a tremor in her hands and that she was dragging her feet when walking. After a year, the tremor was slightly worse so Angela was referred to a consultant neurologist, who confirmed that she did have Parkinson's Disease. For a while she took medications but it gave her a severe stomach upset so she had to stop taking it. Angela now takes slow-release medicines at bed time.

The biggest problems Angela experiences are difficulty sleeping and walking. She takes other medicines to help relaxing and an occasional sleeping tablet. But she is very tired a lot of the time which affects her day to day life.

As well as the tremor and dragging of feet, she experiences freezing when she is walking and she gets rigidity in her limbs at times, which can be painful.

She tries to stay positive by using humour to cope with the symptoms, and although she felt quite depressed when she was first diagnosed, she has more good days than bad days at the moment. It helps to meet others at the local support group to compare notes and to be in the company of people who understand what it is like to live with Parkinson's disease.

Angela tried acupuncture but she didn't think it made any difference. Besides gait rehabilitation and training exercises, more recently she has been having Bowen treatment with a local practitioner once a week, which is a very soft muscle manipulation. It makes her feel very relaxed and it takes the tenseness in the body away for a while.

Angela is always well dressed and like wearing a bit of make-up. She likes jewellery and she wear a watch given by her mother. Angela don't like feeling disabled, she tries harder and harder to do all her daily tasks independently.

Modern technology is definitely an issue for her. She has problems reading small words and her hands are presenting constant tremors. She likes simple things and rely on a old phone for her daily conversations.

Angela uses visual cues for walking inside her apartment. The physician recommended that she could use visual memory notes to help her overcome freezing episodes. She usually hang post-its on the walls.

Considerations

Understanding the User perspective proved to be crucial for the development of the project. While applying UX methods, it was possible to guide the project direction and find important aspects of user behaviour and needs. The persona and scenario created will help to summarize all the information collected and provide grounded feedback as stories indicate reasoning.

This will help eliciting aspects specific to the context, in relatively little time. It will provide validation over multiple points of the project to assure that it is on the right track, from the user's perspective.


DESIGN PROCESS

5. DESIGN PROCESS

After the conducted research and iterations it was decided to focus the project on the theme of visual cueing in treatment of FOG in Parkinson Disease. The choice for the visual cueing could also be combined with different sensory cueing approaches.

Projects using this method already exist which was partly influential for the choice. The potential of visual cueing has not been fully explored in current state of art and that creates design opportunities to develop innovative and useful projects.

The first idea is based on a wearable concept of delivering visual cues for a user to guide his/her steps during a freezing episode.

The User Experience of such device might be on the top priority during the project development. Most of the devices available are not fully interactive, reliable, engage-able or playful. In order to deliver a good experience and intelligent solution, a holistic approach is necessary.

From the first explorations, it was possible to outline some design guidelines for the concept development.

Specific requirements for Rehabilitation of PD patients

Improvement in comfort and ergonomics

Usability, patients have impaired cognitive and motor abilities

Wearable system

Readability. Easy to read and interpret the information displayed.

Ease of use (user interface, software, etc)

Independent use. The device needs to work in indoor environments (home, etc) without external assistance.

The detection of such episodes are of great interest

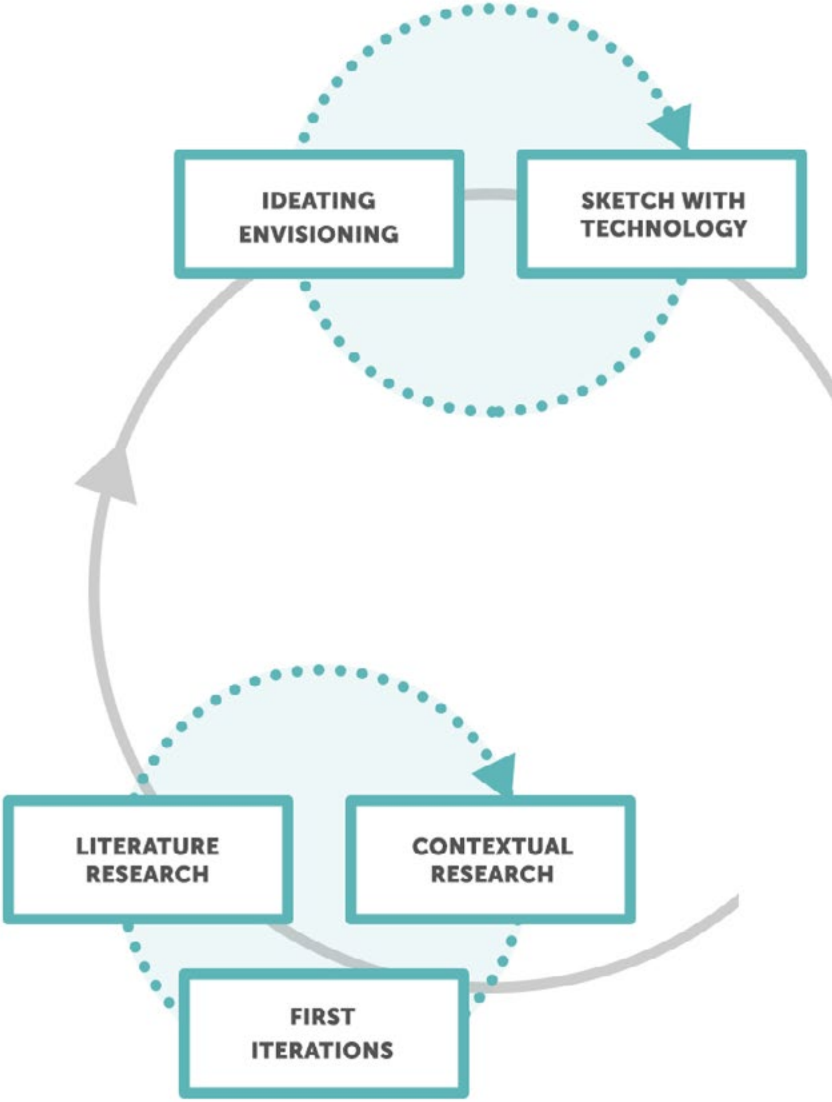
Open ended design, enabling the system's upgrade by the user's involved

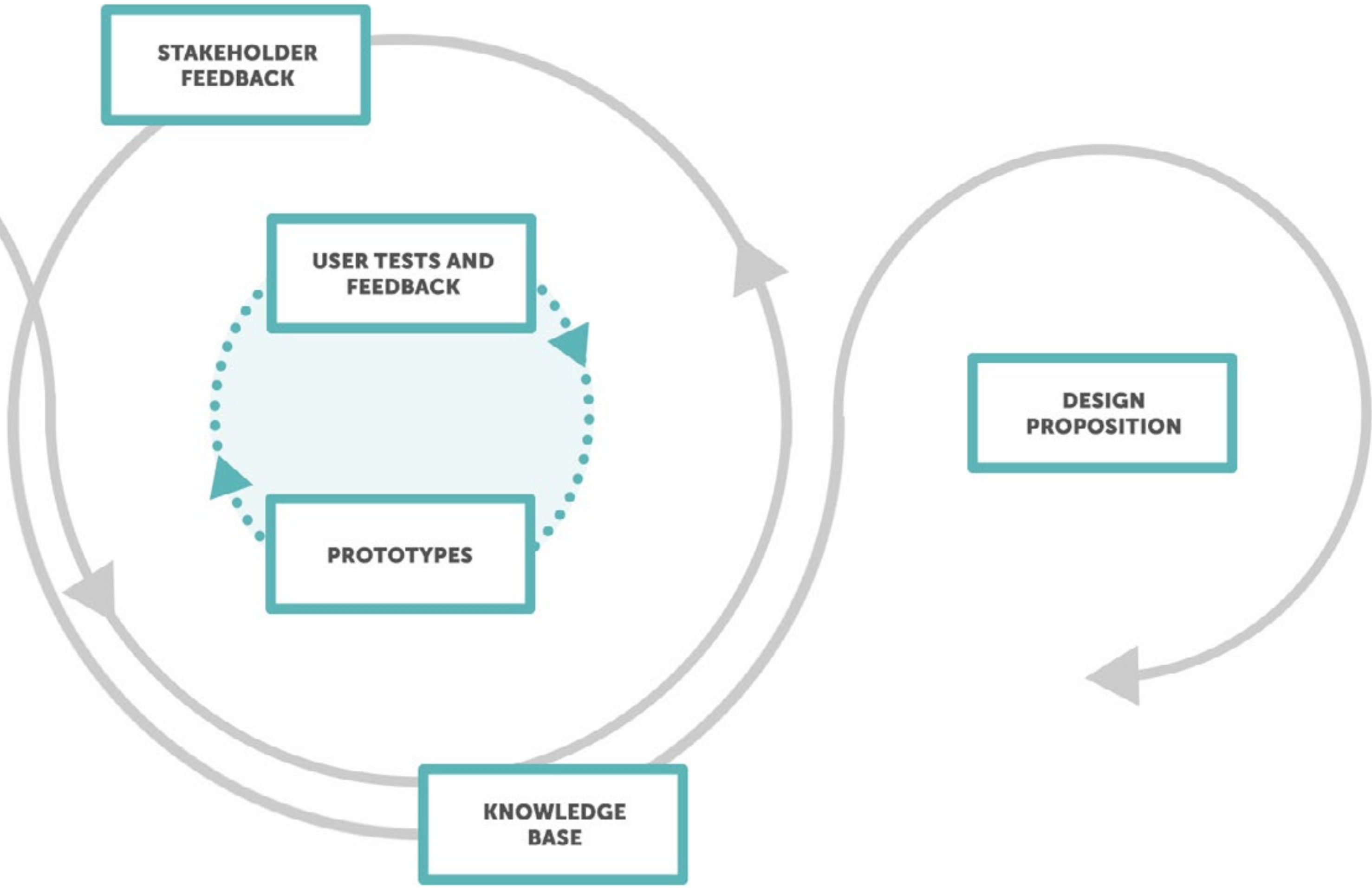
The experiential approach will be applied in order to provide as much quality insights as possible. With the requirements and guidelines in mind the first concepts were created with which can be found in the next session.

