Social Navigation.

Assisting people that are blind or have low vision in finding and navigating towards familiar individuals in close proximity

Master Thesis - 2023

Lotte van der Jagt

“Yes, this really means something to me, that these kinds of things are possible...”

~ Quote by Sam, 23 years old and completely blind

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Master Thesis

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Design for Interaction - Integrated Product Design
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TU Delft

envision

Abstract

Imagine going to a bar to meet your friends. When you arrive you try to spot them in a room filled with people, but your view is blurred which disables you from recognizing your friends. How would this make you feel? People that are blind or have low vision (PBLV) are all around us and can be found in any context of life. Just like sighted people, they feel the need to attend to social situations. However, socially navigating themselves, meaning finding and navigating toward familiar people around them, can be more challenging for them due to missing sight.

Literature describes that having a visual impairment can greatly impact your social life (Brunes et al., 2019; Desrosiers et al., 2009; Grow et al., 2015; Oehler-Giarratana & Fitzgerald, 1980). This was confirmed by PBLV, during interviews that were executed in advance of the project. There seems to be a gap in exploring how design could help PBLV with the challenges they experience in their social life. With a participatory approach, this project attempts to contribute to filling this gap. During the project, the goal was to *'develop a supporting device that makes PBLV feel more at ease in social situations'*.

Interviews and shadowing sessions with PBLV, and a literature study resulted in the definition of eight areas where PBLV experience challenges in their social life. Together with studying the technological developments in the field of social life of PBLV, resulted in composing the design goal to: *'Design a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings.'*

With this design goal and the conducted research in mind, the conceptualization phase followed. During this phase several concepts were generated, (rapid) prototypes were created, and additional tests and studies were executed. Knowledge gathered from this phase resulted in the design of the final concept called 'Sofi'.

'Sofi', the social finder, is an application and add-on for the Apple Watch which supports PBLV in their social navigation. It does so via communicating the identity, and location of familiar others nearby through vibrations. In addition, it helps PBLV to navigate towards these familiar others when desired.

Based on prototyping and testing elements of the final concept, and gathering feedback from PBLV, 'Sofi' seems to be a promising concept that could have potential for further development. The findings of this project, in particular, the research on social challenge areas for PBLV, and the design exploration can contribute to the knowledge on using design to help PBLV tackle the challenges they experience in their social life.

Acknowledgment

This project has been one great journey, with many ups and downs along the way. I would like to show my gratitude to a couple of people here because, without their help and support, I would not have gotten the same result I have now.

First of all, I would like to thank the team of Envision for offering me the opportunity to graduate from their company. For their constant support, understanding, and interesting insights. But also the fun team events that made me enjoy my time at Envision even more. I would like to give a special thanks to Ferkan Metin, who has guided me throughout my whole project, and helped me out when I got stuck.

I would like to thank mysupervisors Stella Boess and Gerd Kortuem, for supervising this project and sharing their expertise in the form of interesting and critical feedback. I also want to thank them for their motivational support, that they provided when I needed it.

I am grateful for my (old) roommates which I could always reach out to if I was in need of some help with brainstorming or prototype testing. Furthermore, I want to thank my friend Dave and a former colleague Fri that provided me with prototyping support if needed.

I would like to thank my family and boyfriend for their constant support during my project. A special thanks to my grandmother, she is unfortunately visually impaired herself. Though her visual impairment was the reason for me to get interested in medical design. During this project, my grandmother provided me with a lot of inspiration, information, and motivation.

Along with Envision, Leo Markenstijn, an employee at VISIO, has been of great help by introducing me to helping devices on the market for PBLV and helping me to connect with PBLV during the project, for which I am grateful.

Last but not least I would like to thank all the PBLV that helped me during my project. Without their willingness to share experiences with me, I would not have been able to complete this project.

Figure 1: Illustration of a PBLV sitting at a barstool

Table of Content

Glossary

Below an overview of abbreviations and definitions is provided.

Term	*Intended Meaning*
IPD	Master Integrated Product Design
DfI	Master Design for Interaction
PBLV	People that are blind or have low vision, or a person that is blind or has low vision.
VI	Visual Impairment
SP	Sighted people/person
UWB	Ultra-Wideband

Table 1: Overview of important abbreviations that are used througout the report

Note
I will often refer to people that have low vision or that are blind as PBLV, which stands for people that are blind or have low vision. Visually Impaired People (VIP) is an alternative, better-known term in the field, however personally, and at Envision, we preferred using the term PBLV, where we use the people-first language so that the disability attribute does not define the individual.

List of Characters

During this project I received help from twenty-one PBLV, some helped during interviews, some during testing, and some helped with both. Next to PBLV, sixteen sighted people helped with tests and ideation sessions. Furthermore, one ergo therapist, I. ten Have, specialized in helping PBLV, helped via an interview as well.

To capture the richness of the insights all these people provided me with, I will use their stories and some of their quotes throughout my report. Most of the quotes are originally in Dutch, but for convenience have been translated into English in this report. I also use pictures of interviews, shadowing sessions, and tests. For both gathering data and taking pictures, permission was asked in advance. Most pictures used in the report are anonymized, but some are not. For the ones that aren't anonymized extra permission was asked.

For a better understanding of the information received from PBLV, and their quotes that I used in this report, a description of personalities is considered useful. Therefore, to give an impression of the PBLV that helped me in this project, a table with descriptions of each of them is created. On this page, only a short version is provided (table 2). For the complete list of PBLV with descriptions, and sighted people (named SP 1 t/m16) that helped, when they helped, and what they gave permission for please consult appendix 1. To ensure confidentiality the names of the PBLV have been changed.

Name	*Description*
Sophie	A woman in her forties, with a strong visual impairment for over 20 years. She is working as an experience expert[1].
Hans	He is nearly seventy years old and for twenty years suffers from Macula Degeneration. He also works as an experience expert[1].
David	A male in his thirties that has been legally blind since birth. He has a job in the nightlife.
Maria	A woman in her eighties that has been suffering from Macular Degeneration for thirty years now.
Alice	A woman in her sixties that has been completely blind for twenty years now. She lost her vision relatively suddenly. She works as an experience expert[1].
Nora	She is in her fifties and has had deteriorating low vision since she was in her twenties. She has an office job.

Table 2: Short overview of PBLV that helped througout the project

1 In this example, someone who has experience with being blind or having low vision themselves, and uses this to support others with similar experiences.

Introduction . . . . . .

In the first two chapters of this introduction section I will explain the topic and the approach of my project. The two chapters that follow will provide background information on the target group, PBLV, the company Envision, and other stakeholders.

After this Introduction section, the Explore section will follow, where I present the main research parts of my project.

1. Project Description

> *"...Because I do not recognize people on time, and later I hear that this and that person also went there, and then I think 'gosh, what a pity, I would have loved to catch up with that person"* ~ Quote by Hans

This project focuses on the social life of people that are blind or have low vision (PBLV), and forms the MSc graduation project of the double degree in Design for Interaction and Integrated Product Design. Both Masters were executed with a Medisign specialization, and are offered by the Faculty of Industrial Design Engineering (IDE) at the Delft University of Technology (TU Delft).

The project is conducted in collaboration with Envision, a company that develops an AI service for smartphones and Google Glass that can describe the world for PBLV. In addition, the Delft Inclusive Design Lab and the organization Visio provided help during the project.

The project aims to ***'Develop a supporting device that makes PBLV feel more at ease in social situations'.***

During the project, an inclusive approach has been taken, by including the target group as much as possible to gain insights and gather feedback. The project focuses on people with severe visual impairment, which cannot be sufficiently corrected by glasses.

I started the project with introducing myself into the context (chapters 3 and 4). After this, I dived deeper into the challenges PBLV experience in their social life (chapter 5), and read up on existing projects and technologies that tried solving social issues for PBLV (chapter 6). After gaining this deeper understanding, the design goal of this project was formed:

'Designing a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings.'

The definition of the design goal was followed by a phase of conceptualization (chapters 7 until 11). Here, through brainstorming, concept generation, design explorations, tests, and feedback gathering, a basic idea was created on how to design a tool for social navigation. During the last phase of this project, this idea was translated into a final concept called 'Sofi' (see chapter 12).

In the next three chapters the project strategy, background, and involved stakeholders will be further explained.

2. Project Strategy

As a designer I love to design for vulnerable target groups and emerging myself in their world in order to find what they truly need. I approached my project in such a way that it allowed me to explore what PBLV need, and adjust my project goal toward those needs. What characterizes my project is that I tried to include PBLV and others as much as possible during my project, via interviews, tests, brainstorming sessions, and feedback-gathering sessions.
My project approach consisted of four phases:

- **Empathizing phase:** This phase I conducted prior to starting my actual graduation project, I talked to five PBLV and an ergo therapist for PBLV, to empathize with my target group and decide where I wanted to focus my project on. To further empathize, I also conducted simulation sessions, where I blindfolded myself and undertook several activities. During this phase, I decided I wanted to focus my project on 'Developing a supporting device that makes PBLV feel more at ease in social situations'. Insights from this phase will be used throughout the project, however as the activities happened prior to the project they will not be separately covered in this report.
- **Exploration phase:** During this phase, I dived deeper into my earlier selected topic: the social life of PBLV. I did so by interviewing eleven PBLV, shadowing three PBLV in a social setting, and conducting a literature study. By synthesizing the insights I was able to define eight main areas where PBLV experience challenges in their social life. In addition, I conducted a literature study to get a better understanding of helping devices for and design projects on the social life of PBLV.
- **Conceptualization phase:** Here, I started converging my knowledge to the more concrete design goal of "Designing a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings". With this design goal in mind, I generated several ideas to tackle the problems around social navigation for PBLV. Based on these ideas I decided that I needed to gather more knowledge on haptics and digital positioning systems which I planned to use in my designs. After some more exploration in these areas, I converged my knowledge gathered in this phase into two concepts, which I prototyped and tested with PBLV.
- **Final design phase:** In this phase, I use the knowledge gathered from the previous phases to compose my final design 'Sofi', an application and add-on for the Apple watch. The design uses vibrations and UWB to help PBLV to identify, locate and navigate toward familiar people around them. Even during this phase, I created time to explore design decisions via iterative prototyping and testing.

During my project, I went through several cycles of diverging and converging to get to my final design 'Sofi'. During each phase, I tried to include the target group as much as possible. My project strategy is further illustrated in figure 2.

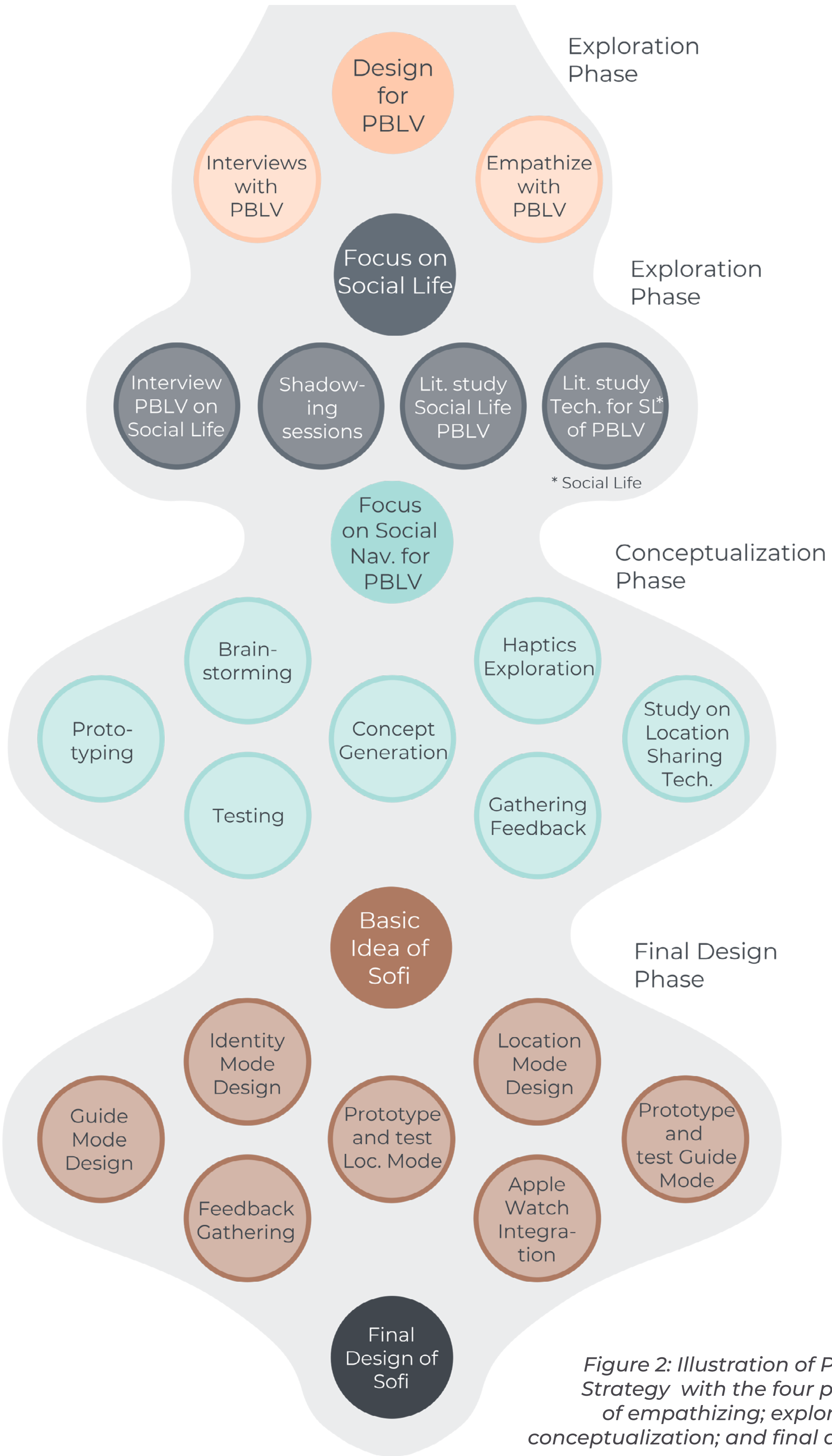


Figure 2: Illustration of Project Strategy with the four phases of empathizing; exploration; conceptualization; and final design

3. Background, People that are blind or have low vision

3.1 Introduction

In the Netherlands there are estimated 300.000 people with a visual impairment (Oogfonds, n.d.), of which about 76.000 people are considered legally blind (Oogvereniging, n.d.). Many people have a clue what blindness means, however, the diversity in which visual impairments can occur is often unknown. In 2021, worldwide an estimated 258 million people were visually impaired, of which 43.3 million are blind (Prevent Blindness, 2021). There are correlations between visual impairment and age and gender. In the Netherlands, 85% of the people with a visual impairment are +50 years old, and twice as many people with a visual impairment are female rather than male (Oogfonds, n.d.).

An eye condition is considered a visual impairment when someone's sight cannot be corrected to a normal level (The University of Pittsburgh, n.d.), for example by means of glasses or medicine.

Visual impairment has a great impact on the daily life of PBLV. It influences people's ability to be independent, for example regarding mobility; or information access. Along with the practical issues, a visual impairment also influences people's social life. It was for instance found that loneliness is more prevalent for people with a visual impairment (Brunes et al., 2019; Grow et al., 2015). Furthermore, adult PBLV have decreased participation in daily life activities compared to adults without PBLV (Desrosiers et al., 2009), and have decreased social networks (Kef, 1997).

3.1 Visual Impairment and Social Life

One area of life that is greatly impacted by visual impairment is social life. PBLV tend to have lower social roles (Desrosiers et al., 2009), smaller social networks (Kef, 1997), and increased risks of experiencing loneliness which negatively influences their perceived quality of life (Brunes et al., 2019; Grow et al., 2015).

At the start of the project, I talked to five PBLV to get an understanding of their daily lives and the challenges they experience. During these conversations, they explained that they often struggle to take part in socially busy situations, as those situations require a lot of energy and effort because of multiple reasons. PBLV predominantly relies on audio and haptic input during communication with others, which easily gets overwhelming, as explained by ergo therapist ten Have.

Figure 3: A PBVL entering a social gathering in a park (merge of images; Lupan, 2021; Viktor, 2019)

They often miss out on nonverbal communication like body language, which complicates understanding the intentions of the other person. In addition, people that are blind or have low vision struggle to recognize others, especially in busy surroundings. They have to determine who is talking to who, and whether people move around, join, or leave the room. A sighted person will obtain all this information more easily via visual input. Still, a visually impaired person desires to receive all this information as well. The struggle is visualized in figure 4.

Each situation brings along its challenges; birthday parties, going out in clubs or a bar, office meetings, having dinner with friends, etc. Because of the high amount of energy and effort these situations require, people with a visual impairment need to take a moment for themselves in the situation, take time off afterward, or they might even decide not to join social events. Literature (Brunes et al., 2019; Desrosiers et al., 2009; Grow et al., 2015; Kef, 1997; Oehler-Giarratana & Fitzgerald, 1980) confirms that PBLV experiences social challenges, though there seems to be a research gap on why they experience these challenges, and how those challenges differ per situation. For example, what is the impact of having to process audio input while missing out on the visual input?

Furthermore, there are many devices (often referred to as 'assistive technology') on the market for people with a visual impairment, which mostly focus on mobility, navigation, information access, communication, household, and leisure. However, there are actually very few devices on the market that have a direct social focus. Such as a device that would help PBLV to read body language.