Experiential Design approach

Designing innovative products provides serious challenges from a design management perspective. Since users have no frame of reference it is often not possible to ask, using traditional research techniques, for the requirements of these future products.

The combination of a reflective transformative design process, a open system with strong involvement of users and experts, the generation of quality insights can take place. An experiential design approach will be applied.




STAKEHOLDER FEEDBACK
USER TESTS AND FEEDBACK
PROTOTYPES
DESIGN PROPOSITION
KNOWLEDGE BASE

5.1 IDEATING & ENVISIONING

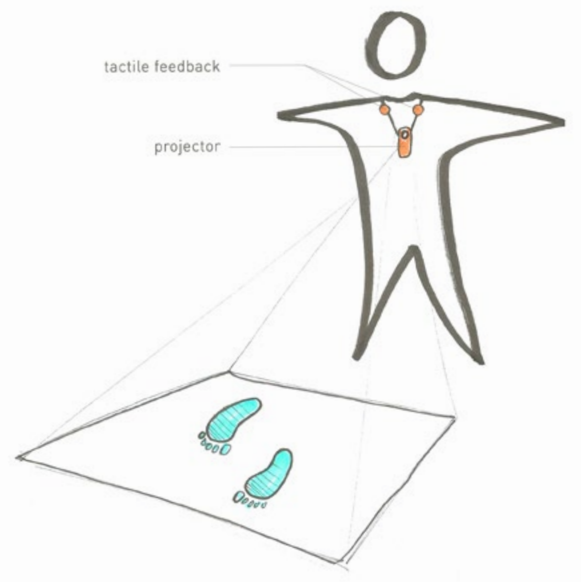


Image 25. Smart beamer/projector mounted in a necklace

The first concept is based on the use of a small interactive projector attached to a necklace. The idea is to implement interactive visual cueing. Images of steps will appear when a freezing episode is detected. The assumption is that the visual feedback can serve as a guide for improving the patient's gait.

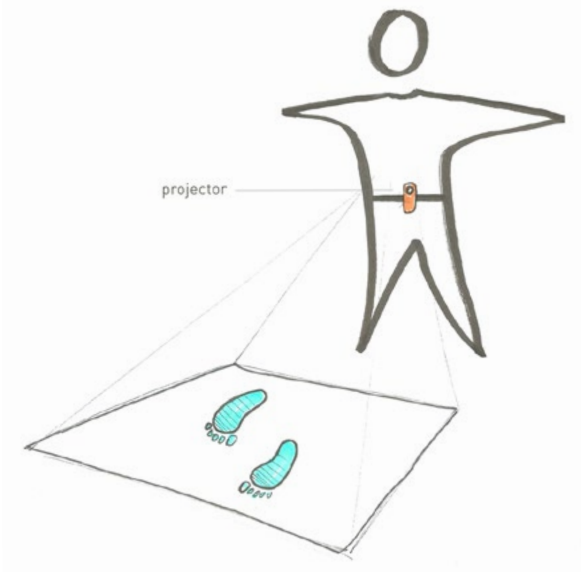


Image 26. Smart beamer/projector mounted in a belt

The second idea is based on the use of a small interactive projector attached to a belt. Images of steps will appear when a freezing episode is detected. The assumption is that the visual feedback can serve as a safe way to guide the patient's gait.

5.2 PROTOTYPES

Prototype 1 - Necklace

The first Prototype is based on a Touchjet Pond projector. The device has a Android OS and a built-in Infrared camera and Stylus pens (IR) for interaction. The projector is mounted inside a MDF box. A velcro band is attached to the box so it can serve as a necklace.

Image 27. Prototype mounted in a necklace

Image 28. Prototype mounted in a necklace

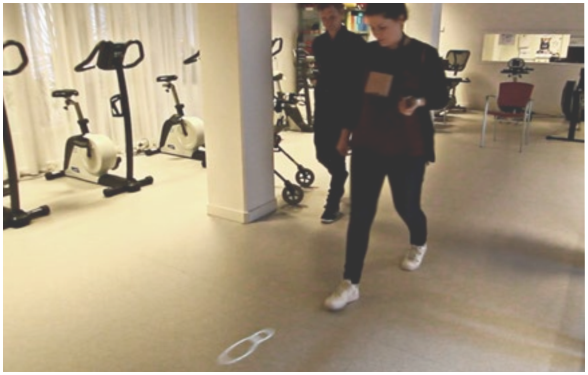


Image 29. Experts testing the prototype

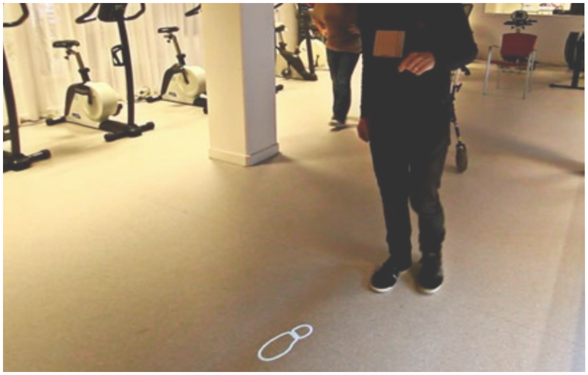


Image 30. Experts testing the prototype

The use of video and interactive images showing steps and movements helped to illustrate the interaction intended. The basic test occurred at Archipel Landrijt. The feedback was positive. However, the physiotherapists believe that the necklace can be harmful for the patient´s postural balance. The experts feedback can be found next.

Expert's feedback

The first tests with the projector mounted on the necklace was positive and opened opportunities for further explorations. The physiotherapist agreed that the projections can help the patients in certain occasions. He believes that, although the projections are not stable enough, it is possible to guide the patients during freezing episodes.

Han also mentioned that the projections need to be simpler and respond to the user´s behaviour. He thinks that using sensors for understanding the patients body is an interesting solution. He would like to know how the patient is moving and how the device can respond accordingly.

The test was also performed by another physicians at Archipel Landrijt. While testing the projector with one female therapist it was clear that the circumference of the chest can greatly influence the angle and reach of the projection.

The physiotherapists agree that the necklace may be painful for the patients and badly influence in their posture and balance.

Prototype 2 - Belt

The second prototype uses the same Touchjet Pond interactive projector mounted on a belt instead of a necklace. The projector is mounted on a steady cam support attached to a neoprene belt.

Image 31. Smart beamer/projector mounted in a belt

Image 32. Smart beamer/projector mounted in a belt

Image 33. Expert tests with belt

Image 34. Using geometric visual cues

Image 35. Experts testing the portable device in a stroller

It was tested different types of visual cues such as stripes, geometric shapes, video of a person walking and a chess pattern. It was also investigated how can the equipments used by the patients interfere with the projections and cues. Tests with walking sticks, strollers and walkers helped to foresee some problems that could occur in the design development. A portable and easy to use device can bring some light in the current developments. The experts feedback can be found next

Expert’s Feedback

The first tests with the second prototype took place at Archipel Landrijt and presented beneficial insights for the project development. The Projector mounted on a belt proved to be a better choice for the physiotherapists.

Han believes that the prototype can be more comfortable and safe to use then the first one. He agrees that the projector on the belt is much more stable and does not bring risks of suffocating and injuries for the patients. The physiotherapists agreed that the belt can be easier to use then the necklace due to the fact that some patients can not stand their arms over the shoulders. The therapists agree that the belt does not interfere on the patient´s balance and posture.

The different cues tested proved to be beneficial in different aspects. Han believes that providing geometrical cues (arrows) for guiding the patients in a path can improve the stride length and amplitude. He also believes that using continuous cueing can be beneficial when the patient is already walking. This will keep the patient´s walking cadence.

During the tests it was also possible to iterate with different equipments used by the patients. Walking sticks and a strollers were tested. The therapists agree that a portable device could be interesting. An easy to use solution that could be mounted in diverse locations.

Han also mentioned the importance of understanding the patient´s needs in a real-time situation. Using sensors that provides feedback form posture, balance, quantity of episodes, etc. He believes that an online platform could be created in order to follow the patients progress. The idea of creating an App that could connect physicians and patients could bring a bigger value to the system.

Detecting freezing episodes is of great interest for the patients. Han believes that a smart detection system can be applied to the concept. The solution has to be open for upgrades, in order to provide different approaches and training exercises.

The therapists agreed that this concept could be a good solution for triggering a more playful gait training. Having a device near to the body is beneficial for sensing the physical changes on the patients

After the first tests it was decided to focus solely on the projector mounted on the belt. Few improvements will take place in order to adequate the prototype for the first User tests.

5.3 USER TESTS

User test 1 - Projecting footsteps on the floor for continuous walking

The first User test was held at Archipel Dommelhoef. The prototype is based on a Interactive projector mounted on a belt.

The aim for this test is to identify the possibilities of using visual cues to help the patients to overcome freezing episodes. The Users target group was composed by two male patients with approximately 80 years old.

The test was based on projecting footsteps for continuous walking. The goal is to understand how the patients react to the cues and how can the cues influence the gait of PD patients.

The cues are provided each time the patient step inside the image. After the first step, footstep projections will keep appearing in order to guide the user into an end point inside the room.

The feedback was mainly positive but there are also different issues while using the cueing system. These are explained on the User´s feedback below.

Image 36. Continuous walking projections

Image 37. Continuous walking projections

User’s feedback

From the user´s feedback was possible to identify points for improvement and exploration.

Patients found that the visual cue was not very clear for interpretation. The footsteps were too straight and sometimes could mislead the patient to step in the wrong foot image.

The patients didn’t experienced any freezing episode while using the prototype. This indicates possibility of using it in a real-life situation.

The floor tiles proved to be a hurdle for the patient´s attention and focus. The patients complained that the floor tiles were interfering in the projections. This is a concerning problem that needs attention.

Patients agreed that the visual cues can be more responsive to their body. They believe that an interactive system that detects the episodes and react accordingly. The patients also believe that interactive projections can be easier understood. The projection should only react when the user steps in.

User test 2 - Projecting geometric cues for directional guided walking

The second User test was held at Archipel Dommelhoef. The prototype is based on a Interactive projector mounted on a belt.

The test was based on projecting a small white dot on the floor. The goal for this iteration is to provide visual cues that can guide the user in a determined direction. The objective is to understand how the patients react to the directional visual cues and how can the cues influence the gait of PD patients.

The cues are provided randomly through out the room. The white dot display three possible directions, front, left and right.. The patients need to follow the dot according to each command.

The patients turn slowly taking numerous steps. It seems that the directional cue helped the patients to smooth the freezing on turning, while they focus their attention solely on the dot. In this case the floor tiles didn´t interfere to the patient´s focus and attention.

The patients agreed that the directional visual cue could help them while they are trying reaching or sitting in a chair. The dot could slightly indicate the patient how to turn and sit.

Image 38. Directional cueing tests

Image 39. Directional cueing tests on turning state

Image 40. Directional cueing test

Image 41. Directional cueing tests on turning state

User's feedback

The feedback provided during the user tests helped to build a clear vision about the improvements that had to be made.

The patients responded well to the visual stimuli, following the directional cues as soon as they were presented. Some critical insights from the second user test are presented below.

While turning, the patients felt more confident and safe. No freezing episodes occurred during the test.

The visual cues were simpler to read and easy to understand.

The white dot could display movement to indicate clearer the direction.

The patients indicated that the belt was not comfortable. One patient complained about the usability. He found difficult to close the velcro at the back. The projector was heavy and the belt too small for one of the patients.

A more responsive projection could help the patients to accomplish simple tasks like sitting in a chair or bed.

5.4 IMPROVED PROTOTYPE

Prototype 3 - Belt with interactive projector using a IR emitter mounted in a shoe's sole

The final prototype is based on a smart interactive projector with infrared camera mounted on a belt. A infrared emitter is mounted inside a shoe sole. The sole is composed by three layers; two layers are covered by copper tape and one layer of EVA foam between.

The projector is running a Processing 3.0.1 sketch directly in the Android. The sketch is based on interactive footsteps that react according to the user interaction.

Image 42. Infrared emitter sole

Image 43. Infrared emitter sole

Image 44. Interactive projector and IR emitter

The prototype was tested with a voluntary patient at his home environment. Although the software is working well, the interaction is still not completely satisfying. Some minor tweaks will provided a more interactive and responsive experience.

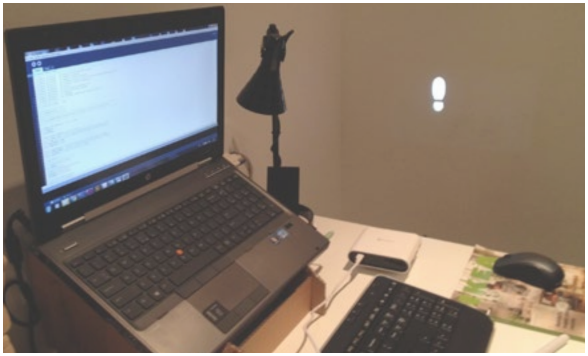


Image 45. Processing sketch running on Android device

Image 46. IR emitter sole inside a sock

Image 48. Interactive projections

Image 47. Interactive projections

Testing

The prototype 3 was tested with a voluntary PD patient and other elderly users. The prototype proved to be more interactive than the first tests. However, the software can still receive some minor upgrades.

The IR emitter sole is a simple solution that can be applied in a future product. The sole is very sensitive and it is activated when the user step on the floor.

The result was satisfactory, proving that the concept can become a realistic product in the future. Improvements on software as well as engineering can push the development further.


FINAL DESIGN

6. FINAL DESIGN

6.1 DESIGN CONCEPT

Combining the knowledge acquired during the User research and tests it is possible to outline the final concept.

Paadje is a wearable gait assistant for Parkinson's patients. It is based on an Interactive projector mounted on a belt and it provides visual cues automatically when a freezing episode is detected. The concept is based on empirical data collected from Literature research as well as from the user tests and iterations.

Paadje is designed for elderly people above 70 years suffering from PD (Advanced stage) and FOG symptoms. It can be used independently at indoors environments or where else the patients experience freezing episodes. Paadje is portable and can be attached in different surfaces.

The device can also be used as a tool for gait training. Through an online application the patient can choose the specific training provided by their physician. The App also allows the patients to choose the most adequate visual cues for each situation.

Paadje App was designed for a better communication between patients and physicians. The application collects data about the daily life of the patients and translate it so the physicians can follow the advancements of the user and suggest new trainings.