Figure 4: Difference in perceiving a social situation from a sighted perspective (left) and a PBLV perspective (right). Based on a picture from Du Preez (2018)

4. Stakeholders

4.1 Envision

Figure 5: Group picture of collegues at Envision

My graduation project has been conducted in collaboration with Envision (see figure 5). A company that makes visual information more accessible to PBLV, via their Envision app and Envision glasses (see figure 6). Both services use AI to translate visual information into audio.

The company was founded, as part of the YES!Delft Incubation programme, in 2017 by Karthik Mahadevan and Karthik Kannan. Over the years they managed to gather 40.000 active users worldwide.

Their service offers functions such as text recognition, bill recognition, finding objects, describing scenes, and the newest feature 'call an ally'. The latter allows PBLV to video call friends, family, people at Envision, or professional helpers of Aira via their Envision glasses if they are in need of help beyond the AI skills of the service.

They have allowed me to conduct my research at their company. During my project, they shared their knowledge on (designing for) PBLV with me, provided feedback on my work, helped me with issues when I got stuck and helped me to connect with the target group. In return, I share all my research insights and design insights with the company. Especially my research into the social challenges of PBLV might be interesting for further development of their Envision services.

Figure 6: Picture of a woman with a visual impairment reading recipe instructions with her Envision Glasses

4.2 Visio

Although not a direct stakeholder during this project, the organization Koninklijke Visio has provided great help during the project. The organization functions as an expertise center for people that are blind or have low vision. During my project, Visio has helped me get an understanding of the helping devices currently available on the market for PBLV and furthermore has helped me to connect with the target group.

Visio helps PBLV in multiple ways, they function as a helpdesk for any questions on blindness or visual impairments that people might have. Furthermore, they research visual impairments and related topics, they offer rehabilitation, counseling, and education.

They do not only offer support for people with a visual impairment, but also for people that have a mental, physical, or any other sensory impairment. They also offer support for people that are either professionally or personally involved.

Figure 7: Logo of Koninklijke Visio (Koninklijke Visio, n.d.)

4.3 Delft Inclusive Design Lab

Via the help and feedback of the project chair Stella Boess, Delft's Inclusive Design Lab has also been involved during the project. They promote, as the name indicates, designers to design as inclusive for as many people as possible. They research how to design (more) inclusively, and help designers and societal stakeholders connect to promote inclusion. During the project Stella, in name of the Inclusive Design Lab has helped me explore how I could include my target group in my design project.

Figure 8: Logo of Delft Design Labs (Delft Design Labs, n.d.)

Explore . . . .

In this part of the report I will present my main study into the challenges PBLV experience in their social life, followed by a chapter on projects that have attempted to tackle some of the challenges in the past.

This section forms the foundation of my project on which the design goal has been based. After this, the section Conceptualize will follow, where the design goal and design iterations will be covered.

5. Main challenges for PBLV in Social Situations

For an in-depth understanding of the social challenges PBLV experience in social situations, I have conducted a literature study and interviews, of which findings will be presented in this chapter.

The study was focused on the following research questions:

What are the main challenges PBLV experience in social situations?
And
Which elements influence the experience of these challenges?

At the end of this chapter, the influence of this research on the project will be discussed.

5.1 Method

Several types of sources have been consulted to answer the above-stated research questions. The resources that were consulted, in what manner, and how the insights were combined will be explained in this subchapter.

5.1.1 Information Sources

Prior to the start of this project I conducted **semi-structured interviews** with five PBLV and one ergo therapist, named I. ten Have. The goal of these interviews was to empathize with the target group and to get an initial understanding of the challenges they experience in daily life. These interviews also provided many insights into the social life of PBLV and have therefore been used as a source of information in this research.

The interviews took place mostly online, and once at a PBLV's home. During the interviews, which took about 1.5 hours each, I asked PBLV general questions about their visual impairment, but also more specific questions about the challenges they experience in their daily lives (topics like social life, personal care, transportation, and information access). I asked the ergo therapist similar questions on what type of challenges her patients experience.

At the start of each meeting, I explained that these interviews served as preparation for my graduation project for PBLV (at that time I did not choose to focus on social life yet). Furthermore, I explained that I liked to use the insights for my project, and asked people's permission for taking video recordings and using the data in an anonymous manner. I also stressed that participants could decide not to answer a question or stop the meeting at any time. When participants gave me permission, I started the recording and asked them to repeat their permission statement so that it was recorded. Participants were recruited via Visio and community Facebook pages for PBLV.

The **primary source** of information came from a **second round of interviews** with nine PBLV (out of which three helped during the first interview sessions as well). These interviews specifically focused on the challenges PBLV experience in social life. The interviews took 1.5 hours on average and took place either at the home of the PBLV or online. The interviews were again semi-structured.

During the interviews, this time, I asked PBLV more specific questions about their social life. For example, I asked them how their visual impairment influenced their experience of a specific social situation and continued asking how that made them feel. Or I asked them more general questions like 'For which situation would you wish that your VI had a less great role in the situation?'. If needed, I used a list of example social situations to start the conversation with, like playing games with friends at home, visiting a restaurant with family, or having a community barbeque in advance.

In advance of each interview, I explained the goal of my interview and my project, highlighted that people could always decide not to answer a question or stop the meeting, and asked permission for (video)recording and use of data anonymously, in a similar manner as described for the first round of interviews. Next to the participants that I already had contact with during earlier interviews, the other participants were recruited via Envision and community Facebook pages for PBLV. For more information on the interview plan, please consult appendix 2.

Next to the interviews, two **shadowing sessions** were organized. The goal of the shadowing sessions was to get an impression of smaller, detailed challenges that would easily get lost during interviews. Three PBLV were shadowed during two sessions.

The first shadowing session was at an office where a PBLV, whom I already knew from previous interviews, was working. That day she gave a presentation to the stakeholders of the company. I was joining that presentation and observed how she was interacting with the stakeholders, and how stakeholders were reacting to her presence and behavior.

The second shadowing session took place at a community center where a Bingo evening was organized. I observed two PBLV that evening. One of those PBLV I already knew from previous interviews, and the other PBLV was a friend of her that also joined the Bingo session. I did not join in playing the game but

solely observed the behavior of the two PBLV and others around them. For both shadowing sessions, I first introduced myself and explained what my role was that evening. Furthermore, I asked permission to take pictures, take notes, and use the insights in my project. Two PBLV allowed me to use the pictures while leaving them un-anonymized and only anonymizing the other people present in the setting. Two pictures of the shadowing sessions are shown in figure 9 and 10.
In total, twelve PBLVs contributed to this research.

Figure 9: Picture of shadowing session at office presentation

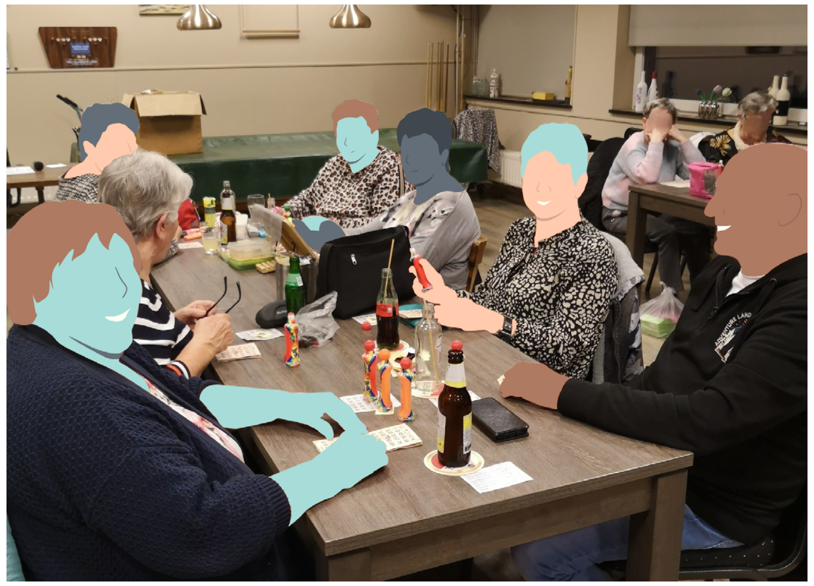


Figure 10: Picture of shadowing sesson at the Bingo event

Table 3 summarizes in what way each PBLV contributed. For more information on the interviewees and shadowed PBLV, please consult the list on page 9, or appendix 1.

PBLV	***Interview session 1:*** Initial understanding of the challenges PBLV experience in daily life.	***Interview session 2:*** Understanding of social challenges experienced by PBLV in daily life.	***Shadowing session*** Detailed and real-life understanding of (social) challenges in daily life.
Sophie	x	x	x
Hans	x	x	
Karin	x		
David	x	x	
Maria	x		x
Laura		x	
Alice		x	
Nora		x	
Zoe		x	
Bas		x	
Lia			x
Lisa		x	

Table 3: Overview of PBLV that contributed to this research

Lastly, findings from the interviews and shadowing sessions are supported by a **literature study** on social challenges for PBLV. The literature study was conducted in parallel with the second round of interviews and the shadowing sessions. For the literature study, ten different sources have been consulted, of which the most important one was the book "Blind Spots; The Communicative Performance of Visual Impairment in Relationship and Social Interaction" by Frame (2004).

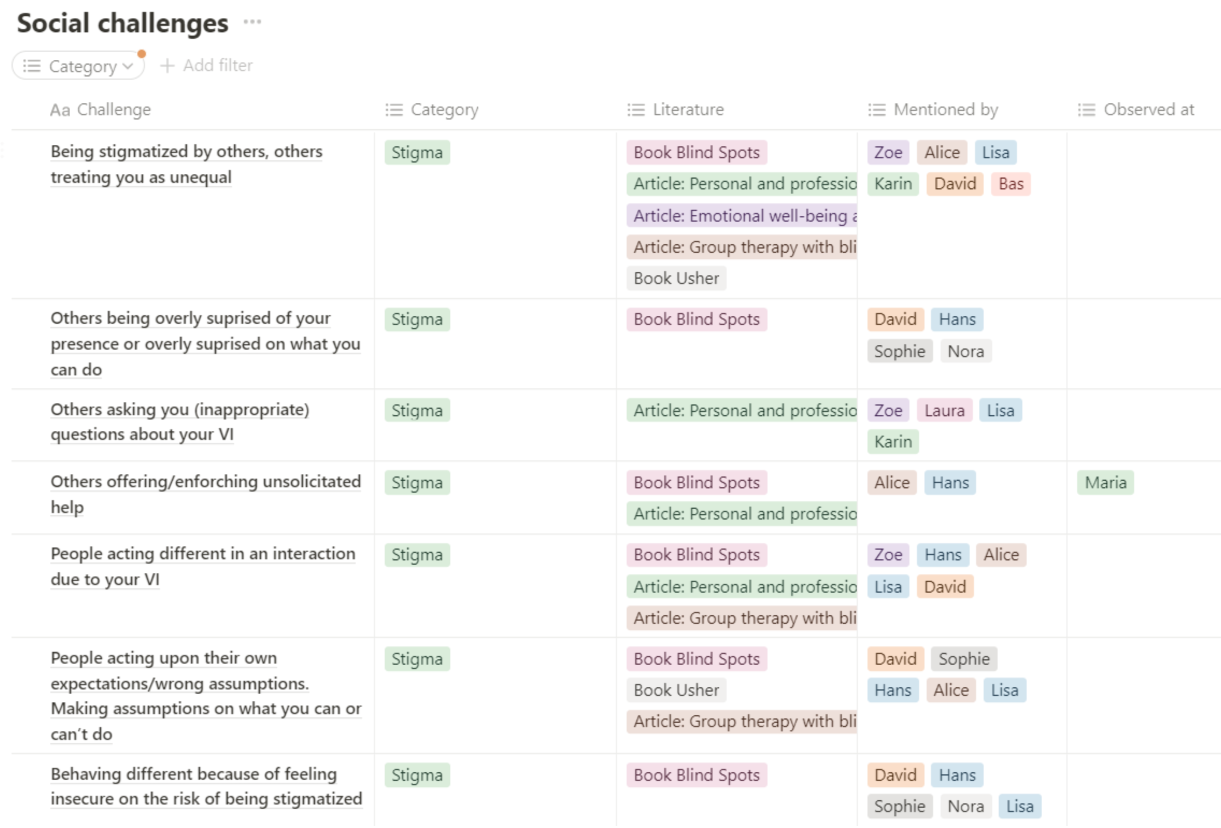
5.1.2 Information Processing

To analyze all the gathered data and information, I started by making extensive notes on all the interviews, shadowing sessions, and literature sources described in chapter 5.1.1. Subsequently, I read through all the notes and structured all the challenges I came across in a large table. Next to writing down the specific challenges, I also wrote down who explained to experience these challenges,

and/or whom I observed the challenges, and/or which literature sources covered the challenges. This resulted in a large table with numerous small challenges retrieved from the interviews, shadowing sessions, and literature sources described in chapter 5.1.1. A segment of the table is shown in figure 11, for the entire table, please consult appendix 3.

During the creation of this table, I concluded that the high diversity of challenges described made it impossible for me to pick out a few and present them as 'the main challenges'. Though, I did notice some overarching categories within the challenges described, which gave me the idea to cluster the challenges. For this clustering, I used the same table and added a column where I wrote down the overarching categories I noticed. With this clustering, I managed to find eight social challenge areas, as will be explained in the next two subchapters (chapters 5.2 and 5.3).

During the analysis of the data, I also noticed that each challenge could be experienced slightly differently depending on the exact context where it was experienced in. Similar to the social challenge areas, I wrote down the context characteristics that I noticed influenced the challenges experienced.


Social challenges ···
Category + Add filter

Aa Challenge	Category	Literature	Mentioned by	Observed at
Being stigmatized by others, others treating you as unequal	Stigma	Book Blind Spots, Article: Personal and professio, Article: Emotional well-being a, Article: Group therapy with bli, Book Usher	Zoe, Alice, Lisa, Karin, David, Bas	
Others being overly suprised of your presence or overly suprised on what you can do	Stigma	Book Blind Spots	David, Hans, Sophie, Nora	
Others asking you (inappropriate) questions about your VI	Stigma	Article: Personal and professio	Zoe, Laura, Lisa, Karin	
Others offering/enforching unsolicitated help	Stigma	Book Blind Spots, Article: Personal and professio	Alice, Hans	Maria
People acting different in an interaction due to your VI	Stigma	Book Blind Spots, Article: Personal and professio, Article: Group therapy with bli	Zoe, Hans, Alice, Lisa, David	
People acting upon their own expectations/wrong assumptions. Making assumptions on what you can or can't do	Stigma	Book Blind Spots, Book Usher, Article: Group therapy with bli	David, Sophie, Hans, Alice, Lisa	
Behaving different because of feeling insecure on the risk of being stigmatized	Stigma	Book Blind Spots	David, Hans, Sophie, Nora, Lisa	

Figure 11: Segment of the table used for collecting insights on Social Challenge Areas. In the table, first, the challenge is described, followed by the challenge category. The three columns on the right describe which literature and interview sources it was retrieved from, and at which PBLV I observed the challenge.

“... Sometimes I am afraid that I am just staring at someone constantly, and that is very uncomfortable, you know...”

~ Quote by Lisa, who has been completely blind since she was three

Contextual factors that influence the challenges

General category

Influence	Explanation	General category	Variables	Source
Type of VI	What type of VI someone has, and what the percentage of leftover vision is, influences the challenges someone experiences	VIP specific	Nightblindness, Photophobia, Low vision, Legally Blind, Completely Blind	David, Sophie, Bas, Hans, Alice, Maria, Lia, Nora, Zoe, Laura, Lisa
Onset of VI	The onset of the VI seems to have an influence in how well you adapted to missing the visual cues.	VIP specific	From birht/early in life, Later in life, sudden, gradual	David, Sophie, Maria, Bas, Inge ten Have, Alice, Lisa, Lia
Visability of VI	How obvious it is to others that you are visually impaired or not	VIP specific	visible, invisible	Book Blind Spots, Zoe, Nora, David, Hans, Sophie, Laura, Bas, Alice, Lisa, Lia, Maria
Identity integration	To what extend have VIP 'accepted' their condition, this has often a great influence on if they feel comfortable telling others or asking others for help.	VIP specific	Multiple stages	Nora, David, Zoe, Lisa, Hans, Laura, Bas, Maria

Figure 12: Segment of the table used for collecting contextual factors. The first two columns explain the characteristic in keywords and detail respectively. The middle column shows the contextual factor it belongs to is described. The fourth column explains the variables of the specific characteristic. The last column, explains which literature, interview, and shadowing sources the characteristic was retrieved from (chapter 5.1.1).

Again, I structured them with subsequent sources in a large table. A segment of this table can be seen in figure 12, for the complete table please consult appendix 4. The characteristics found could be clustered into three contextual factors, as will be explained in chapter 5.4.

5.2 Main challenges in social situations

From the contact with PBLV and the literature study, an extensive list of both small and large social challenges appeared. As explained, the high diversity in challenges described made it impossible to pick out a few and present them as ‘the main challenges’.

Nevertheless, it was possible to cluster all the challenges, which resulted in eight challenge areas. Chapter 5.3 will elaborate on these challenge areas, explain how they were derived from interviews and relate to the literature. To orient the reader here, a brief overview of the clusters will be presented below.