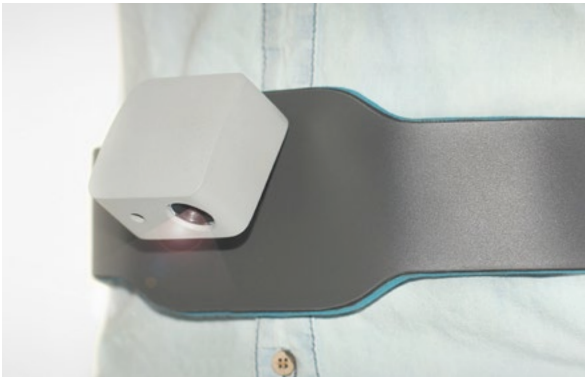
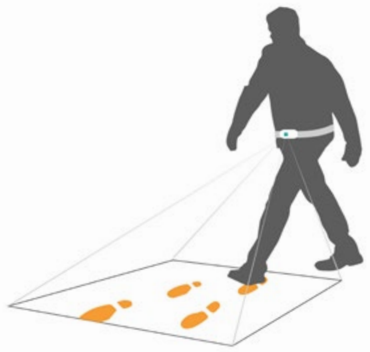
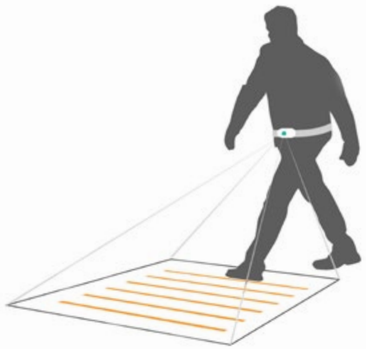
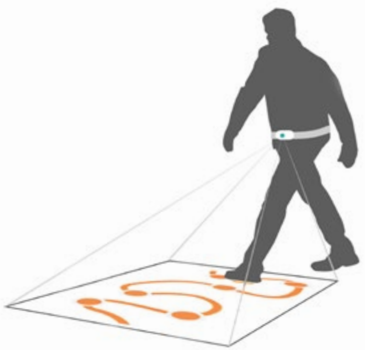


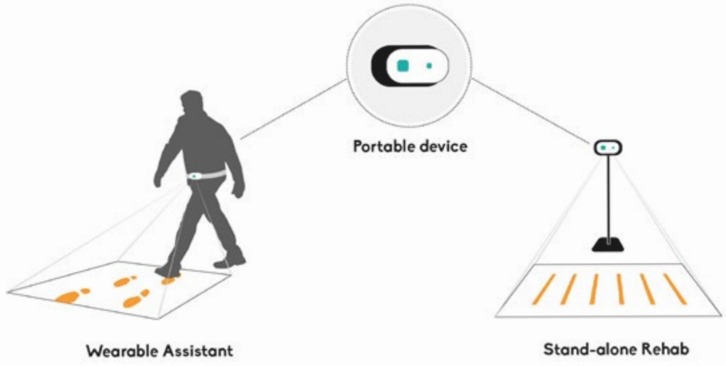
Image 49. Paadje smart beamer mounted in a belt

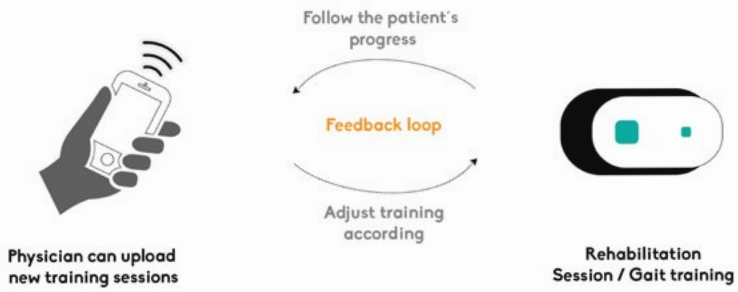
Image 50. Paadje App








Portable device
Wearable Assistant
Stand-alone Rehab


Follow the patient´s progress
Feedback loop
Adjust training according
Physician can upload new training sessions
Rehabilitation Session / Gait training

Building the belt

Following the requirements presented during the User research, comfort and usability of the belt are a top priority. The belt is designed with breathable fabric and silicon cushions covered by a plastic band for stable support of the projector. The belt carries a manual gyroscope with magnets that attach to the projector's case. The steps of the construction are displayed on the next images.

Image 51. Materials for the belt construction

Image 52. Cushions for better comfort

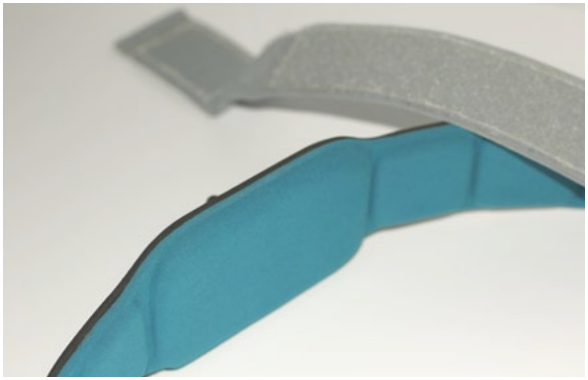


Image 53. Paadje belt details

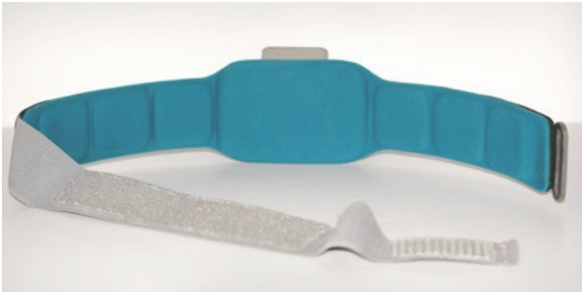


Image 54. Paadje belt details

Image 55. Paadje belt with manual gyroscope

Building the Case for projector

The case for the projector was designed to ensure the best use of space and to deliver a good usability for the patients. An iterative process for deciding the adequate form was performed. A simple and clean design will help patients to understand the interface and use the product correctly. The development steps are presented in the next images.