- **Stigma:** being stigmatized by others results in spoiled interactions, which makes PBLV feel insecure or frustrated and behave differently in social settings.
- **Processing stimuli:** processing all environmental impulses with limited to no vision requires more effort and energy for PBLV, which sometimes makes them feel overwhelmed and behave differently.
- **Orientation:** Related to processing stimuli and being dependent on others, PBLV often have to put in extra effort orienting themselves in social situations. Difficulties with orientation might limit them in having **social** interactions or require them to make minor adaptations to make the situation better manageable.
- **(In)dependence:** The constant tension of having to ask others for assistance negatively impacts PBLVs' experience of social situations. The dependence on others takes away some control, which results in feeling frustrated. Furthermore, PBLV often worry about being a burden to others in social settings.
- **Nonverbal perception:** having a visual impairment greatly influences one's ability to perceive the nonverbal communication of others. This makes it harder to properly understand and empathize with others.
- **Nonverbal expression:** Furthermore, PBLV also experience struggles with expressing nonverbal communication, mostly revolving around the inability to make eye contact.
- **Recognizing others:** Another factor that greatly influences social life for PBLV is their (in)ability to recognize others. It makes it hard to approach people or greet them. This behavior may be perceived as rude by sighted people.
- **Understanding of others:** It was found that PBLV struggles with making others understand what they go through, what their vision is, and what their subsequent needs are. Which could impact bonding and empathizing.

Next to the challenge areas, I noticed that there are several elements within each context that influence the challenges experienced. The elements that I found could be clustered into **three contextual factors**: **personal characteristics** (PBLV specific), **audience characteristics** (the other people attending the social situation), and **environmental characteristics** (the environment in which the situation takes place). These three contextual factors will be explained elaborately in chapter 5.4.

5.3 Social Challenge Clusters

Cluster 1: Stigma

Themes within this cluster are described in numerous literature sources (de Ruiter, 2020; Frame, 2004; Giarratana-Oehler, 1976; Krishna et al., 2008; Nyman et al., 2012; Oehler-Giarratana & Fitzgerald, 1980), ergo therapist ten Have, and eleven PBLV.

Based on the theory of Goffman (1963), Frame (2004) describes stigma as "an attribute of one's social identity that is deeply discrediting" (p.8). Stigma is generally known to negatively influence someone's social life. People with physical disabilities are often uniquely stigmatized because

> *"(a) they are often blamed for a stigma beyond their control, (b) they often require or need the assistance of others, (c) prejudice against them serves no current or historical economic or social cause, (d) their physical condition could happen to anyone, causing others to recognize their vulnerability, and (e) most are not raised by disabled parents and/or do not grow up disabled"* (Frame, 2004, p. 8)

All eleven PBLV that were interviewed, explained to experience struggles with being stigmatized. An illustration of stigmatization is provided in figure 13. The examples that they provided could fill a few extra pages of this report. For example, Lisa explained that she used to get annoyed when strangers directed questions about her visual impairment toward her mom only, which made her feel like she was treated like a baby. David explained that it frustrates him that others often react overly surprised when he attends regular events like a party:

> *"You should not make things more special than they are, that is bullshit!!"*
> ~ Quote by David

Alice told numerous examples of extreme situations, from enforced unsolicited help, to the extent where she was nearly abused by others as a result of stigmatization.

Figure 13: Stigmatization, two people that are talking behind the back of a PBLV, discussing 'what she might have'

The stigma creates tension for PBLV on whether or not to tell others about their visual impairment (de Ruiter, 2020; Frame, 2004; 5 PBLV; and ten Have).

> *"Sometimes I try really hard to make sure that others don't know I am blind, because, I don't know, then I am again seen as an exception, and that I simply don't like"* ~ Quote by Lisa

Where some decided to hide their visual impairment, other interviewees explained that it made them feel forced to explain their VI to others. In addition, five PBLV mentioned it made them behave differently in certain situations because they felt at risk of being stigmatized.

Cluster 2: Processing Impulses

Themes within this cluster have been described by (Frame, 2004; Nietsch, 2015), ten Have, and eight PBLV and observed at two PBLV.

Being visually impaired results in processing stimuli from the outside world in a different manner than sighted people do. In general, PBLV constantly have to put more effort into answering questions like 'Where am I', 'Who and where are the people around me?', 'What does my environment look like?', 'Who is the person that is talking to me?', 'Where do all the sounds come from?' (ten Have). The struggle with processing stimuli is visualized in figure 14.

Figure 14: Processing Impulses, a PBLV that is struggling to process all the sounds and voices around her

During an interview, Hans explained his struggles with processing stimuli when his vision was at its worst. He explains how busy situations make it harder for him to recognize others by their voice.

> *"That is difficult, and disturbing, also when I am attending a gathering. That then requires a massive amount of energy, because you have to focus intensively on what you are hearing."*
> ~ Quote by Hans

Nine PBLV explained that processing stimuli often requires a lot of energy, and sometimes makes them feel overwhelmed during, or after the social situation. Especially dark and unknown environments and environments with many people make processing stimuli more energy intensive.

> *"Yes, that has a very large influence, especially sound, and people. I also often have, when I would have gone to that bar, at that moment that evening I feel okay until I step outside, then I get an intense headache of all the impulses, signals, or things that got fired on me during the previous three hours at the bar."*
> ~ Quote by Bas

In addition to the overwhelmed and tired feeling that results from processing stimuli, PBLV might change their social behavior to deal with the situation. For example, during the shadowing session at the Bingo event, it was observed that Maria and Lia could barely socially engage at the event because processing the environmental stimuli and playing the game required all their focus. The sighted people that attended the Bingo session were chatting a lot while playing the game, while Maria and Lia could often not join these conversations.

Cluster 3: Orientation

Themes within this cluster have been described by eight PBLV and observed at four PBLV.

Related to processing impulses, PBLV sometimes struggle to orient themselves in social settings, which is illustrated in figure 15. Getting to know where things and people are can be challenging, as was confirmed by five PBLV during the interviews, especially in unknown settings.

> *"If I am going somewhere new and I know it is gonna be with a bunch of people that I do not know very well and I do not know what the environment is, I am on edge."* ~ Quote by Nora

The difficulty to orient themselves can influence their social behavior. For example, during the shadowing session at the presentation, Sophie happened to be facing toward her left side, which resulted in her having less contact with the people on her right.

Furthermore, five PBLV explained that in busy social settings, they had a preferred location to sit or stand at, to improve their orientation abilities. For David, Sophie, and Nora this meant that they preferred to sit/stand next to the bar in a club or cafe rather than standing in the open space.

> *"Yeah, I think I will stay by a wall or a safe thing to hold on to. Because people don't know that you can't see, and they can knock you over, [...] and when you lose contact with somebody then I am like 'Shit!', you know, 'Where am I'. And it takes me such a long time for my eyes to adjust to what I was looking at. That can be really disorientating."*
> ~ Quote by Nora

Four interviewees also explained that they sometimes try to make small environmental adaptations to make sure they can orient themselves as well as possible. Making such adaptations was also observed at three PBLV. For example, Sophie adjusted the illumination during her presentation, to allow her to see others as well as possible. They also often try to be at the location of the event early, so that they can take the time to properly orient themselves (de Ruiter, 2020; and four PBLV).

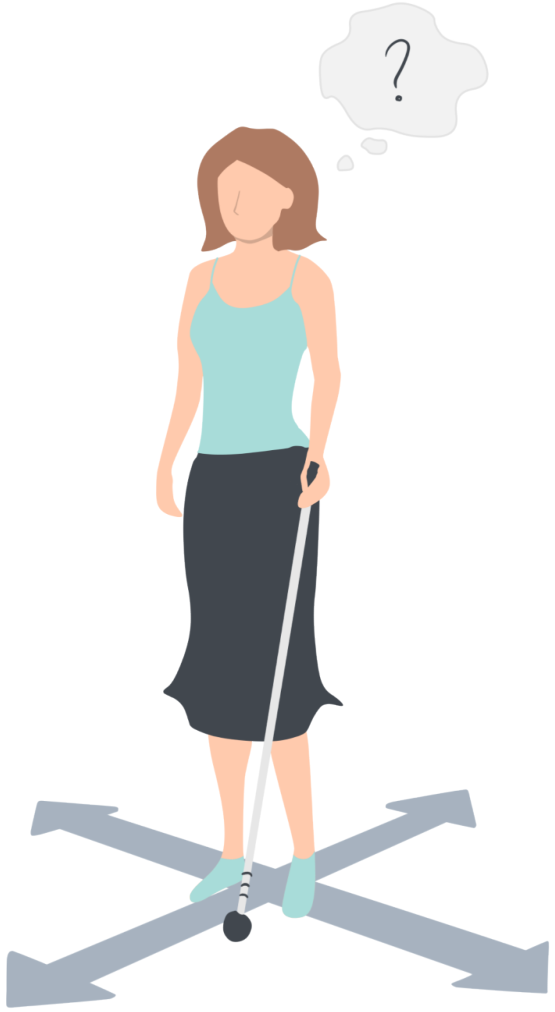


Figure 15: Orientation, a PBLV struggling to decide which way to go, because she struggles to orient herself

Cluster 4: (In)Dependence

Themes within this cluster have been described by (de Ruiter, 2020; Frame, 2004; Oehler-Giarratana & Fitzgerald, 1980), and twelve PBLV.

Even today, PBLV still have to ask for help, on tasks sighted people often take for granted. This decrease in control can result in feelings of frustration or insecurity.

> *"... I find that very bothersome for myself, but also for the other person..., because yeah then I think, yeah, shit someone else has to do this, that I dislike, and for myself, I think jeez ... I cannot do that myself..."*
> ~ Quote by David

PBLV often have to prepare for (social) events elaborately (de Ruiter, 2020; Frame, 2004; and three PBLV) which makes it hard to attend spontaneous events. Transportation is one of the major preparation tasks. How and when can I get where I need to be, and who am I gonna ask for help on this? These are questions PBLV often have to ask themselves.

Despite the preparation, PBLV often still need help during the event. For example, help with social navigation (three PBLV), help with reading things (de Ruiter, 2020; Frame, 2004; and five PBLV), and help with orientation (de Ruiter, 2020; Frame, 2004; and seven PBLV). An example is illustrated in figure 16.

Having to ask for help is not only bothersome for themselves, but they are also often worried about being a burden to others (de Ruiter, 2020; Frame, 2004; Nyman et al., 2012; Oehler-Giarratana & Fitzgerald, 1980; and three PBLV)

As discussed by Frame (2004), some PBLV might feel like others have great control over their life, due to their disability. Frame (2004) found that belief in powerful others' locus of control (LOC) can increase the positive effect of perceived stigma on depression.

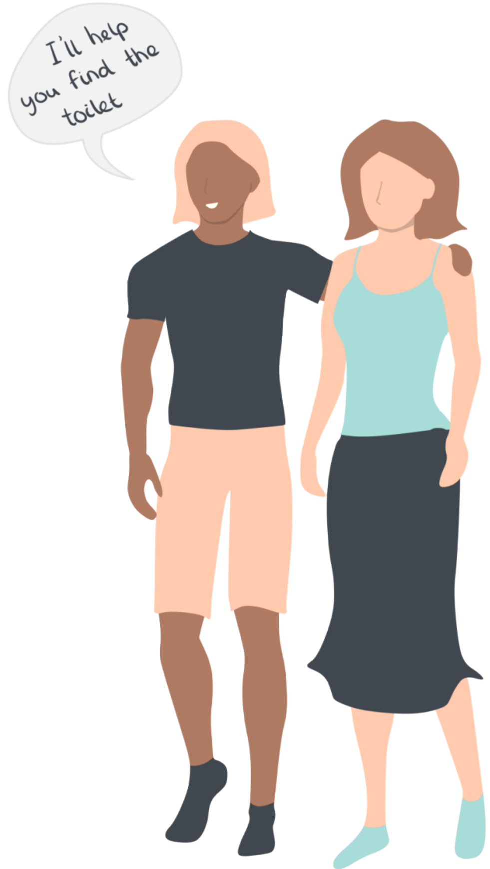


Figure 16: (In)dependence, a PBLV receiving help from a sighted person to find the toilet

Cluster 5: Nonverbal Perception

Themes within this cluster have been elaborated on in multiple literature sources (Buimer et al., 2018; Frame, 2004; Hayden, 2014; Krishna et al., 2008; Nietsch, 2015; Qiu et al., 2020), and have been described by twelve PBLV. Furthermore, it was observed at six PBLV both during shadowing sessions and interviews.

As PBLV have limited to no vision, they often miss out on many nonverbal cues provided via the facial expressions and body language of others. This can make it hard for them to understand or empathize with others, as is illustrated in figure 17.

Like Sophie explains how she misses the ability to make eye contact with others, especially in a bar when she is trying to figure out if someone likes here or not:

> *"Then you are in such a bar, and it used to be my thing to make eye contact, [...].That part, yeah, isn't possible. And I can estimate if someone is or isn't my type after a while, but really that, yeah, the flirty game is gone..."*
> ~ Quote by Sophie

The list of information they miss out on is long and reaches from very small details, like somebody that looks at their watch to indicate it is time to end the conversation (Krishna et al., 2008), and missing out on jokes (mentioned by Bas and observed by Maria and Lia), to missing out on how others are feeling (Buimer et al., 2018; Krishna et al., 2008; Qiu et al., 2020; and ten Have), or missing out on when someone makes eye contact with you (Qiu et al., 2020; and seven PBLV).

> *"Yeah, that is very difficult, because sometimes people around you are signing things or making gestures to each other that are very funny, or making funny faces, or something like that. Well, imagine, at a cozy cafe or at a drink, that people are signing a lot, or waving with their fingers like 'how much [beer] should I order?', that kind of thing you miss out on."*
> ~ Quote by Bas

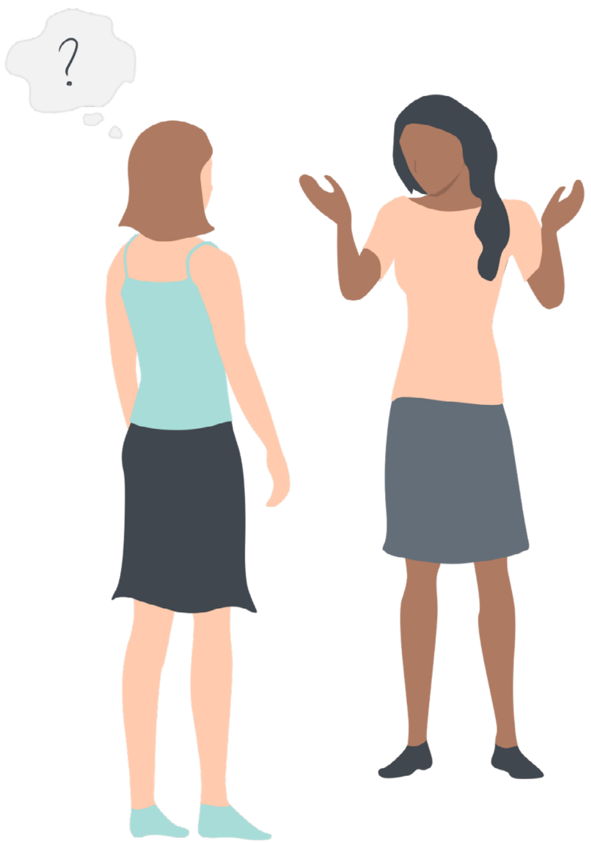


Figure 17: Nonverbal perception, a sighted person communicating through body language with a PBLV, but the PBLV is not aware of this

Cluster 6: Nonverbal Expression

Themes within this cluster have been described by (Frame, 2004; Krishna et al., 2008; Qiu et al., 2020), and eleven PBLV.

Related to nonverbal perception, PBLV also often struggle with nonverbal expression. A big struggle within the theme of nonverbal expression is the inability to make eye contact (Frame, 2004; Qiu et al., 2020), or the inability to know when you are accidentally making eye contact, as Lisa explained:

> *"...sometimes I am afraid that I am just staring at someone constantly, and that is very uncomfortable, you know..."* ~ Quote by Lisa

Furthermore some people can, because of their visual impairment, also act out different body mannerism in a social situation then sighted people do (Krishna et al., 2008). For example, they might have learned different gestures, or might not got used to turning their head toward the person talking (Frame, 2004), as is illustrated in figure 18. This was also observed at five PBLV.

The type of visual impairment can sometimes also influence the nonverbal expression of that person. For example, Zoë is only blind to one eye, in a social setting. It could be that people that are sitting on her left, might have less interaction with her than people on her right. As a solution, she puts herself differently at each table, so that it is comfortable for her to be able to interact with everybody.

Figure 18: Nonverbal expression, a PBLV having a conversation with sighted people, while looking into another direction

Also, the strong desire to make others feel at ease, combined with struggles in processing stimuli can sometimes lead to PBLV behaving overly expressive in a social situation to manage the interaction, as confirmed by three PBLV. For example, Sophie explained that a busy setting, when having to process all the stimuli, can sometimes make her behave much more energetically, which friends do not always understand. They see her as a busy person, but they do not really understand why she becomes busier in such settings.

Cluster 7: Recognition

Themes within this cluster are covered elaborately in literature (de Ruiter, 2020; Frame, 2004; Hayden, 2014; Krishna et al., 2008; Nietsch, 2015; Qiu et al., 2020) and are described by eleven PBLV and ten Have.

Because of missing visual cues, PBLV often struggle to recognize familiar people around them (Frame, 2004; Hayden, 2014; Krishna et al., 2008, ten Have; and nine PBLV). Many PBLV explained to use voice recognition instead, however, in busy settings, surrounding noises can make this more difficult.

For example, Sophie told about a frustrating situation where she was visiting a bar in her neighborhood, with a friend who comes from another neighborhood:

> *"Many fellow townspeople from the past, they also come there, and those people I don't recognize. My friend, she isn't from around here, she asked like 'And?', that was 'Do you recognize people?' And then I had to tell her multiple times like 'Yeah sweetheart, I don't see that, I see a mass [of people], I don't see [individuals]'. And that gave me a feeling of frustration"*
> ~ Quote by Sophie

Not being able to recognize people on time, can cause awkward situations where a familiar person greets you, and you are not able to respond properly. Such a situation is illustrated in figure 19 on the next page. Furthermore, it can also become harder to know who is talking to whom in a social setting, and therefore harder to follow conversations.