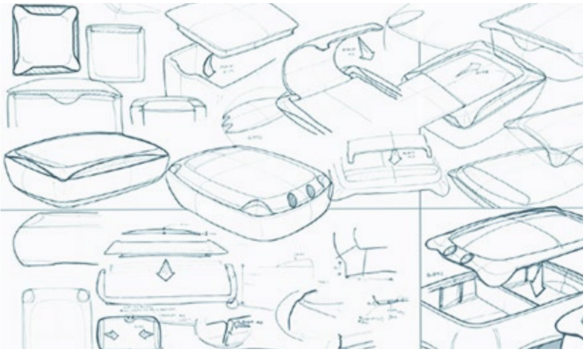


Image 56. Sketches for projector´s case

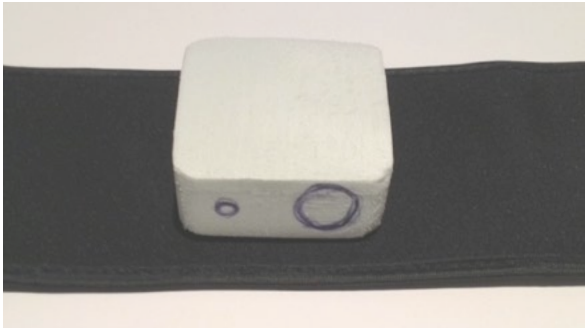


Image 57. Projector´s case Mock up

Image 58. Projector´s case

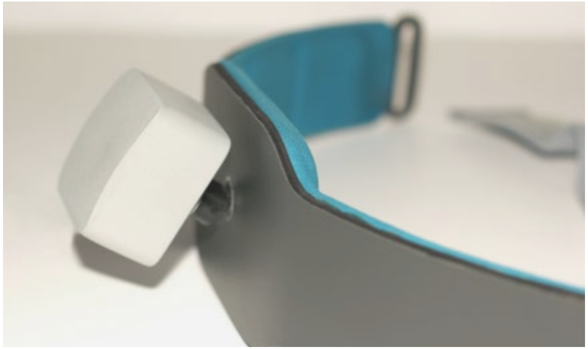
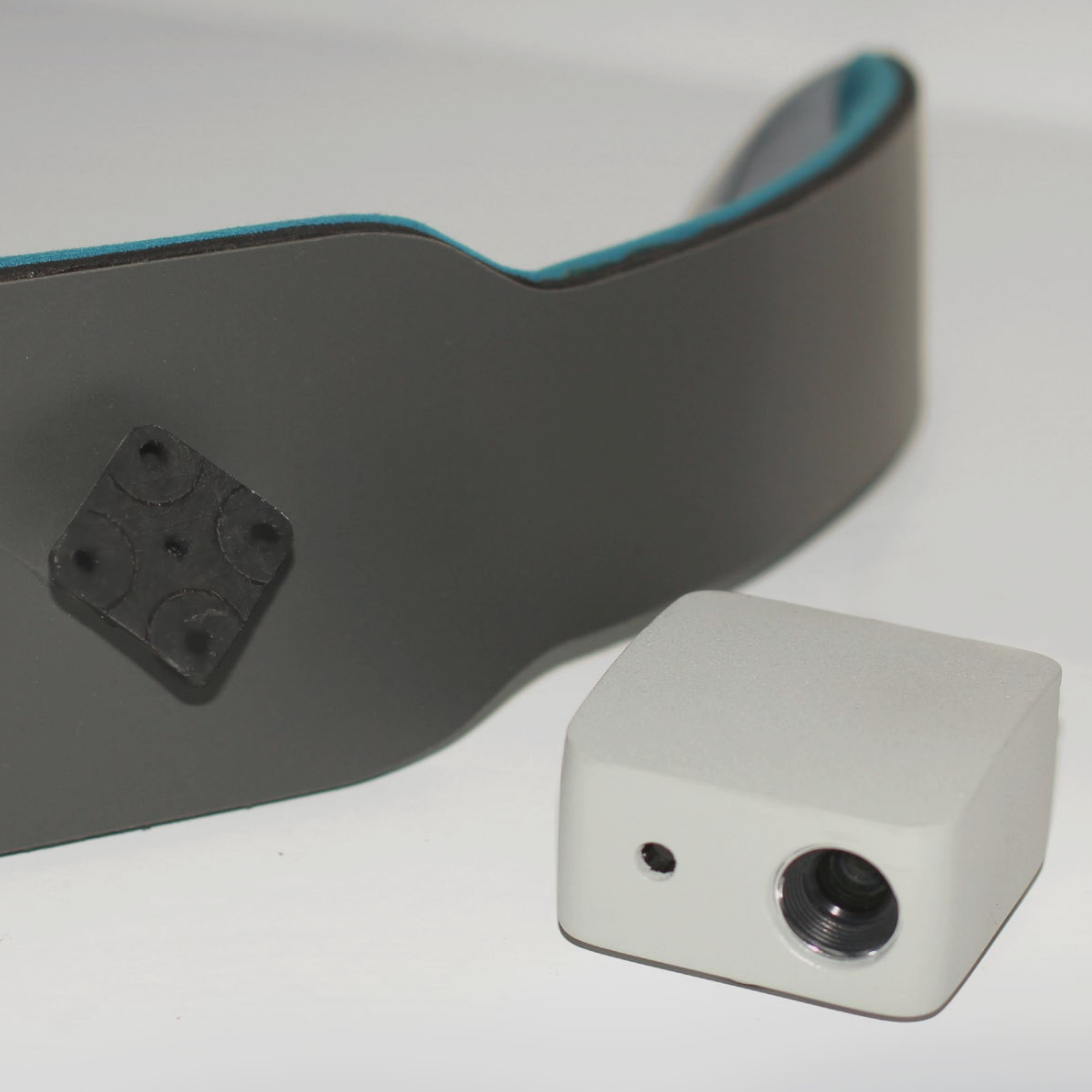


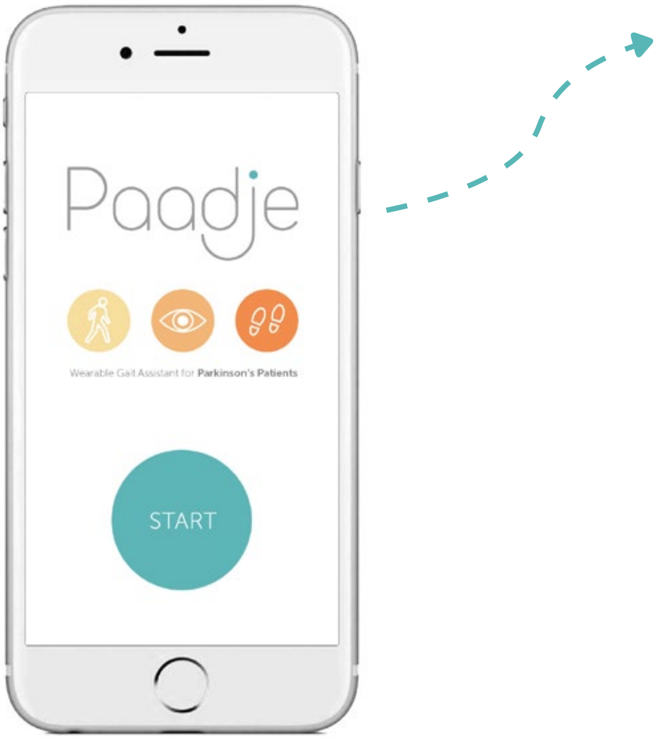
Image 59. Beamer mounted on the belt´s gyroscope

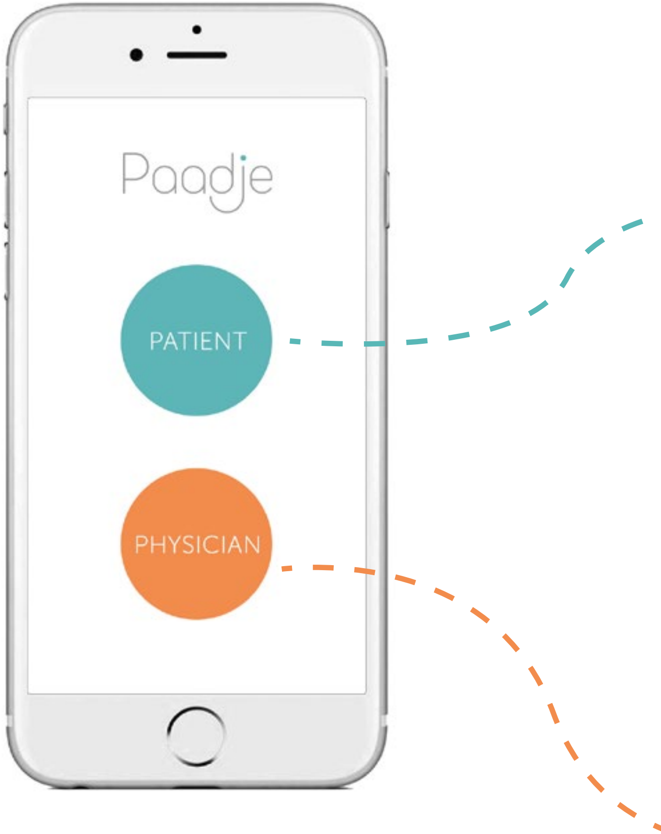
Image 60. Paadje in use

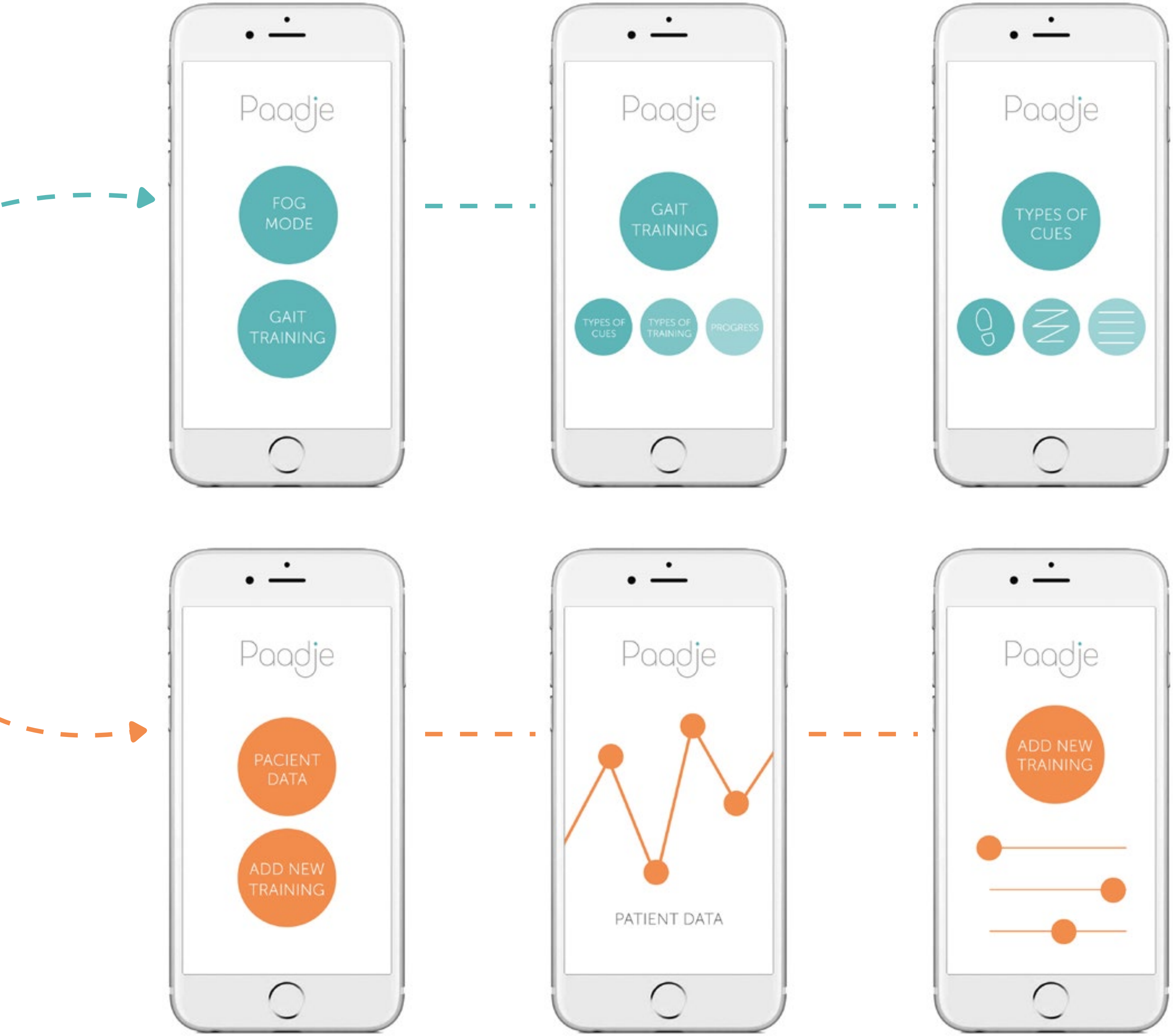


Paadje App development

Paadje App aims to connect patient to physician in a online platform. It also provides an open sourse system where the patients and physicians can control training intensity, types of cues and rehabilitation modes. The physicians have access to the patients data and can adapt the trainings according to the progress. Paadje can work on FOG mode or as a training device (Rehab).






Paadje
FOG MODE
GAIT TRAINING
Paadje
GAIT TRAINING
TYPES OF CUES
TYPES OF TRAINING
PROGRESS
Paadje
TYPES OF CUES
Paadje
PACIENT DATA
ADD NEW TRAINING
Paadje
PATIENT DATA
Paadje
ADD NEW TRAINING

6.2 ENGINEERING AND TECHNOLOGY

Pico projector

For the final product it was purchased the smallest pico projector found at that point in time. The projector was then disassembled and hacked with a powerful battery. The size of the projector reaches only 5cm x 5cm x 3cm.

Image 61. Smart beamer/projector

Processing 3.0 and Android App development

In order to provide a realistic experience for the user, a Processing 3.0 sketch was designed. The sketch was then uploaded in the Android system inside the Touchjet Pond projector. The Processing sketch was exported as a .Apk file and it is running as an Android app on the device. The interactive projection reacts when the user step on the footsteps displayed. The IR emitter mounted on a sole is responsible for sending the IR signal to the IR camera on the device

The Processing sketch can be found in the appendix.

```
int scrWidth;
int scrHeight;

// FOOT-RELATED VARIABLES -- set in 'setup'
ArrayList<Foot> feet; // used to store each walking 'foot' as a separate object
boolean left = true; // used to alternate left and right for a walking animation
float startHeight = 100;
boolean newPress = false;

PVector locationLeft; // default location where a left foot object is dropped
PVector locationRight;  // default location where a right foot object is dropped
PVector footOffset; // offset of a foot to its middle

// VOID SETUP //
//------------------------------//
//== program startup actions ==//
void setup(){
  // set screen-size
  size(displayWidth,displayHeight,P2D);
  scrWidth = displayWidth;
  scrHeight = displayHeight;

  // set foot-related variables
  feet = new ArrayList<Foot>();
  locationLeft = new PVector(scrWidth*0.35,startHeight);
  locationRight = new PVector(scrWidth*0.65,startHeight);
  footOffset = new PVector(0,0);
  addNewFoot();
}

// VOID DRAW //
//========================//
//-- program main loop --//
void draw(){
  // clear the screen at the start of each loop
  background(30);
  // if there are no feet, create one
```

Image 62. Processing sketch

Image 63. Android app running on the device

Paadje | Foot

```
//----------------------------------------------------------------------------------------\\
//-- This program draws moving footprints alternately to examplify a walking motion.
//----------------------------------------------------------------------------------------//

// SCREEN SIZE VARIABLES -- set in 'setup'
int scrWidth;
int scrHeight;

// FOOT-RELATED VARIABLES -- set in 'setup'
ArrayList<Foot> feet; // used to store each walking 'foot' as a separate object
boolean left = true; // used to alternate left and right for a walking animation
float startHeight = 100;
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PVector locationLeft; // default location where a left foot object is dropped
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PVector footOffset; // offset of a foot to its middle

// VOID SETUP //
//-----------------------------//
//-- program startup actions --//
void setup(){
  // set screen-size
  size(displayWidth,displayHeight,P2D);
  scrWidth = displayWidth;
  scrHeight = displayHeight;

  // set foot-related variables
  feet = new ArrayList<Foot>();
  locationLeft = new PVector(scrWidth*0.35,startHeight);
  locationRight = new PVector(scrWidth*0.65,startHeight);
  footOffset = new PVector(0,0);
  addNewFoot();
}

// VOID DRAW //
//------------------------//
//-- program main loop --//
void draw(){
  // clear the screen at the start of each loop
  background(0);
  // if there are no feet, create one

  // for each Foot object
  for (int i = feet.size()-1; i >= 0; i--){
    Foot foot = (Foot)feet.get(i);
    // if the object's lifespan hasn't come to an end yet
```

6.3 VALIDATION

The final concept was presented to the experts and patients as well as to the public visiting the final demo days. The Design process presented during the demo day can be found on page 59.

The feedback from the experts and users was positive and main advices on continuing exploring the interaction using different visual cues and sensors as well as exploring the interactivity of the system. The comfort and usability were highly improved on the final design.

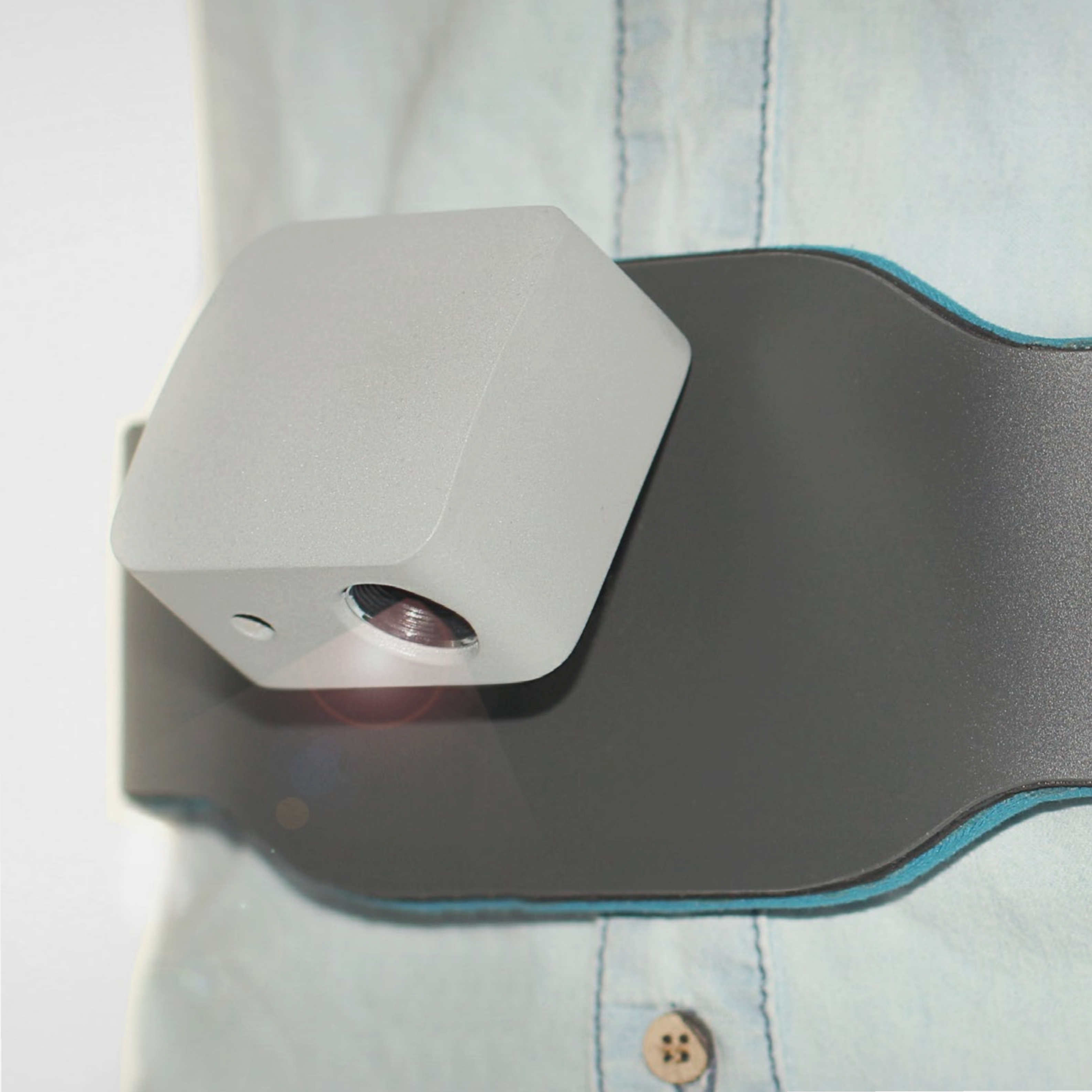
The visual cueing system proved to be effective under certain circumstances. A solution that can be explored further.