> *"...or I don't see faces, people get upset with me, cause they wave at me or they say something to me and I don't see them. And especially when I am going past on a bike [...] they had like 'why didn't you see me?!'"*
> ~ Quote by Nora

PBLV explained that problems with recognition are most prevalent in larger settings with many people. Therefore in these settings PBLV often take on a more passive role, waiting for others to come to talk to them (explained by 5 PBLVs and observed in 2 PBLVs). As Hans explains:

> *"I always prefer it when people come over to me so that I do not have to walk around searching for everyone"*~ Quote by Hans

Although this might sound like a fine solution, it does make PBLV more dependent and can evoke negative emotions as Hans further explains:

> *"I do find that disturbing sometimes, I even think that is a loss. Because I do not recognize people on time, and later I hear that this and that person also went there, and then I think 'gosh, what a pity, I would have loved to catch up with that person"* ~ Quote by Hans

Concluding, not being able to recognize familiar others on time, can make it harder to start and follow conversations, especially in larger social settings, which can feel like a loss to PBLV.

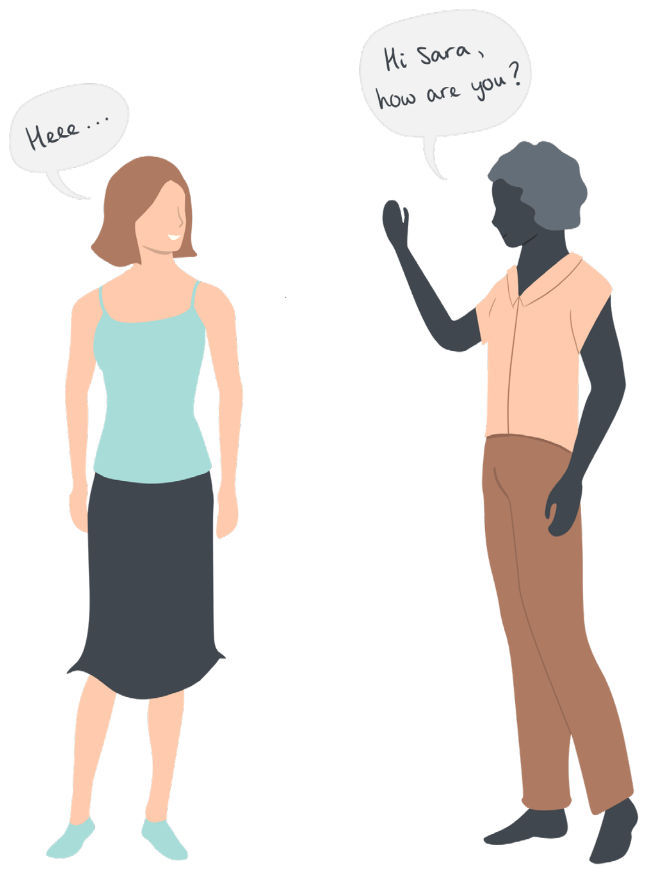


Figure 19: Recognition, a PBLV being greeted by someone else, while she is not able to recognize that person on time

Cluster 8: Understanding of others

Themes within this cluster are discussed by de Ruiter (2020), Frame (2004), and Nietsch (2015) and, ten PBLV.

The last cluster to discuss is the struggle PBLV experience with making others understand their visual impairment and the implications it brings along, as illustrated in figure 20.

Frame (2004) explains that this issue is most prevalent in people with a partial visual impairment. Society thinks of visually impaired people as being completely blind, and using a cane and/or a guide dog. For other people that have problems with their eyes, their vision can be corrected with glasses or surgery. Understanding the vision of someone that falls in the middle of these two categories is often difficult.

> *"I have had a point where people like would say 'Oh yeah, hmm, okay, well go and get some stronger glasses', or something like that"* ~ Quote by Nora

Bas figured that using analogies to explain his VI to others worked well:

> *"... for me some parts of my retina work and others don't, that is very hard to understand. Therefore I always explain to others 'Grab your phone and hit it with a hammer, and what you see then is what I have to look through the entire day'..."* Quote by Bas

Not only explaining their VI can be a struggle, often PBLV find it difficult to discuss their personal needs in a social setting (de Ruiter, 2020; Frame, 2004; Nietsch, 2015; and five PBLV). Furthermore, they sometimes get the feeling that they have to prove to others what they can and cannot do (de Ruiter, 2020; Frame, 2004).

Figure 20: Understanding of others, a PBLV trying to explain her VI to a sighted person

5.4 Contextual Factors

As explained in the chapter above, the eight challenge areas include many sub-challenges. The same analysis of the interview, shadowing, and literature data, showed that even a single subchallenge could be experienced differently depending on the context.

Regarding (in) dependence, the feeling evoked when asking for help, can for example change dependent on the familiarity of the person you ask for help. Like, five interviewees mentioned they struggled with having to ask others to read stuff for them but experienced different levels of insecurity dependent on who they were asking for help. For David, the specific struggle was that friends had to read the menu for him when visiting a restaurant, while Laura was feeling more frustrated when having to ask strangers to help her read the public transport communication boards.

Contextual factors that accounted for the differences in experience, were found when asking PBLV to compare situations where they were dealing with the same challenges while experiencing them differently. Furthermore, during the interview questions were asked like if the number and familiarity of people at a social event influenced their experience. Analyzing the data gathered, allowed dividing the contextual factors into three categories: **'personal characteristics'**, **'audience characteristics'**, and **'environmental characteristics'**, their meaning and impact will be further discussed in the subchapters below. This chapter will make clear that you cannot design a product to help in a specific context and automatically assume it will work in different contexts as well, but that different contexts need to be taken into consideration while designing.

“I am happy that I have been able to see something, because therefore I do know what colors look like, and am able to talk along with others...”

~ Quote by Lisa, who has been completely blind since she was three

5.4.1 Personal characteristics

Effects of personal characteristics on the outing of social challenges were described by eleven PBLV, ten Have, Frame (2004), and Giarratana-Oehler (1976).

From literature, interviews, and observations it appeared that five personal characteristics influence the experienced social challenges:

- **Type of visual impairment:** Every visual impairment is different, which greatly influences their experience and challenges in social life (as confirmed by eleven PBLV). One that has cataract vision might be able to see details, like a face, but miss out on greater things like someone approaching them. Whereas someone with overall blurred vision might see the person approaching, but have no clue who he/she is.

- **Onset of the visual impairment:** Six PBLV and ergo therapists ten Have confirmed that the onset of the VI influences the social challenges. Generally speaking, if a person is born visually impaired or turned visually impaired at a very young age, he/she usually experiences fewer challenges in processing stimuli or feels less limited by missing out on body language, than someone that turned visually impaired at a later age. Though on the other hand, never having experienced what vision is like, might make PBLV feel more left out when others talk about visual experiences.

- **Identity Integration:** During interviews, it appeared that many PBLV (had) struggled with ‘accepting’ their VI. Giarratana-Oehler (1976, p. 3) explained how it might not be about acceptance but rather about identity integration, which they explained to be: ‘a state of self-actualization in which the individual has learned to live with his disability, to realize his limitations, to involve himself in a world outside of himself, and to return to the fulfillment of life goals.’ One that has not fully integrated the VI into their identity, might feel more limited and influenced by stigma and feel more frustrated because of their dependence on others.

- **Visibility of VI:** The visibility of a VI can both positively and negatively influence the challenges PBLV experience in their social lives, as explained by eleven PBLV and Frame (2004). Being open and clear about your VI, and having an obvious VI might take away social boundaries and insecurities of others, and therefore lead to less stigmatization. But the opposite is also true, that increased visibility can lead to increased stigmatization, because of being perceived as ‘more different’ than others.

- **Personal identity:** Lastly, there is no need to explain that every person is different, and therefore each individual will experience different challenges, or experience challenges in different manners with different intensities. David, for example, explained how he had such great levels of energy during the day, that he does not easily get tired by social events, or has to take rest afterward. In contrast, Bas explained how he sometimes gets headaches after visiting crowded areas, because it took him that much energy to deal with the situation.

5.4.2 Audience characteristics

The influence of audience characteristics on the social challenges experienced is explained by eleven PBLV, ten Have, and Oehler-Giarratana and Fitzgerald (1980).

Next to personal characteristics, audience characteristics also influence the challenges experienced. The main audience characteristics that are of influence will be discussed below.

- **Amount of People:** Generally speaking, for PBLV the more people that are present in a social situation, the more challenging that situation will become (as appointed by/observed by nine PBLV and mentioned by ten Have). It can increase challenges with recognition, orientation, and processing stimuli. Especially group interactions are perceived as challenging.

- **Familiarity of people:** Ten PBLV mentioned how the level of familiarity with the others present influenced their experience. The most challenging are situations with people with mixed familiarity, this mostly increases challenges with recognition.

- **Type of Setting:** Three PBLV and ergo therapist ten Have explained how the type of setting is of influence. Settings can be formal, informal, practical, or emotional. For example, Bas explained how in formal settings he prioritizes perceiving practical non-verbal cues, and in his private life, he prioritizes emotional non-verbal cues.

5.4.3 Environmental characteristics

The effect of environmental characteristics on the experienced social challenges has been described by eleven PBLV and ten Have.

Lastly, PBLV's experience of social situations is highly influenced by environmental characteristics.

- **Familiarity with the environment:** nine PBLV appointed that the more unknown an environment is, the greater the number of challenges they experience.

- **Size of the environment:** Larger settings (often including more people) are experienced more challenging by PBLV, not only related to crowdedness but also to the amount of unknown space, as confirmed by six PBLV.

- **Background noises:** Eight PBLV explained that loud environments are often experienced as more challenging and disturbing than silent ones, as it limits their ability to audio focus.

- **Timing:** This aspect highly correlates with the type of visual impairment. Seasons and time of day do influence the type of challenges and the intensity of them experienced. For people that have photophobia, for example, summer outdoor events at midday will probably be most challenging. The timing factor was confirmed by eight PBLV and ten Have.

- **Activity:** The exact activity influences the challenges experienced, and their relative importance, as mentioned by six PBLV. For example with activities that have a social focus, non-verbal communication seems to gain more importance. On the contrary, in a situation like attending a group sports session, challenges regarding orientation and (in)dependence gain more importance.

- **Spontaneity:** Proper planning allows PBLV to manage their social situations more easily, as five PBLV explained. In contrast, spontaneous events are considered much more challenging, for example going to a restaurant before having read the menu in advance, makes PBLV more dependent on others.

5.5 Limitations

For this study several resources have been consulted, with the interviews with PBLV being the main source of input.

The interview brought along some limitations that might have had some influence on the results of this study.

The primary limitation is that it was very hard to bring the above **latent needs** of PBLV regarding social challenges. Latent needs are needs that are more under the surface, people are not very aware of the fact that they have these needs, or are not aware of the problems they experience. PBLV are often used to their life and take most of the challenges for granted. They do often not consider the challenges they experience as things that can be solved, which made it harder for them to express their emotion towards the challenges. For example, many PBLV struggles to perceive non-verbal communication, but they don't feel like anything can change that, and therefore they do not often dwell upon it.

Secondly, because of the semi-structured interview method, **topics weren't fixed**. Along the way, it was discovered that larger social situations (including multiple people) are generally experienced more challenging. Therefore the interview focus shifted a bit more towards discussing larger social situations, rather than small ones like visiting a friend. The non-structured approach and shifted focus resulted in variation between interviews on what was discussed and what wasn't. This might cause for some of the challenges not being confirmed by some PBLV, while they actually do experience those challenges but they were simply not discussed.

With the high diversity and variation of challenges experienced (for the entire list of sub-challenges per theme consult appendix 3), the list of challenges can **never be considered complete**. Nevertheless, the challenges described in this study can be used as topics for consideration while designing for PBLV and can function as an inspiration for new design projects to tackle the social challenges PBLV experience

5.6 Project Takeaways

These results aimed to get a better understanding of the social challenges PBLV experience in their daily lives. The original goal was to find what ***'the main challenges PBLV experience in social situtaions'*** are. However, I found that, due to the high diversity of social challenges, it was **impossible to pix** a few specific challenges and present them as 'the **main challenges**'. Instead, I was able to identify eight overarching categories in the different challenges, and clustered them accordingly to **eight challenge areas**: stigmatization; processing stimuli; orientation; (in)dependence; nonverbal perception; nonverbal expression; recognition; and understanding of others. I also identified three factors that influence the challenges experienced: personal characteristics, audience characteristics, and environmental characteristics.

For developing a supporting device to make PBLV feel more at ease in social situations, which is the goal of this project, this study provides many possible focus areas. Furthermore, this study made me aware that designing a supportive device for one specific context, won't directly mean that it will be useful in other contexts as well. This is because the **contextual factors** influence the challenges experienced and therefore also the needs of PBLV.

Thus, this study gave multiple possible directions for narrowing down the project goal towards a design goal. To decide upon a direction, it is also important to consider which helping devices are currently on the market, and which design projects on the social life of PBLV have already been executed. This will be treated in the next chapter. In chapter 7, insights from both studies will be combined and converged into this project's design goal.

6. Design Context: Technologies for improving social situations for PBLV

In the previous chapter we have learned what type of challenges PBLV can experience in social life. In order to ***'Develop a supporting device that makes PBLV feel more at ease in social situations'*** (the project goal), it is also important to know if and what kind of supporting devices are already on the market with a similar focus, and see if I can learn from these designs.

Numerous helping devices have been designed and developed for PBLV, though few of them have had a social focus (Buimer et al., 2018; Hayden, 2014; Meza-de-Luna et al., 2018) despite its importance (Buimer et al., 2018; Hayden, 2014; Krishna et al., 2008; Qiu et al., 2020). Though, there are some design projects that did attempt to design supporting devices for the social life of PBLV.

Therefore, in this chapter seven projects that did attempt to improve social situations for PBLV will be addressed. Four of them will be studied in detail, in order to learn which challenges and what goal they defined; what solutions they proposed; and what the strengths and weaknesses of their projects were. Followed by a reflection on their current availability/visibility in the helping device market for PBLV.

Although the seven projects all had slightly different focuses, overarching topics were identified. In total, the seven projects together attempted to solve seven specific social challenges. Those challenges are presented in table 4 on the next page, along with the literature sources they were derived from. All of these specific challenges, except for the one on creating awareness of social distance, were also identified during the study on social challenges described in chapter 5. All seven topics, even the one on social distance, easily could be related back to the eight challenge areas that are described in chapter 5. Therefore, the challenges areas that the topics are related to are also presented in the last column of table 4.

Addressed Challenge	*Literature Sources*	*Related Challenge Areas (chapter 5)*
Face detecton & tracking	Hayden (2014); Krishna et al. (2008)	Orientation
Face recognition & recognizing people	Hayden (2014); Krishna et al. (2008)	Recognition
Counting and locating people	Krishna et al. (2008)	Orientation & Recognition
Reading face actions & facial expressions	Buimer et al. (2018); Krishna et al. (2008); Krishna & Panchanathan (2010); Meza-de-Luna et al. (2018)	Non-verbal perception
Reading body gestures and physical descriptors	Krishna et al. (2008)	Non-verbal perception & recognition
Gaze behaviour	Qiu et al. (2020)	Non-verbal expression & perception
Awareness on social distance	Gilfeather-Crowley et al. (2011)	Orientation & non-verbal perception

Table 4: Overview of addressed challenges in seven design projects on improving social life of PBLV

From these seven technological developments, I studied four in more detail. I studied the projects of Krishna et al. (2008), and Hayden (2014) in more detail because they tried to tackle multiple challenges at once. I studied the project of Buimer et al. (2018) in more detail because they had a unique approach to using haptics to communicate with the user. Lastly, I studied Qiu et al. (2020) in more detail, because this study tried to tackle an issue for PBLV and the sighed people that interacted with PBLV simultaneously. Short descriptions of their project are provided below. For more information on the four projects, please consult appendix 6.

Project 1: A Systematic Requirements Analysis and Development of an Assistive Device to Enhance the Social Interaction of People who are Blind or Visually Impaired (Krishna et al., 2008)

The focus of this project was to allow PBLV to more freely engage with sighted others, by designing a system that allowed PBLV to receive information on nonverbal communication. This topic was selected based on the results of a survey with PBLV.

The result was a **smart-glass system** that was able to **detect, track and recognize faces, count, and locate people**. If a person was detected within the field of view of the camera, an audio signal would be sent to the user to communicate that someone was approaching. How exactly these audio signal works is not elaborated upon. If the device was able to identify the approaching person, the identity would also be communicated with the user via audio.

Figure 21: *"The prototype Social Interaction Assistant: Hardware"*(Krishna, et al., 2008)

The paper does not explain what would happen in a situation where multiple people are present. For example, if there is a lot of background noise (which makes it harder for PBLV to orient themselves via audio), how would the PBLV know from which direction the person is approaching? Although the design seemed promising, there has not been a follow-up of the project.

Project 2 Wearable-assisted social interaction as assistive technology for the blind (Hayden, 2014)

The goal of this project was to design *"an end-to-end wearable system designed to learn and assist its (potentially blind) wearers with daily social interactions"* (Hayden, 2014, p. 3). A prototype was realized that could detect social interactions taking place and afterward based on audio snippets ask the user to identify the person he/she was talking to. This information would be linked to visual input on that person's appearance and would allow the **system to recognize others** the next time the user would encounter them. The system would update the user on the presence of familiar people by telling the familiar person's name via Bluetooth earphones. Although identity could be communicated by the system, communicating the the location of that familiar person is not included.