Similar automated devices have proven to be effective under testing. The majority of users indicated that this was beneficial. It is suspected that the device can have similar success, with the additional benefits described above. The potential exists to not only aid in the cessation of freezing episodes, but also in the collection of data, perhaps leading to a greater understanding of the freezing of gait phenomenon and its root causes.

Paadje is a proof of concept and need further exploration to prove its benefits in long term.

Image 64. Paadje presentation poster


Image 65. Interactive footsteps using Paadje



DESIGNING A WEARABLE **GAIT ASSISTANT** FOR **PARKINSON'S** PATIENTS

Literature Research
Focused on Parkinson's disease and Freezing of Gait (FOG) symptons

Goal
Understand how Visual Cues (stimuli) can help PD patients (elderly) to overcome FOG episodes

Stakeholder
Archipel Kenniscentrum

Expert
Han Vissers
Senior Physioterapist

Collaboration
Full expertise support and access to Archipel facilities, equipments, physioterapists caregivers and Parkinson's patients

User Perspective
Several patients participated on the process

Goal
Explore and understand the User needs by applying UX methods and tools (Qualitative interviews, Co-creation, Stoyply, etc.)

Validation

Design solution
Paadje is a Interactive Wearable Gait Assistant for PD patients with FOG

It helps them to walk safely by providing Visual Cues (stimuli) on-demand or automatically

It can also be used for Gait Training

App

First Iterations
Interactive Projector on the ceiling provides visual cues to guide and help patients to walk safely

Second iteration using a floor-grid to guide and help the patients to walk with confidence

User
Patients with Parkinson's disease and FOG symptons

Feedback
Expert feedback, Brainstorm and Co-creation session with physioterapists and patients

Necklace

Belt

Ideation and Prototyping
First prototypes using a Pico Projector with Interactive Infra-Red camera and Shoe-mounted Infra-Red emitter

User tests - Experts
Prototype tested by experts, physioterapists and doctors

Professional feedback helped to create guidelines for the User tests with patients

User tests - Patients
Several patients participated on the User tests

The many iterations helped to shape the concept and the design process

Feedback was very positive, while helping patients to walk safely

Concept Development
Sketching
Final concept
Embodiement
Usability
Materials

Engineering and Technology
3D modelling
Processing Sketch
Gyroscope
Sensors and actuators
Technology development
3D printing


CONCLUSION

7. CONCLUSION

Differing opinions exist as to the best way to improve a patient's gait, and solutions that involve visual cueing have been proposed to some success. Visual cueing using portable cueing devices has been effective for gait training in rehabilitation programs with Parkinson patients.

The tests with the interactive prototype showed that patients react properly to the stimuli. However, the long term benefits has yet to be investigated. The user group was rather small and the data collected during the design process was not conclusive. Further tests with different technologies and approaches will be beneficial.

Visual cueing provided by this wearable technology may have practical applicability in rehabilitation therapy. It provided additional benefits on gait in patients with advanced Parkinson Disease.

The use of visual cues was beneficial in many situations, especially when the patients used the directional visual cues. This can lead to a larger investigation on types of visual cues and its benefits to each patient.

Paadje can be a wearable solution for PD patients. The potential to help improving the user´s gait is great and a deeper investigation on technologies and methods is needed.

7.1 FUTURE WORK

Paadje is under development and new tests and iterations will be designed in a near future. The technological aspect of the project provides a diverse number of opportunities for innovative solutions. The use of more interactive and responsive technologies can push the project to achieve a optimal level and subsequently help the patients to live better.

New methods and tools will be explored during the next iterations. Some of these approaches are summarized bellow.

Applying a Short-Thrown Lens to amplify the image size and subsequently providing a greater area for interaction.

Using a Kinect-like camera system, in order to provide a more responsive and precise interaction user-projection. The camera can automatically detect the user's feet. No need for the shoe sole IR emitter.

Integrating sensors and actuators around the belt. These sensors can range from accelerometers and gyroscopes to vibrotactile feedback. Understanding the user's position and balance and providing tactile feedback to help overcoming freezing episodes.

The software can be further explore using Processing and Android App. It can be more interactive and smart, including new parameters and inputs.

7.2 REFLECTION

This project presented a lot of challenges, especially related to User research and integrating technology.

In the beginning of the project I was anxious about the directions I should take. It took sometime to define the concept, due to the fact that the data collected during tests and iterations were overwhelmingly diverse. Designing for the specific user group is a complicated task. Each patient has its own physical characteristics and behaviour, making it almost impossible to design for all the patients together. Understanding one patient in-depth helped me to focus on specific aspects and design a solution adequate for the patient persona.

Analysing the data was a complex task. I recorded approximately 5 hours of interviews and tests. I couldn't find a appropriate tool for the task. I had to manually analyse the data and summarize it. I believe I could have developed a better way for analysis, but due to time constraints, this will be done after final presentations.

One of the biggest problems during this semester was to successfully program a code on the interactive projector. I spent weeks trying to fix a problem with the projector. In the end everything went well. The processing sketch was transformed in a Android App and it is perfectly running now. I feel quite satisfied to achieve this goal and learn about Processing 3.0 sketch and Android app development.

I am satisfied with my design process during the project. It was a very rich experience, involving extensive literature research and analysis of existing state of art. That combined with constant consideration of possible problems and looking for solutions by engaging users and interviewing specialists have made this semester an intensive and productive time. Additionally using UX methods enabled me to perceive problems faced by patients and doctors from a more personal perspective.

Another important aspect I developed during the semester was related to Teamwork and Communication. The interaction with the experts and patients proved to be very productive. The feedback loop created during the process helped to evaluate each step of the design and its outcomes.

This was the most intensive and rewarding semester here at TU/e. I now can see a bigger horizon of opportunities. I started asking myself where I want to go and who I want to become. The answer is clearer in my mind. I design for Healthcare and I intend to continue developing my skills in this field. I am interested in learning new programming languages as well as User research methods and tools.

In the end it was possible to translate the effort and results into a meaningful and tangible solution. My next steps will involve more explorative approach as I'm planning to create more interactive and responsive prototypes and test them with users and specialists as soon as possible.

I envision Paadje as a potential product that could enter a real market and therefore I would like to look for professionals that could assist me with the technological and software aspects of the design in order to make it more realizable.