One of the project insights was, for a user to use the product either the value provided should be high or the inconvenience of wearing it should be low. Although useful, the design itself wasn't considered valuable enough, therefore one of the areas for future improvement is to expand product functions, like further recognition abilities, or detecting contextual attributes like location, etc.In addition, it is wise to consider privacy issues and public acceptance during further development and to test the concept in a real-life situation.

Project 3 Conveying facial expressions to blind and visually impaired persons through a wearable vibrotactile device (Buimer et al., 2018)

This project explored the possibilities of designing a **sensory substitution device** (SSD) that would **detect and communicate facial expressions** of others to PBLV in real-time. Their prototype consisted of a head-mounted camera and a haptic belt. To recognize facial expressions from the camera data, they make use of the FaceReader 6 software (Viscar Vision, n.d.). The software uses an artificial deep neural n network to classify facial expressions into six basic emotions. These emotions are translated towards different vibration signals on the haptic belt around the user's waist.


Figure 22: *"An overview of the sensory substitution system worn in the study."* (Buimer et al., 2018)

They tested their system and the results showed that PBLV were well able to distinguish among the different vibration signals while using their other senses simultaneously and that their ability to detect facial expressions improved. However, there are some limitations concerning AI's ability to detect and interpret facial expressions (Hagerty & Albert, 2021; Joshi, 2022; Purdy et al., 2019). Furthermore, privacy issues and stigmatization should still be covered.

Project 4: An Evaluation of a Wearable Assistive Device for Augmenting Social Interactions (Qiu et al., 2020)

During this project a concept of an assistive device was designed that could **simulate gaze behavior for PBLV**, and allow them to **perceive the gaze behavior** of others. The project result was a prototype of gaze-simulating glasses, a camera setup that tracked eye movements of sighted others, and a tactile wristband that notified PBLV when eye contact was made. So far, the design needs an environmental setup to work.

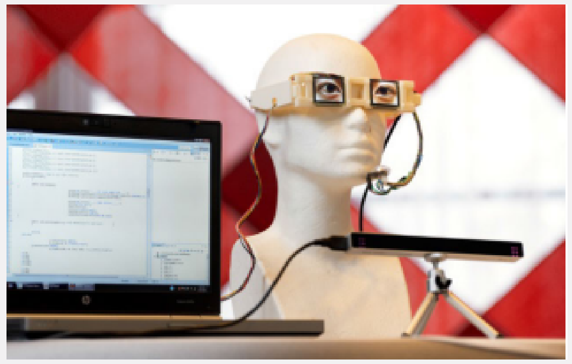


Figure 23: *"A dummy wore a glasses device with the interactive gaze"* (as mentioned in Qiu et al. (2020); photo taken by Bart van Overbeeke, Eindhoven)

They tested their concept in organized social interactions with both sighted people and PBLV and afterward provided the participants with a questionnaire about their experienced communication quality. The results of the test were positive but also varied considerably. The possible effect of wearing such a gaze-simulating device on stigmatization has not been taken into consideration.

Unfortunately, none of the projects seems to be continued, and none of them seems to be developed into sold helping devices on the market. Furthermore, conventional helping device markets do not seem to sell similar assistive devices/services that address the challenges mentioned above (Sell, 2020; Slechtziend.nl, n.d.; The American Foundation for the Blind, n.d.; Works, 2015; Worldwide Vision, n.d.).

Envision is an exception, as they do in fact sell the Envision Glasses which are able to detect the presence of people, and if pictures of the detected face are added to a certain database, recognize them (Envision, n.d.). Although this is not the main focus of their product, it presents interesting areas to expand upon.

6.1 Project Takeaways

Studying these projects provided many insights. Some of them, I consider interesting to take into account during this project and are therefore presented below.

- **Large project scopes:** Despite the good aims of all of the studied projects, none of the designs made it into a real product on the market, which is a pity. A big reason for this is that the projects functioned as research projects and not as commercial projects. However, an additional reason could be that all the projects either tried to solve very large and complex problems (like emotion recognition) or tried to solve multiple problems at once.

  For example, Krishna (2008) tried to solve issues regarding orientation, recognition, and non-verbal perception with one design. Krishna (2008) and Hayden (2014) tried to design a system that could detect all people in a surrounding and recognize as many of them as possible. While Qiu et al. (2020) tried to solve an issue of non-verbal perception and expression at the same time. For a project to lead to a finished product, it might be wise to pick a smaller scope from the start.

- **New product design:** All four projects studied in more detail tried to design a new smart helping device, rather than adding to an existing one. This might be more convenient for the initial design phase, but leaves more information gaps to be filled during further development. In addition, Hayden (2014, p. 65) rightfully mentioned that *"One challenge facing wearable computers is that the value they provide must be high, or else the inconvenience of wearing them must be very low"*. None of the other three projects seemed to take a similar consideration into account. In order to overcome this issue, it might be more convenient to add functionalities to existing helping devices, rather than designing new ones.

- **Use of camera systems:** The four studied projects all used a camera system to receive the necessary information from the surroundings of the user. It might seem very straightforward to translate visual information (that the user often misses out on) to audio or haptic information and communicate this with the user. Though, the success of using a camera in social settings can be argued, as it can infringe on people's privacy (Eveleth, n.d.; Hayden, 2014; Kudina & Bas, 2018).

- **Audio versus haptic communication:** The designs by Krishna (2008) and Hayden (2014) both used audio as a form to communicate with the user, whereas Qiu (2020) and Buimer et al. (2018) used vibrational cues. The decision of which sense to use to communicate with the user is an interesting tradeoff. Although audio is fast, familiar, and can convey complex information, it is a sense that is often already overly used by PBLV in social settings. Therefore, the projects that used this sense for communication, might not have taken into account the challenges PBLV experience in processing stimuli. If using haptics, PBLV can still use their hearing sense for communication with their surroundings. Possibly the use of haptics can therefore be more suited for designs used in social situations.

- **Design appearance:** At least two of the projects (Qiu et al., 2020; Buimer et al., 2018) did obviously not take into account stigmatization in their design projects yet. Although it wasn't their project's focus to design against stigmatization, I feel that while designing a supporting device, designers should at least attempt not to add stigmatizing effects through their designs.

Based on the insights gathered from these projects, I will try to pay attention to sufficiently narrowing down my project scope. Furthermore, I should keep challenge areas that are not the main focus of my project in mind, while creating a design to tackle a certain challenge. This is to make sure that I don't add problems in one challenge area while trying to solve problems in another one. For example, I think it is interesting to consider using haptics for communication rather than audio, to prevent causing more issues with processing stimuli. Lastly, I want to consider not using a camera in my design, which is related to stigmatization, but also to public acceptance.

Conceptualize . . . .

In this report section, I will explain how I derived my design goal from the overall project goal and the gathered knowledge.

After explaining the design goal, design and research iterations will be presented. The iterations lead to the final design 'Sofi' which will be introduced in the next section of this report.

7. Design Goal

At the start of this project the project goal was defined as ***'Develop a supporting device that makes PBLV feel more at ease in social situations'***. The research described in chapters 5 and 6 both made clear that there is a need to further narrow down this goal, and gave possible directions for this. In this chapter, I will explain how I narrowed down my project goal towards a more concrete design goal. In the first subchapter, I will explain the iterations needed to get to the final design goal, and in chapter 7.2 I present the final design goal.

7.1 Goal iterations

The research in chapter 5 made clear that I could focus on eight different social challenge areas within my project goal. Though, I consider focussing on eight areas a too wide scope, and therefore, as I will explain below, I narrowed down the project goal towards a more concrete design goal.

To get a design goal out of the challenge areas described in chapter 5, first, I conducted a semi-quantitative and qualitative analysis. With this analysis, I tried to see if the challenge areas could be ranked in importance. This analysis showed that, although still important, the challenge areas of **processing stimuli** and **nonverbal expression** were **less often mentioned** by PBLV and literature, compared to the other challenge areas, and were furthermore considered **less of a priority** to be solved according to PBLV. For more information on this analysis, please consult appendix 5. Based on this analysis, I decided not to focus on both of these areas. This left left six areas to further consider.

In addition, I decided that I want to focus on the challenge areas in which solutions could have a direct social impact, and offer enough personal learning space. This resulted in **focusing on** the challenge areas of **orientation**, **(in)dependence**, **nonverbal perception**, and **recognition**. These four challenge areas were translated into the following initial design goals:

- *Helping PBLV to improve their social navigation (social navigation meaning being able to mingle around, recognize people, find people to talk to, etc.)*
- *Allowing PBLV to initiate interaction*
- *Allowing PBLV to perceive non-verbal cues during interactions*
- *Allowing PBLV to feel more in control when asking for and receiving help*

To select one of these design goals, I conducted creative activities to get a feeling of where I could make the most impact and which design goal inspired me the most. These activities are briefly explained on the next pages.

7.1.1 Changing stories (figure 24)

Creating detailed stories of social situations PBLV could encounter, and rewriting those stories with solutions for different design goals in mind, helped me understand the impacts I could make. I wrote two stories, one where a PBLV was going to a bar with friends, and another where a PBLV would visit a BBQ birthday party in her friend's garden.

Each story I rewrote four times, with the four design goals in mind respectively. This gave me insights into the smaller impact details, such as finding the friend you agreed to meet up with at the entrance of the bar (recognition), being able to know the right moment when to join an interaction (initiating interaction), or being able to see when a friend wants to go home (facial expressions). Furthermore, by creating summaries of the impacts, I realized that the design goal of being able to initiate interaction was overlapping with the design goals of improving social navigation and reading non-verbal cues. I considered the design goal of **initiating interactions** to be too complex and therefore decided **not to focus on it**. The complete stories can be found in appendix 7.

Figure 24: Changing Stories

7.1.2 How Can We's (HCW)

To get some initial inspiration on solutions for each design goal, I decided to use the HCW method. Based on the changing stories, I made up a set of 19 HCW questions that covered the design goals described earlier. I tried coming up with solutions for these HCWs on my own and with roommates (SP 5 and 8, see figure 25). The results of these HCWs provided me inspiration for further brainstorming sessions, as will be explained in the next paragraph.

Figure 25: Picture of two roommates helping me out with HCW's

7.1.3 Brainstorming sessions

To get more concrete ideas for each design goal, I conducted several brainstorming sessions. Both traditional brainstorming and idea brain dumping, as well as a self-developed design method called 'Cards against Designers' (CaD). This brainstorming method was based on the input from How Can We (HCW) sessions. The basic idea was to combine single HCW answers to compose crazy concepts for very specific challenges of PBLV. Two sessions were organized, both at Envision (SP 1, 2, 3, 4, and one PBLV, see figure 26), as well as at home with roommates and friends (SP 5, 6, 7, 8, and 9). Both people with a design and non-design background joined the session.

These sessions resulted in several strange ideas. For example, one problem statement was 'Being blind and wanting to order drinks at the bar, but the bartender isn't noticing you. The solution to this problem was a belt with wires so that you could always pull the bartender towards you when you want to order drinks (see figure 27). Although these ideas were never really directly applicable, they did inspire me to create more feasible ideas during this brainstorming phase. Next to providing me with interesting concepts, as will be discussed in chapter 8, the brainstorming phase also gave me the insight that I did **not have** the **inspiration** to design something **for making PBLV feel more in control** during asking for and receiving help.

Figure 26: Cards against Designers session with colleagues at Envision

Therefore, I decided not to focus on the design goal of feeling in control. Along with the decision not to focus on the design goal of initiating interaction, the two design goals of social navigation and nonverbal perception remained. During the brainstorming sessions, I noticed I felt **most inspired** by **designing for social navigation** and decided to **continue with this design goal**.

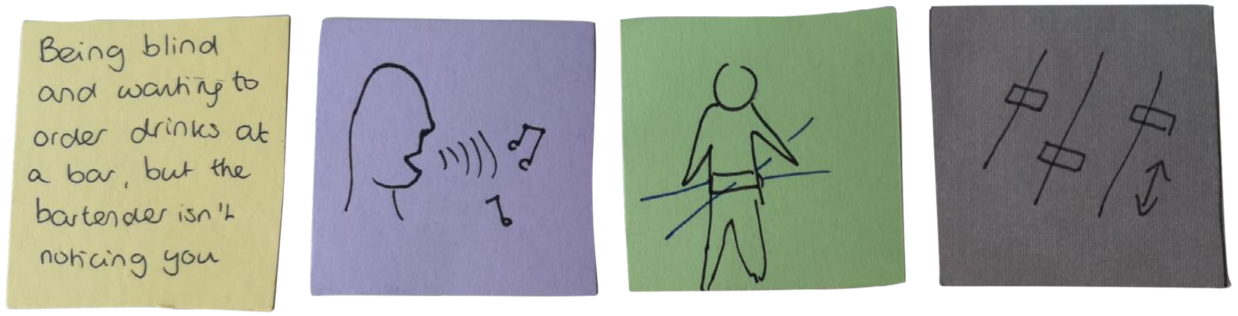


Figure 27: Example of a Cards against Designers solution

In summary, this subchapter explained how I narrowed down my project goal with the eight social challenge areas towards one **design goal** on **social navigation**, the next subchapter will explain the selected design goal in more detail.

7.2 Final Design Goal

The final design goal of this project evolved to be:

'Designing a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings.'

Designing for this goal can decrease the challenges experienced with **orientation**, **recognizing others**, and the **feeling of dependence**.

Entering a busy social setting while having a visual impairment, can feel like being lost in an unknown forest, not knowing where to go, or where you are. My design should function like a compass in this situation, allowing PBLV to socially navigate themselves despite being in a difficult setting. The analogy is visualized as interaction vision in figure 28.

Figure 28: Illustration of the Interaction Vision: Having a compass that can guide you through an unknown forest.

A design for social navigation could allow PBLV to mingle around at a party, instead of having to wait until someone else approaches them, or finding back the table they were seated at in a restaurant. It could make them feel less clueless when someone familiar unexpectedly approaches them in a random situation, or allow them to find that colleague they wanted to talk to at work.

“Yeah, I think I will stay by a wall, or a safe thing to hold on to...”

~ Quote by Nora, who is in her fifties, and has deteriorating low vision since she was in her twenties

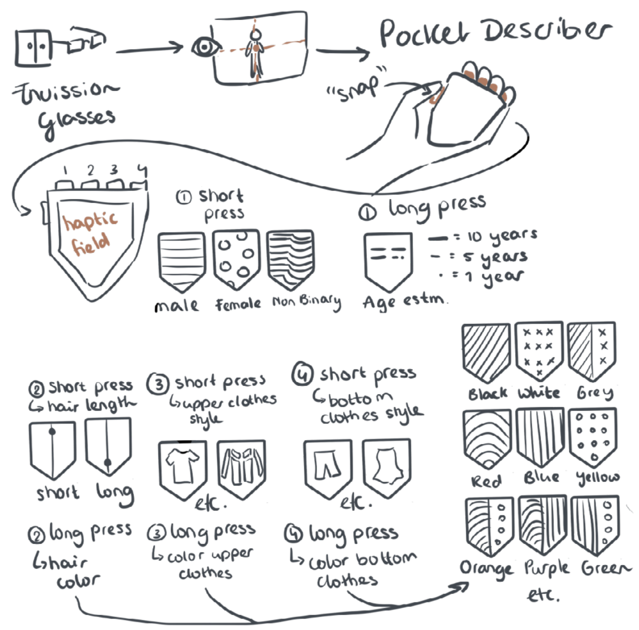
8. Initial Idea Generation

During the development of the design goal ‘Design a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings’, numerous ideas were generated (chapter 7.1). Some small, some very crazy, and some actually useful. From all the ideas generated, twelve presented solutions to help PBLV with social navigation. Seven of them I considered useful, and will therefore briefly be described below. One of them is more detailed than the others, and will therefore be explained first, along with a more extensive visual.

- **Idea 1 Look and Feel** (figure 29): The name of the idea is look & feel, it is a hand-held device that works together with the Envision glasses to describe the appearance of others to the user. The system will translate visual information of the person in view towards haptic patterns that can describe the person’s appearance towards the user.

- **Idea 2 Social Vibe** (figure 30 on the next page, top left): A bracelet that captures sounds, GPS signals, and Bluetooth signals of familiar others nearby. With this information, it determines the locations of the familiar others, which it communicates with the user.

Look & Feel



The Envision glasses will, when the camera is turned on, notify user when someone is in their center view.

User can take a picture of that person, pressing the thumb button.

When the image is processed, the user can receive all sorts of descriptive info about the person in front of him, via haptic communication

Figure 29: Idea Look and Feel

- **Idea 3 Shoe finder** (figure 30, top right): A shoe insole that can let you feel which other people are facing you, via tactile feedback in the insole.
- **Idea 4 Double Watch** (figure 30, middle left): A tactile map on a watch-shaped wearable, that can let you feel where familiar others are nearby. The back of the device can also communicate the names of familiar others through braille-like haptics.
- **Idea 5 Sleeve Language** (figure 30, middle right): Envision glasses that take a picture of a person in front of you, and translate the pixel information towards small electronic input on your arm. Basically, the image would be transformed into vibrating pixels on an arm patch, so you would be able to 'see with your arm'. It is inspired by the Brainport v100 concept (Stronks et al., 2016).
- **Idea 6 Identity Pattern** (figure 30, bottom left): A tactile watch that communicates the identity of people through tactile patterns on top of the watch. Each familiar person would have their own descriptive pattern.
- **Idea 7 FriFi** (figure 30, bottom right): When going to a social event you would hand out identity bracelets to the people you want to be able to locate. Their identity bracelets will share the location with your bracelet via Bluetooth. The user's bracelet would communicate the location and identity of the familiar persons via vibrations.