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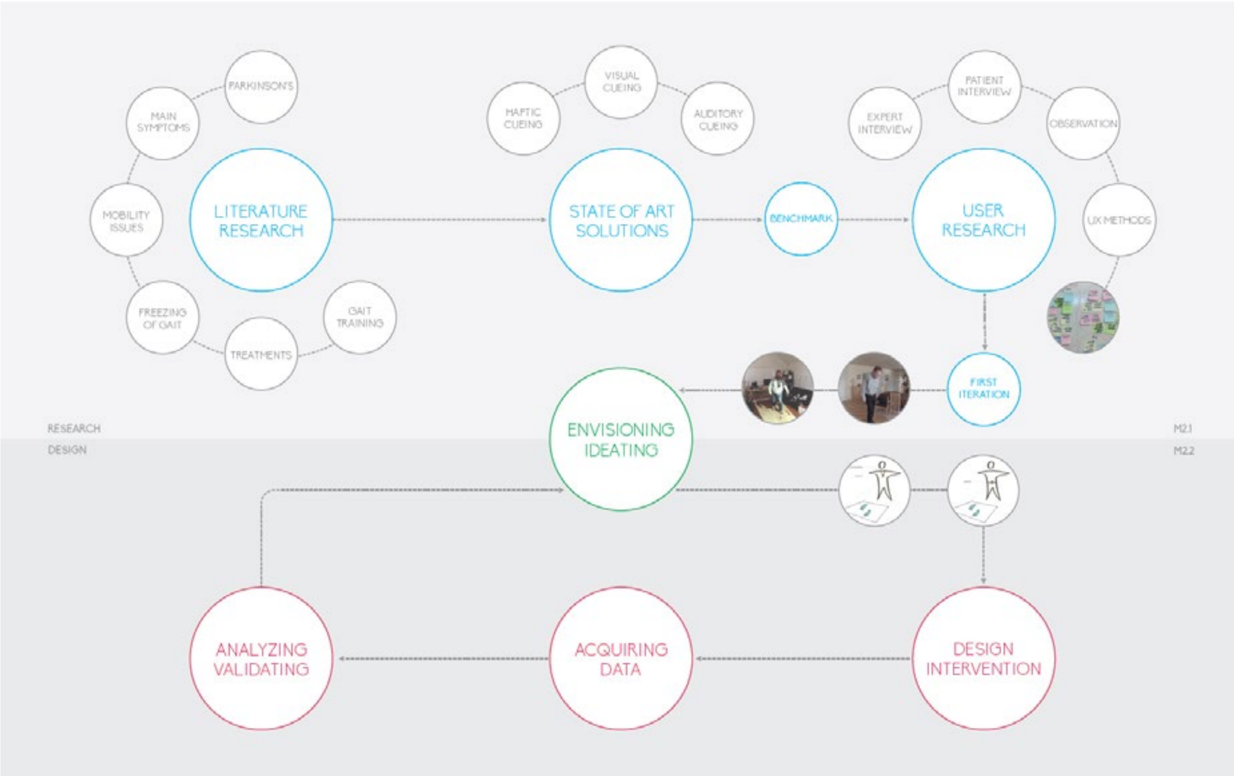
APPENDIX

DESIGNING FOR GAIT ASSISTANCE IN PARKINSON'S DISEASE



Overview of ambulatory systems for FOG detection.

Method	Base Algorithm	Online	Sensors	Participants	Experiment	FOG events (duration)	Evaluation
Han et al. (2003)	Wavelet comparison	No	2 accelerometers (ankles)	2 patients 5 control	Laboratory (walk, turn)	-	-
Moore et al. (2008)	FFT with FI (6 sec window)	No	1 accelerometer (left ankle)	11 patients	Laboratory (walk, turn, stand, doorway, obstacle)	46 (2-128 sec)	78% FOG events detected correct 20% stand events incorrect
Zabaleta et al. (2008)	STFT analysis	No	6 accelerometers (6 points on leg and hip)	3 patients	Laboratory (walk, turn, sit-stand, obstacle, dual-task)	-	-
Jovanov et al. (2009)	FFT with FI (0.32 sec window)	Yes	1 IMU module (foot)	1 patient 4 control	Laboratory (walk, sit-stand)	-	-
Bächlin et al. (2009a, 2010a,b)	FFT with FI (4 sec window)	Yes	3 accelerometers (trunk, thigh, shank)	10 patients	Laboratory (straight walk, obstacle, dual-task)	237 (0.5-40.5 sec)	73.1% (88.6%)[a] sensitivity 81.6% (92.4%) specificity
Djurić-Jovičić et al. (2010)	DT with ANN (1 sec window)	No	6 IMU modules (feet, shanks, thighs)	4 patients	Laboratory (walk, sit-stand, doorway, turn)	-	-
Niazmand et al. (2011)	DT with FI (1.5 sec window)	No	5 accelerometers (shanks, thighs, belly)	6 patients	Laboratory (walk, turn)	-	88.3% sensitivity 85.3% specificity
Cole et al. (2011)	DNN with upright detection (2 sec window)	No	3 accelerometers (shank, thigh, forearm), 1 EMG (shank)	10 patients 2 controls	Laboratory	87 (> 1 sec)	83.0% sensitivity 97.0% specificity
Zhao et al. (2012)	DT with FI (1.5 sec window)	Yes	5 accelerometers (shanks, thighs, belly)	8 patients	Laboratory (walk, turn)	-	81.7% sensitivity
Mazilu et al. (2012)	RT, RF, DT, BN, KNN, MLP, Adaboost, BAG (1 or 4 sec window)	Yes	3 accelerometers (trunk, thigh, shank)	10 patients	Laboratory (straight walk, obstacle, dual-task)	237 (0.5-40.5 sec)	62.1% (99.7%) sensitivity 95.2% (99.9%) specificity
Tripoliti et al. (2013)	NB, RF, RT, DT (1 sec window)	No	4 accelerometers (wrists, shanks), 2 IMU modules (waist, chest)	5 patients 11 controls	Laboratory (walk, stand-up, open door, drink)	93 (2–20 sec)	81.94% sensitivity 98.74% specificity
Moore et al. (2013)	FFT with FI (2.5, 5, 7.5, 10 sec window)	No	7 accelerometers (back, thighs, shanks, feet)	25 patients	Laboratory (walk, stand-up, turn)	293	84.3% sensitivity 78.4% specificity

[a]with optimal user specific parameters

```
//------------------------------------------------------------------------------------------------------\\
//-- This program draws moving footprints alternately to examplify a walking motion.
//------------------------------------------------------------------------------------------------------//

// SCREEN SIZE VARIABLES -- set in 'setup'
int scrWidth;
int scrHeight;

// FOOT-RELATED VARIABLES -- set in 'setup'
ArrayList<Foot> feet; // used to store each walking 'foot' as a separate object
boolean left = true; // used to alternate left and right for a walking animation
float startHeight = 100;
boolean newPress = false;

PVector locationLeft; // default location where a left foot object is dropped
PVector locationRight;  // default location where a right foot object is dropped
PVector footOffset; // offset of a foot to its middle

// VOID SETUP //
//------------------------------//
//-- program startup actions --//
void setup(){
  // set screen-size
  size(displayWidth,displayHeight,P2D);
  scrWidth = displayWidth;
  scrHeight = displayHeight;

  // set foot-related variables
  feet = new ArrayList<Foot>();
  locationLeft = new PVector(scrWidth*0.35,startHeight);
  locationRight = new PVector(scrWidth*0.65,startHeight);
  footOffset = new PVector(0,0);
  addNewFoot();
}

// VOID DRAW //
//------------------------//
//-- program main loop --//
void draw(){
  // clear the screen at the start of each loop
  background(0);
  // if there are no feet, create one

  // for each Foot object
```

```
  for (int i = feet.size()-1; i >= 0; i--){
    Foot foot = (Foot)feet.get(i);
    // if the object's lifespan hasn't come to an end yet
    if (foot.life > 0.5){
      // draw and animate it
      foot.draw();
      foot.move();
    // if it's lifespan has come to an end
    } else {
      // delete it from the ArrayList
      feet.remove(i);
    }
  }
  // if the mouse is being pressed
  if (mousePressed){
    // if there is no Foot, try to create a new one
    if (feet.size() == 0){
      addNewFoot();
    // if there is only one Foot
    } else if (feet.size() == 1){
      Foot foot = (Foot)feet.get(0);
      // and that Foot is at the bottom of the screen
      if (foot.location.y > displayHeight*0.7){
        // try to create a new foot
        addNewFoot();
      }
    }
  }
}

// ADD NEW FOOT //
//--------------------------------//
//-- Creates a new foot object --//
void addNewFoot(){
  // only create a new Foot when the mouse has been newly pressed
  if (newPress){
    // see whether a left or right Foot object should be next, and set the appropriate location
    PVector newLocation = locationLeft.get();
     if (!left){
       newLocation = locationRight.get();
       left = true;
     } else {
       left = false;
```

```
    }
    // add a new 'Foot' object to the 'feet' ArrayList
    feet.add( new Foot(
      newLocation, // start location of the foot
      0.7,          // scale of the foot
      5,            // speed by which the foot moves
      left          // is this a left foot (or right foot)
    ));
    // update new press so no new Foot can be created unless the mouse is newly pressed
    newPress = false;
  }
}

// MOUSE PRESSED //
//--------------------------------------------------//
//-- Code that is run when the mouse is pressed --//
void mousePressed(){
  // update newPress to show that the mouse has been newly pressed
  newPress = true;
}
```