The ideas used different (some overarching) methods for detecting familiar people, and communicating this to the user. A summary of those methods is listed below.

To detect familiar people, the ideas used:
- Camera and face/body recognition
- Camera and live connection with a support line
- Identity trackers, wearables that tracked location, which would be provided to a few familiar others
- Digital positioning systems (DPS), like Bluetooth or GPS
- Sonar

And communicates identity and/or location of familiar other with the user via:
- Tactile patterns on different locations on the body
- Vibration pulses on different locations on the body
- Electronic pixels

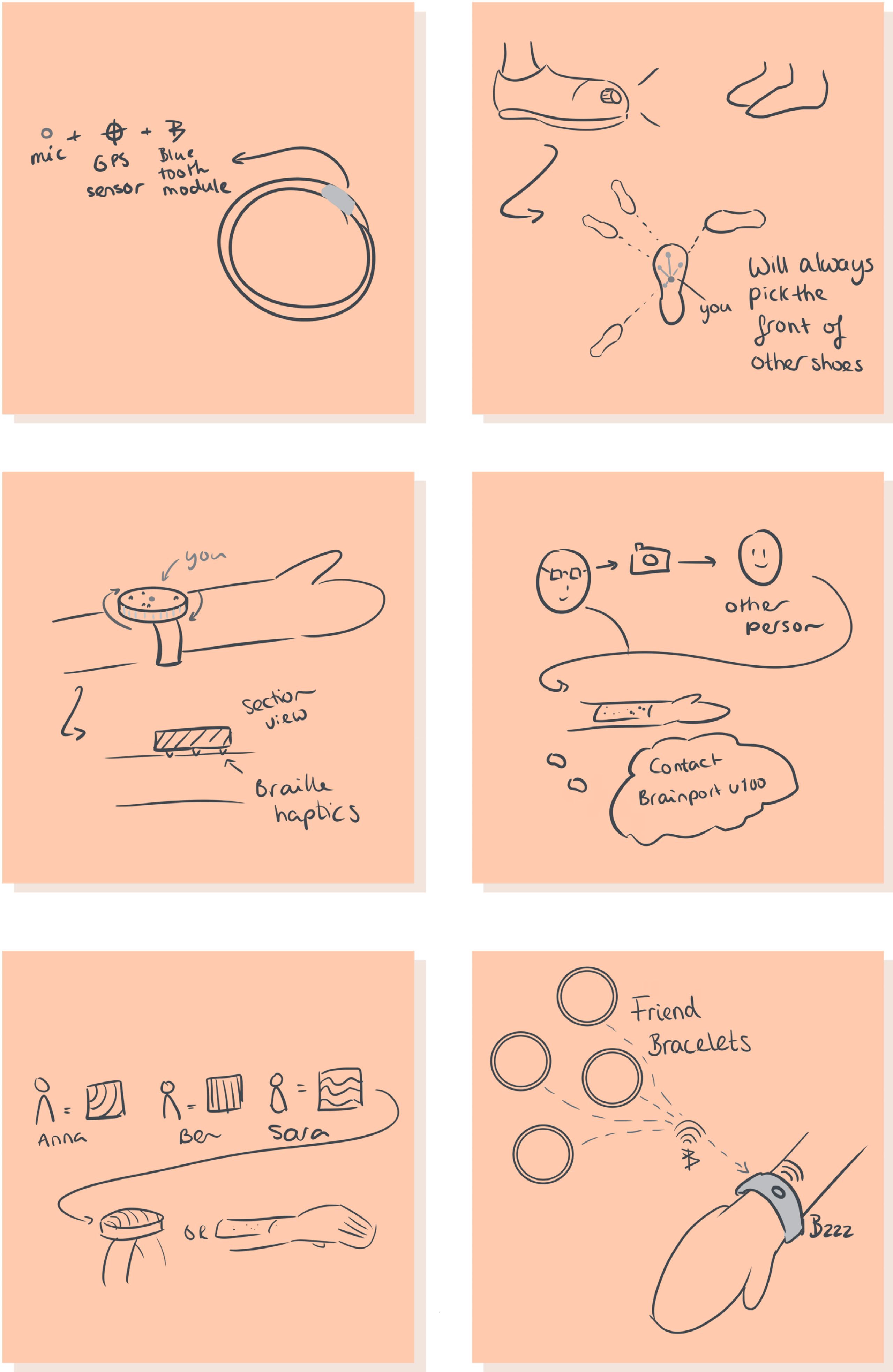


Figure 30: Multiple concept examples

8.1 Project Takeaways

To continue developing these initial ideas into more concrete concepts, I briefly analyzed them based on the insights from the social challenges study (chapter 5) and the study on technologies for the social life of PBLV (chapter 6). I took into account that the designed tool for social navigation (that is related to the challenge areas of recognition, orientation, and (in)dependence, should not add extra problems in other challenge areas (like processing stimuli). Furthermore, I don't want the tool to avoid causing issues with privacy or public acceptance. Lastly, while designing the tool, I want to keep the balance of value versus effort in mind, as described by Hayden (2014) (chapter 6). The analysis of the concepts with these things in mind resulted in the following conclusions:

- The tool designed should be wearable, to make sure that it can be used in multiple situations and is not space dependent. The technology used to detect familiar others in the environment should therefore not be attached to a certain location, but move along with the user. Furthermore, the wearable should be easy to operate for PBLV, and therefore preferably located around the arms/hands.

- The use of haptics to communicate with the user is preferred over visual, audio, or smell input. Haptics can both be perceived by PBLV (in contrast to visual input) and is a sense that isn't overly used yet in social settings by PBLV (in contrast to audio input). Furthermore, haptics can be provided to the user solely, without others being able to notice it as well (in contrast to smell input).

- For tracking the location of familiar others both the use of a camera (with AI recognition) and/or DPS can be suited. The advantage of the camera is that it can be used without the need for live input from familiar others. However, DPS might be more precise, as it can work regardless of the illumination conditions, and is not limited to the field of view of a camera. Therefore DPS are considered more suited for this project.

There are clear reasons to use haptics for communication and potentially use DPS for location tracking, though relatively less is known about these methods. Therefore the next two chapters will go into more detail about this.

9. Understanding Haptic Communication

To help PBLV to find and navigate toward familiar people in their environment, not only the location and identity of the familiar people should be known, but it should also be considered how to communicate this to the user.

As discussed in chapter 8, using haptics to let the design communicate with the user seems suited here, as PBLV are often not limited in this sense. Furthermore, in contrast to audio, haptics is not used during regular social interactions. This means it can more easily be used to communicate to the user, while the user is attending a social situation, and without the user getting sensory overwhelmed.

This paragraph introduces the activities described in this chapter. First, the chapter presents an exploration of three types of haptic communication methods that are potentially suited for the context. They consist of tactile patterns, vibration codes, and locational touch. To gain more insights on how to use them in my design, I conducted a qualitative study with these three communication methods. For this test, I designed 5 different haptic languages (that used the three methods in different manners). I tested these languages in a small qualitative study with three blindfolded participants and two PBLV. The goal of the test was to get a sense of how easy it is to learn certain haptic languages, and learn how people experience the haptic inputs (do they find it hard, comfortable, disturbing, etc.). The subchapters that follow will explain the selected haptic communication methods with the corresponding designed languages; the test itself; and the insights.

9.1 Haptic Communication Methods

In this subchapter the three haptic methods will be further explained, along with the corresponding designed languages. For the tactile patterns, I decided to design three languages, because of the great diversity in which tactile patterns can be designed. For each of the other two methods, one language is designed respectively. Before I will explain the methods and languages, I will first give a brief explanation of the reasoning behind the languages.

9.1.1. Language considerations

The idea behind creating haptic languages, is that it would allow me to test if people can link distinguish between different haptic characters and link them with different meanings. I decided to attach the names of colors to the characters. The reason that I chose this, is because it allowed me (from a sighted perspective) to put some logic in the languages. Especially for the tactile patterns, I had in mind that a certain pattern would mean 'yellow', another one 'red', and a combination of both patterns would logically result in 'orange'. Looking back on this, choosing names of colors as meaning does not perse make sense from PBLV's perspective. However, I only realized that after the testing had been done. Nevertheless, I don't expect it to have influenced my results to a great extent, now for both PBLV the link with the color strategy did not make sense (they both never learned this at school), but it did not make it necessarily harder for them to link in essence a specific 'word' towards a character. In addition, both PBLV had been sighted in the past, and therefore did still have some reference with colors.

Initially, I designed ten characters for each language. Though, during prototyping, I realized that learning ten characters would probably be too hard for participants to learn in a short time frame. Based on some testing on my own, I decided to go for six characters per language.

9.1.2 Tactile Patterns

Tactile sensing is part of the human haptic sense abilities, it involves the ability of the **skin to detect forces on its surface** (Graspian, 2021). With tactile sensing, you directly engage with objects to detect features like edges, holes, and ridges. Our fingers are the most precise in perceiving this tactile information. In the field of designing for PBLV the most known use of tactile sensing is Braille.

The dot language in Braille represents all the letters and symbols in the regular alphabet, and therefore even complex messages can be communicated through Braille. Though, eventually, I want to use haptic language in a busy social setting, to communicate quickly and easily with users. As Braille is often used for the communication of detailed and complex messages, I do not consider it suited. Furthermore, not every PBLV is familiar with Braille, and Braille takes a long time to learn (Blind Low Vision NZ, n.d.).

There are endless possibilities for designing tactile languages. To cover at least some variety, **three tactile languages** have been designed: **symbolic**, **density**, and **dot**. They are designed to be suited to use in busy social settings and to not require much learning. The languages do not have to communicate whole sentences, but would in the future have to be able to communicate a set of identities.

For all three languages, prototypes were created using clay. The **clay-engraved disks** were created by hand. The clay was easy prototyping material, however, due to the nature of clay and making things by hand, it was harder to make the disks' sizes, thickness, smoothness, and engravings of the patterns consistent.

Using tactile feedback gives a lot of design freedom in how to communicate, which is a great advantage. However, there is also one challenge that needs to be tackled, if it would eventually is decided to use tactile feedback in the final design, which is the production of a digital tactile feedback system. Digital Braille readers do exist, however more complex tactile displays are not yet readily available.

Language 1: Tactile Symbolic Patterns

The first tactile language design uses engraved **symbolic patterns** to communicate color (see figure 31). For this prototype clay was used to create the tactile disks with. The language should be perceived by touching the clay disks with your finger. It consists of three main symbolic patterns for yellow, red, and blue, and uses combinations of these patterns to communicate orange, purple, and green. Just like with painting, the combination of the yellow pattern and red pattern forms orange, and red and blue forms purple, etc.

Figure 31: Prototypes of the Tactile Symbolic Patterns

Language 2: Tactile Density Patterns

This language uses the **density of grooves** to communicate six different colors (figure 32). Just like the first tactile language, it is prototyped using clay disks and should be perceived by touching the disks with your fingers. Yellow has the lowest groove density, while green has the largest groove density.

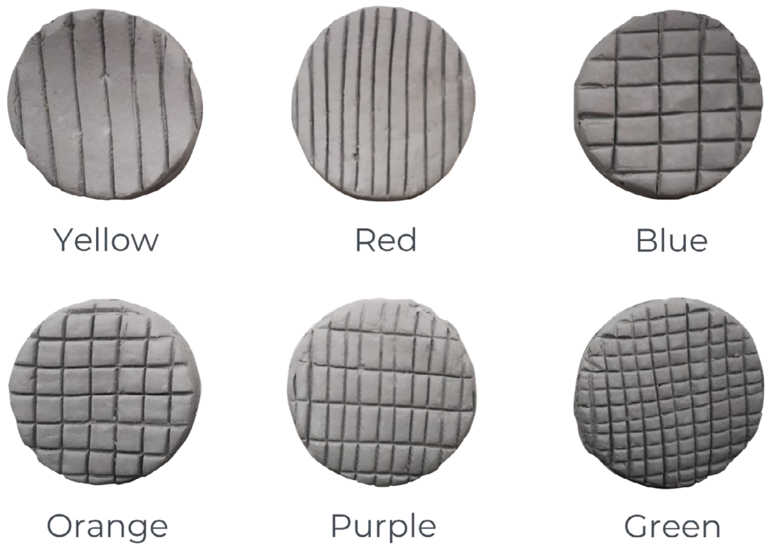


Figure 32: Prototypes of the Tactile Density Patterns

Language 3 Tactile Dot Patterns

The last tactile language uses a similar strategy as Braille, namely **using dots** (see figure 33). However here, the person should search for the **indentations** instead of the raised patterns Braille uses. What sets it apart from the other two tactile languages, is that it uses a **fixed point of reference** from which you should interpret the signal with your fingers, which is the slit at the bottom of the disk.

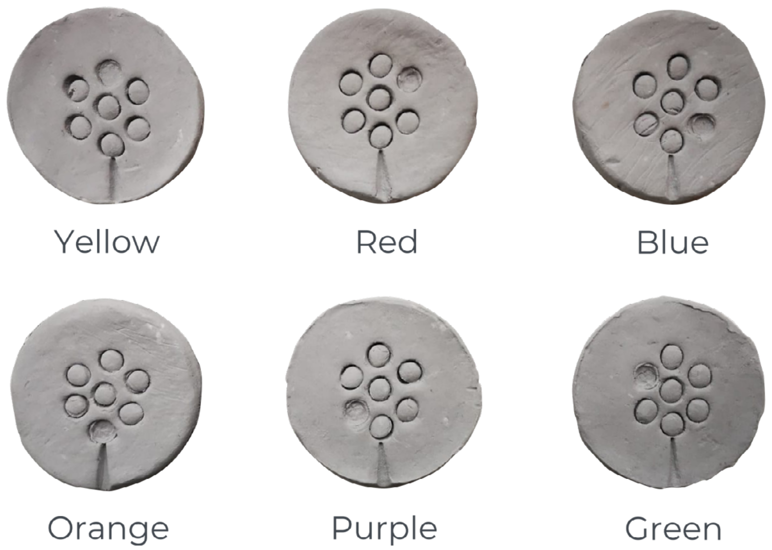


Figure 33: Prototypes of the Tactile Dot Patterns

9.1.3 Vibration Codes

Next to tactile input, we are also able to perceive vibrations. The use of vibrations, be it in a simple manner, is used on daily basis. Think about your phone that buzzes when someone calls. Vibrations are also used in designs for PBLV, like the Sunu band (www.sunu.io) that prevents you from bumping into objects around you, and Wayband (www.wear.works) which with vibrations guides you across a certain route. The advantage of using vibration is that it will be easy to produce, especially compared to producing a tactile display; and for PBLV it comes in handy that you can receive signals without having to use your hands. Though the downside of it is that vibrations itself can be perceived disturbing.

Language 4 Vibration Morse Code

This language uses the concept of **morse code**, executed in vibrations. Though, the language does **not use the alphabet** like it is used in morse code. It communicates a set of 6 different colors with small code segments. To prototype this language, a Seeeduino Lotus with a vibration motor, LED, and a button has been used, as shown in figure 34. One downside of the prototype is that due to the code, the vibration feels quite hard. The corresponding code language is visualized on the right of figure 34.

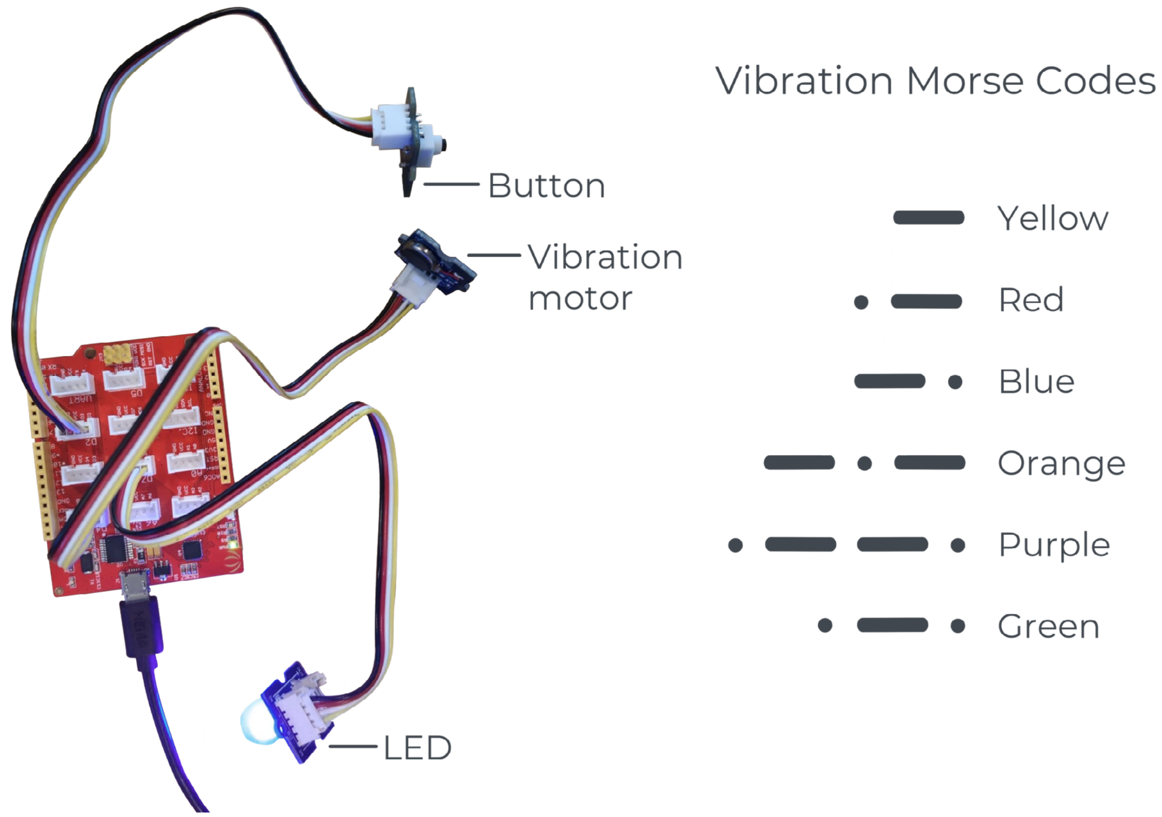


Figure 34: Prototype of the Vibration Morse Code language

9.1.4 Locational Touch

Next to being able to perceive a haptic input, we're also able to define where we receive that input from, our hands, arms, legs, etc. This feature is used as a method itself. By using different locations on the body for touch, code-like signals can be communicated. Think of a vibration on your left or right arm to indicate which direction to move in. As a 'touch' signal, pressure, vibration or even temperature can be used. Just like vibration, it has the advantage that it might be easy to make, as all the actuators are already existing. However, dependent on how it is designed, multiple wearables might be needed, which can be a disadvantage for the user.

Language 5 Finger Coding

For this language **three fingers** on the human hand are used to communicate the color signals (figure 35). Like language 1, it follows the structure of creating colors when painting (yellow + red = orange). One finger and a thumb remain unused but could be used for expanding the number of colors that can be communicated. The language was simply prototyped by touching the fingers of the participants with my own fingers.

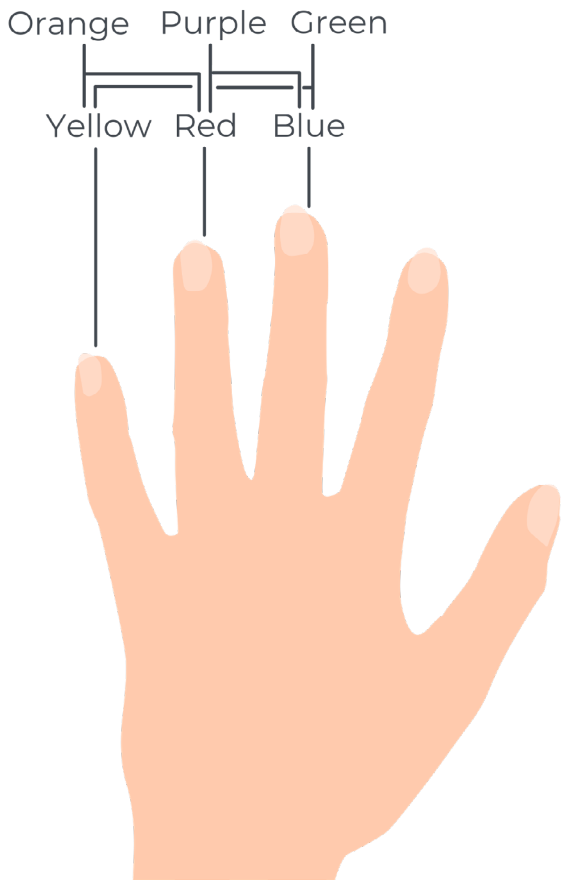


Figure 35: Strategy behind the Finger Coding Language

9.2 Testing of the Haptic Languages

To gain knowledge on how easy it is to learn haptic languages and to gather information on how different languages are experienced by people (comfortable, disturbing, easy, hard, etc.), I conducted a small qualitative study. In this test, five people participated, three blindfolded sighted people (SP 10, 11, and 12) and two PBLV (Maria, and Alice). A distribution of who tested which language is shown in table 5. The goal was to test **at least three languages per participant**, and based on that a distribution was created. However, some participants were willing to test more than three. Therefore, the distribution might come across as a bit random. The order in which the languages were tested was randomized.

Language / Participant	*SP 10*	*SP 11*	*SP 12*	*Maria*	*Alice*
Tactile Symbolic Patterns	x	x	x	x	x
Tactile Density Patterns	x		x	x	x
Tactile Dot Patterns	x	x	x	x	x
Vibration Morse Code	x		x	x	x
Finger Coding	x	x	x		

Table 5: Distribution of tested languages per participant

I started the test by explaining my project focus of helping PBLV with social navigation. I also explained that I wanted to use haptic feedback for communication with the PBLV, and that the goal of this test was to gain more insights on haptic languages. After this, I asked permission for taking pictures and using the data collected in my report. During the test, I presented each participant with at least three different haptic languages. For each language, I took some time to explain each to the participant, and let the participant feel all the six 'colors'. Once the participants indicated that they understood the language, I put them to a test. I gave them three haptic inputs of the language just explained, and each time asked them to identify which color was represented. The correctness of their answers was monitored. At the end of each language test, I asked them questions like "How easy was it for you to understand this language?"; "How comfortable was it?"; and "Could you imagine interpreting such signals while being in a social setting?". The tests took place in my room, and at participants' homes, and took about half an hour. Pictures of the test are shown in figures 36, 37, 38, and 39 on the next pages.

Figure 36: Picture of Maria testing the Tactile Symbolic Patterns. Maria has low vision due to Macula Degeneration.

9.2.1 Hypothesis

- I expect the **vibration morse code** to be the **easiest** to learn, as we are more used to receiving vibrational feedback already.
- Though the **vibrations** will be considered **most disturbing**, as the vibrations are very hard and the participant cannot control when to exactly receive the vibration.
- I expect the **finger coding** language to be **clear and easy** to learn as well. Though less easy than the vibrations, as it is not very common to communicate via touching different fingers.
- I expect the **tactile density pattern** to be **too hard** to learn in the short term, though, in the long term, I think it will be possible.
- People will be **correct** at **interpreting** the **tactile dot pattern**, though it will take noticeably more time because people would have to scan the entire clay disk with their fingers.
- People will have an **okay performance** at interpreting the **tactile symbolic patterns**, it might take longer than the vibrations, but they will find it less disturbing.

Figure 37: Picture of Alice (completely blind) testing the Tactile Symbolic Patterns

Figure 38: Picture of a SP testing the Vibration Morse Codes

Figure 39: Picture of a SP testing the Tactile Density Patterns

9.2.2 Results

General

- Using the **color strategy** that yellow and red form orange etc., **helped** participants that were familiar with the principle of color mixing to understand the languages. However, for participants unfamiliar with this principle, it caused more confusion.

- For all languages it was found that there is a **desire to compare signals** with each other to be able to interpret them correctly.

- Participants were mostly able to **interpret the yellow the best** within all the languages. The reason for this is that yellow was often the simplest pattern, as I started with designing the yellow signal first. Furthermore, yellow was always the first signal they received during the explanation.

Tactile Patterns

- The **tactile disks** were in general considered the **hardest** to interpret by all the participants. Assumptions are that this is primarily due to a prototyping mistake. For the tactile prototypes, clay disks were used. During the testing it turned out that the clay disks themselves had a too rough surface, to be able to interpret texture differences related to the patterns.

- As a coping strategy, it was noticed that four out of five participants started **paying attention to other attributes** of the clay disks as well, such as the thickness and shape/size.

- Within the tactile languages, the **density pattern** was experienced as the **most challenging** by all five participants. They also struggled the most here with correctly interpreting the signals.

- Participants had varying opinions on which tactile pattern was the easiest: the dot or symbolic pattern.

- For the dot pattern it was very useful to have a fixed reference point for interpreting the signals. Nevertheless, the roughness of the clay and the small size of the slit that functioned as a reference point, made it sometimes hard for participants to find the reference point.

- Together with one participant, I also tested the tactile signals myself. While I didn't practice earlier, I did have a good memory of what each signal looks like. Therefore I was able to identify signals from the three languages correctly on the first attempt. This indicates two things.

First, that it might be **easier to learn the tactile languages** for PBLV that have **some remaining sight**, as they can study the visual appeal of the pattern and have that in their mind when interpreting the signal with their fingers. Second, that there is likely a **learning curve** here if you have studied the signals for longer, it becomes easier to correctly identify them.

Vibration Codes

- The two **PBLV** that experienced the haptic languages, both **liked** the **vibration morse code language** the most, and both feel like it is doable to learn to remember them properly.

- Alice indicated that this method would be **less noticeable** for others than the tactile disks and therefore the most socially acceptable one, which was the reason she liked it the most.

- Three of the four participants which tested this language, among which one PBLV, were relatively **good at interpreting** it. Two of them had ⅔ signals correct, and the other had all three correct.

- Experienced **comfort** of this language **differed** per participant, one PBLV found it very comfortable, while one sighted person found it very uncomfortable. Unfortunately, both did not really give a clear reason for this.

Locational touch

- Three participants tested this method, and to my great surprise, all three **struggled with identifying which finger(s) I was touching**. As a reaction, they started moving around all their fingers to feel where the most friction came from (the ones being touched).

- Nevertheless, two of the three participants could **easily identify the colors** during the test. For the other participant, she was not able to identify at all which finger was touched, and therefore we started testing locational touch at her arm and at her back, and that gave similar positive results.

9.3 Project Takeaways

This chapter has explored various methods for haptic communication, using tactile-, vibration- and locational touch feedback. The following insights are useful for developing a tool that helps PBLV with social navigation, which uses haptics for communication:

- Due to a prototyping mistake (using clay), it was only possible to **assess** the use of **tactiles** as a form of communication to a **limited extent**. For further exploration, it should be made sure that the base surfaces of the prototypes are smooth instead of rough.

- All five participants tested the tactile dot pattern. During this test, I observed that when interpreting tactile information, it helps to have a **fixed point of reference**. Alice even mentioned it.

- Using **vibrations** as a form of communication **seems promising** based on this test, as three out of four participants were relatively successful at interpreting the data. Furthermore, two participants explained to like this language and felt that it would be **doable to learn**. Furthermore, Alice explained that the advantage of vibrations is, that it is **less noticeable** to others. For further exploration, it is important to try to make the vibrations more comfortable, for example by making them softer.

- **Locational touch** might also be interesting to use for this project. Though **which body parts** to use should be **further explored**. As, despite the fingers being very sensitive body parts, all three participants that tested this method, explained to struggle to identify which finger I was touching. Locations on the body should be found that are easier to compare with each other.

The test results gave several insights into using haptics for communication. However, it is not yet possible to decide which haptic method is most suited for communicating information on familiar others nearby with PBLV. To assess the appropriateness of tactile languages, improved prototype(s) need to be created. For integrating locational touch into a design, the touch will likely be generated using vibrations. Therefore, it might be interesting to consider if the methods of vibration codes and locational touch could be combined.

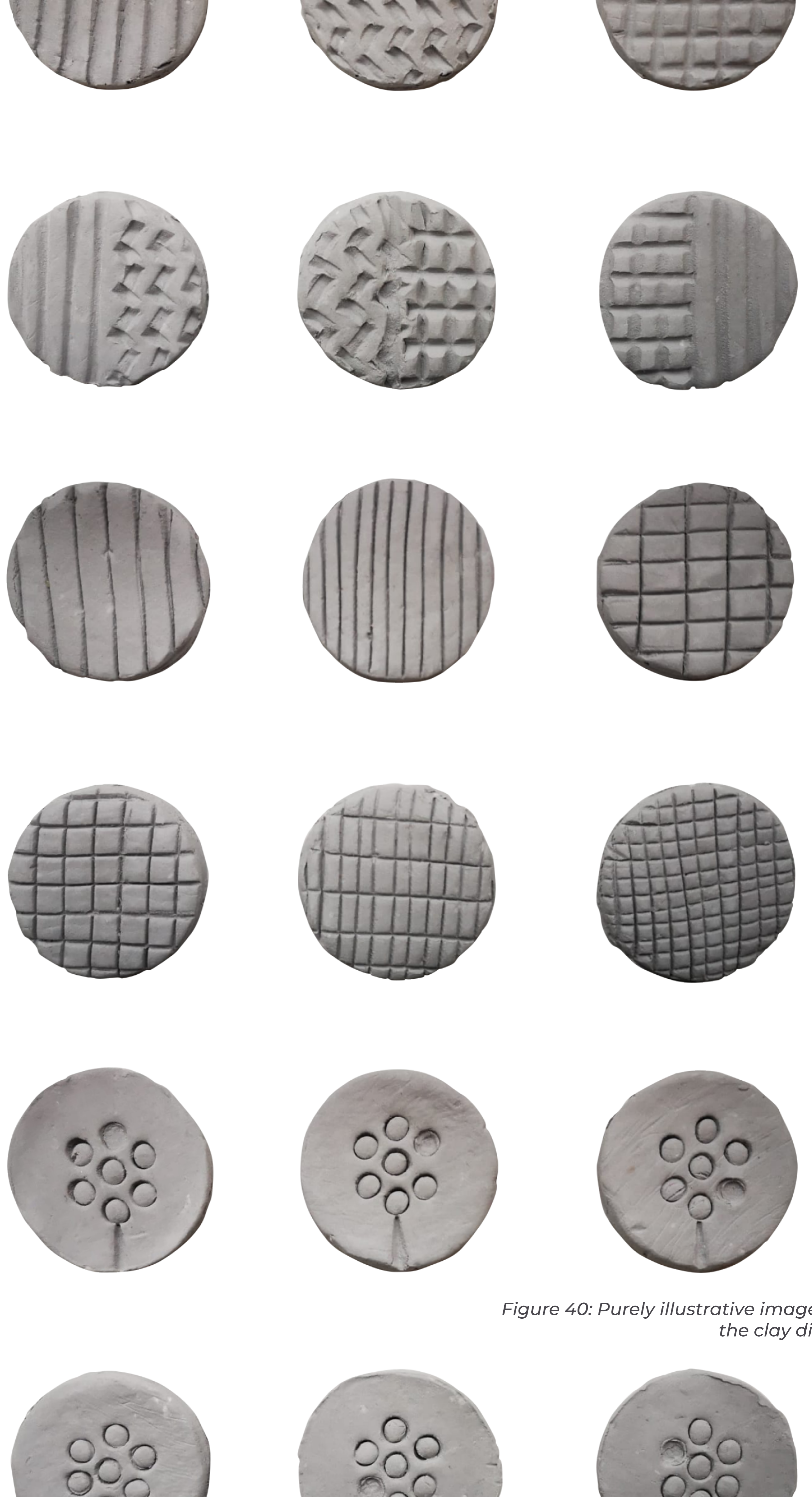


Figure 40: Purely illustrative image of the clay disks

10. Digital Positioning Systems

For helping PBLV with social navigation, the use of digital positioning systems (DPS) to locate familiar others nearby is considered promising, in contrast to using a camera (chapters 6.1, and 8.1). This chapter will explore various digital positioning systems that can be used in the design of a tool for social navigation.

10.1 Introduction

For a system to be useful for this project, that system should be able to **track** the **distance and direction of familiar others** relative to the user, both **indoors and outdoors**. Furthermore, to determine the relative location of the familiar person, the system **should not need any other devices** in addition to the device of the user and the device of the familiar person. These requirements will make sure that the design can be used anywhere without the need for environmental adaptations.

Initially, four systems were considered for this project: Global Positioning System (GPS), Wifi, Bluetooth, and Ultra-Wideband (UWB).

GPS is a common positioning system that uses over thirty **navigation satellites** circling around the earth. All these GPS systems constantly sent out signals, which can be read by for example your phone. By reading signals from four or more satellites, your phone can determine where it is. (NASA Science, n.d.). The advantage is that it would be able to detect both the distance and direction of familiar others. However, GPS can **solely be used outdoors**, which makes it only **partially suited** for this project.

To add to the capabilities of GPS, it might be an option to use **WiFi** for to determine locations in **indoor environments**. There are three common methods to determine location using WiFi: **triangulation**, **trilateration** (/multilateration), and **fingerprinting** (Ashry & Sheta, 2019; Location-Based Services, n.d.). The idea behind using WiFi for indoor positioning systems is that the strength of a WiFi signal decreases as the distance between the device and the WiFi access point increases. A device can determine its position by measuring the strength of the WiFi signals from multiple access points. Therefore, for these methods to work **at least three WiFi access points at fixed and known locations** are needed in an environment (Ashry & Sheta, 2019; Location-Based Services, n.d.). This makes the methods **unsuited** for this project, as the possibility to track the location of familiar others will be dependent on the amount and location of access points in each environment.

Location can also be tracked indoors using **Bluetooth**. One option is to use Bluetooth **Beaconing**. This method can be accurate, but similar to the WiFi methods, small **Bluetooth transmitters** ('Beacons') need to be **deployed at fixed positions** in the environment for a device to be able to calculate its position (Inpixon, n.d.-a). These environmental requirements make it **unsuited** for this project.

Another method using Bluetooth, that doesn't need environmental adaptations is **Bluetooth Received Signal Strength Indicator** (RSSI). It is again based on the idea that the signal strength of a nearby device will decrease when the distance to that device increases. For this project, the advantage is that this technology would only need a Bluetooth device for the user and a Bluetooth device for the familiar person. As Bluetooth is generally integrated with smartphones, this would be an easy fix. Nevertheless, with RSSI **direction cannot be estimated**. Furthermore, **distance calculations** with Bluetooth RSSI are often very **inaccurate**, as the signal strength can be disturbed by interference from WiFi radio signals, solid barriers or metal objects (Ramirez et al., 2021), or even human bodies (Bobrowski, 2020). These problems especially occur indoors. Even though this method initially seemed promising, the large inaccuracies make it **unsuited** for this project.

Fortunately, one method is **suited** for this project, which is **Ultra Wide-Band** (UWB). It is a wireless communication technology that uses a very low-power, wide bandwidth signal to transmit data over short distances. The following sub-chapter will elaborate on this method, and how it can be used for this project.

10.2 Ultra-Wideband

UWB is a communication technology that uses **radio waves/pulses** to let devices communicate with each other (Makerdemy, 2021). It is **fast, reliable, and precise**, which makes it highly suited for **indoor localization** (Kinexon, n.d.). In addition, it can also be used outdoors.

UWB uses very low power combined with high spectrum frequencies (Kinexon, n.d.; Makerdemy, 2021; Mearian, 2019; Stone, 2021), as is illustrated in figure 41. This characteristic accounts for little to no interference with other communication technologies (Makerdemy, 2021), and allows it to penetrate walls and obstacles (Iya et al., 2011; Stone, 2021).

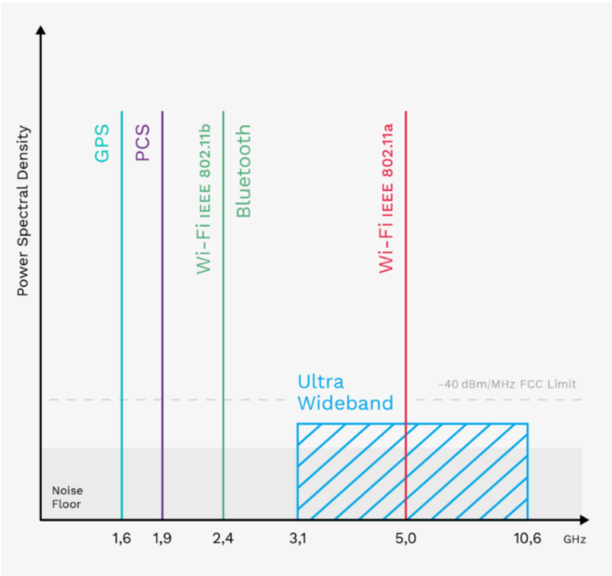


Figure 41: Graph showing distribution of used power levels and frequencies of different radio-based communication systems, among which Ultra-Wideband. (Kinexon, n.d.)

UWB can **determine both the relative distance and direction** of a nearby source. For determining distance, it measures the time of flight (ToF), which requires a "tag" and "anchor" device (Smith, 2020). Roughly explained, by analyzing the time it takes to send a signal back and forth between those two devices, the distance can be calculated.

Dependent on the conditions, UWB can determine distances up to a range of 200 meters (Bleesk, n.d.; Inpixon, n.d.-b), with an accuracy of 5 to 10 cm (Connell, 2015). In the case of a single receiver (in contrast to triangulation technologies), the direction of another device can be determined using the angle of arrival (AoA). Here a receiver needs to have multiple antennas. The device then seeks very small phase differences in the received signal, by which it can determine the direction from which the signal was coming (Smith, 2020).

This technology has been around for a while (for example it was used in military radars (Makerdemy, 2021)). However, it became only widely known around 2019, when Apple launched their iPhone 11 series with an integrated U1 (UWB) chip (Makerdemy, 2021; Telecom Review, 2022), which improved the AirDrop experience. In 2021, Apple introduced the Apple AirTag, a small accessory tracker that you can attach to valuable products (Apple, 2021).

Due to similarities with the use case of this project, it is worth explaining that for short distances the AirTag system uses a combination of UWB and Bluetooth to locate the tags. The range outdoors for this technology is about 25 meters. The range indoors varies dependent on the amount and type of obstacles in the way, with a clear line of sight the range can be 20 meters, and with the tag being tucked away behind multiple layers of wood, the range is about 6 meters (Tech & Travel, 2021). In the meantime, other phone makers such as Samsung and Xiaomi followed integrating UWB into their systems (Telecom Review, 2022).

Although UWB is not widely used yet, expectations are that this technology will **become much more popular** over the following years (Bleesk, n.d.; Fira, 2022; Inpixon, n.d.-b; Mearian, 2019; Pluemer, 2022; Telecom Review, 2022). FiRa, a company that is working on regulatory considerations regarding UWB, even expects UWB to be gradually adopted across all smartphones in the next 5 to 10 years (Fira, 2022). The company is also working on UWB standards and certification programs to ensure interoperability (Fira, 2022; Stone, 2021).

10.3 Project Takeaways

In summary, in this chapter a few digital positioning systems are explored that were considered interesting to use for this project. The use of GPS turned out unsuited because it cannot function indoors. The use of triangulation methods with Wifi and Bluetooth were considered unuseful because it would require environmental adaptations. Bluetooth RSSI was not considered suited due to the low accuracy rates. Luckily, due to the **high accuracy** in determining the location of nearby devices both indoors and outdoors, and **growth expectations**, **UWB is considered a promising technology** to use for this project. Possibly combining it with Bluetooth, like the technology used for the AirTags, will make this technology even more valuable.

11. Concept Generation

During this project research showed there is a need to design a tool that helps PBLV with social navigation. With such a tool, it will become easier for them to mingle around at a party, or find a colleague at work. During the first idea generation (chapter 8) it became clear that it is the most suited if the designed tool is wearable for the user. Furthermore, it was concluded that the wearable should communicate with PBLV using haptics and that the wearable should use a digital positioning system (DPS) to locate and identify familiar others. Based on the research in chapter 10, Ultra-Wideband (UWB) was selected as the most suited DPS to use here. Altogether, this gives a more concrete description of what to design:

'A wearable, that uses haptics to communicate identity and location of-, and helps PBLV to navigate to familiar people, using Ultra-Wideband'

With this description in mind, a second idea generation was executed. During this generation, I designed two concepts, the Location Watch, and the Presence Bracelet. The goal of these concepts was to be able to gather feedback during an Envisioners day[2]. To get the most insights on how to continue, I considered it useful to create two very different concepts. To create two different concepts out of the same description, I made sure that the communication method of the device with the user and the manner of location sharing were different for the two concepts.

Rapid prototypes were created of both concepts and presented to seven PBLV during the Envisioners day[2], and one PBLV another day. The concepts along with the prototypes will be explained in the following two subchapters. Subsequently, the procedure of the feedback gathering will be explained, along with the results of that day. This chapter will end with the project takeaways.

2 Envisioners day, is a day organized by Envision, where they invite many PBLV that use their service to come to Envision. During this day, the team can chat with the users and also users can help testing new features of Envision products.

11.1 Concept 1 Location Watch

The concept Location Watch is a **tactile smartwatch** that allows PBLV to feel a map of familiar people around them, and subsequently receive information on their identity via tactile identity patterns. Just like a braille keyboard, the watch consists of many small pins that can move up to create patterns. To make sure that people can interpret the tactile information, the surface should be as smooth as possible at the places where the pins are collapsed. Furthermore, the difference between a collapsed and raised pin should be distinct. Both these design decisions are based on the knowledge gathered in chapter 9 on haptics. For this system to work, you would have to **send out links to familiar people** in advance, where you ask them permission to share their location with you via UWB once they are within 15 meters from you.

11.1.1 The Map

As explained the first element of the concept is a **tactile map**. The idea is that PBLV will be able to **feel the position of familiar others**, relative to themselves, on that map. The compact group of tactile dots in the middle represents the user, and the smaller dots the familiar people around that user (as shown in figure 42). The map operates at three scale levels. For the largest scale, a small dot at the outer edge of the watch would represent a familiar person being 15 meters away from the user. For the other two scales, the outer edge represents 10 and, 5 meters respectively. The orientation of the dots on the watch is fixed, based on the use scenario that you would hold the watch right in front of you when reading off the signals (as shown in figure 42).

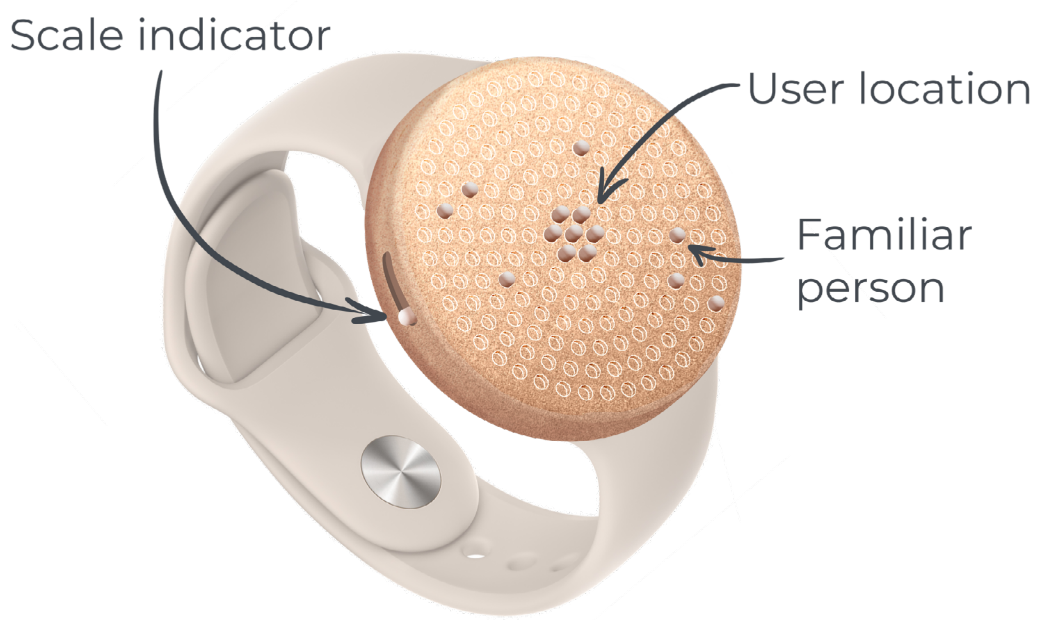


Figure 42: Illustration of the map part of the concept the Location Watch

11.1.2 The Identity patterns

The second element of the concept is a set of **tactile identity patterns**. These are used to **describe the identities of familiar people**. Once the user taps on one of the smaller dots on the map, a subsequent identity pattern of that familiar person would appear on the screen. The tests on tactile patterns described in chapter 9, indicated that it might be hard for people to learn and remember many different patterns. This concept uses two types of identity patterns to limit the number of patterns used. First, the short-cut identity patterns (figure 43), which would relate to the identity of an individual. These should be used for only a few people, like close friends and family. Second are descriptive patterns, which consist of building blocks that describe characteristics of a familiar person, rather than the exact identity (figure 43). For example, it could tell you that a familiar person is a male colleague. These patterns can be used for a larger amount of familiar others.

Figure 43: Illustration of two identity patterns (left), and two descriptive patterns (right)

11.1.3 The Prototype

A prototype of this concept has been created out of cardboard, paper, a rubber band, and some other crafting utensils. As an improvement from the clay tactile prototypes (chapter 9), a **smooth paper** was used and engraved to ensure people would be able to distinguish the surface from the patterns presented on top of them. Five different watch- 'screens' were created, which could be attached and switched around by the use of velcro tape. The prototype is shown in figure 45. Before continuing the prototype was quickly tested with a roommate (SP 13) to check if it was possible to interpret the tactile information, from this test it appeared possible. A picture of the quick testing is shown in figure 44.

Figure 44: A roommate who tests the paper protoype of the Location Watch

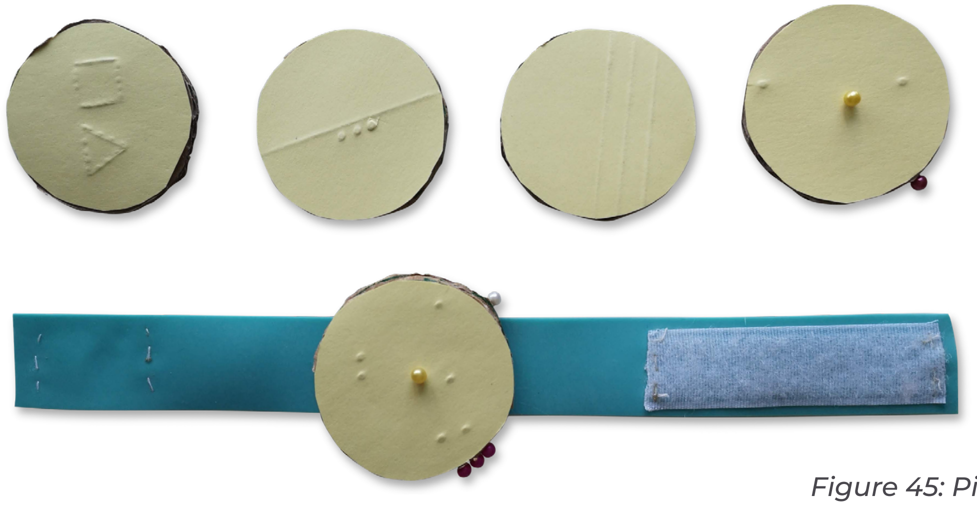


Figure 45: Picture of the Location Watch Prototype

11.2 Concept 2 Presence Bracelet

For this concept a **vibration bracelet** would give PBLV a **notification** when a **familiar person** would be **within a certain preset range** from the PBLV. For example, you can set the watch to notify you when a familiar person is within two meters of you. The device would first give a single vibration to indicate a familiar person is within range, and then if you would click the button, it would provide you with a vibration pattern that would relate to that person's identity. The bracelet would vibrate shortly twice when a familiar person gets out of range. For this system to work, you would hand out about **five identity bracelets** prior to the social setting that you and the familiar people would attend. Via this identity bracelet, the selected familiar persons will share their location with you via UWB. The concept is visualized in figure 46.

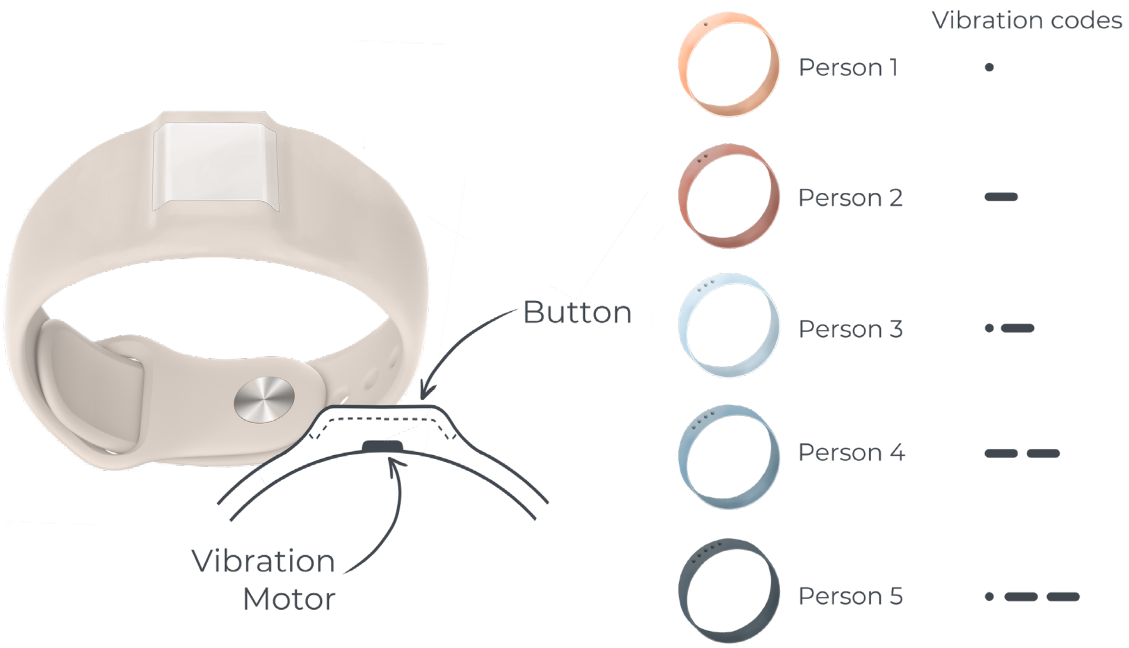


Figure 46: Illustration of the Presence Bracelet concept

11.2.1 The Prototype

For the feedback gathering at the Envisioners day, only the **user bracelet** was prototyped, using a rubber band, a small vibration motor from Seeeduino, and a knot that represented the button. The prototype could be controlled by me, via the Seeduino Lotus and an attached button. One limitation of the prototype was that, due to the code, the vibration signals were quite strong.

Figure 47: Picture of the user bracelet prototype, currently unconnected to the Seeeduino breadboard

11.3 Feedback Gathering

As explained, the concepts were purposefully designed very differently. The goal of gathering feedback on these two different concepts was to get a clear indication of **which direction to continue in** during this project. During the Envisioners day, I presented the concepts to seven PBLV. In addition, I presented both concepts to one other PBLV during a lunch meeting. Thus in total **eight PBLV provided feedback**. During the Envisioners day, it was hard to plan the feedback-gathering moments. Therefore in total, just three PBLV managed to test both concepts. Two participants were not able to test any of the concepts during the Envisioners day but were present while someone else was testing them, and could therefore also provide feedback. In most cases when only one concept could be tested, the other would be explained as well. The distribution of concepts tested by PBLV is shown in table 6.

Concept / Participant	*Nora*	*Ruben*	*Jasmin*	*Bjorn*	*Sara*	*Rick*	*Nick*	*Sophie*
Location Watch		x	x	x		x	obs.[3]	x
Presence Bracelets	x		x	x	obs.[3]			x

Table 6: Distribution of tested concepts per participant

3 Obs = observed another person testing the concepts, and provided feedback based on those observations

At the start of each feedback gathering, I started by explaining my project and asking PBLV if they were willing to provide me feedback on some of my concepts. In addition, I asked them permission for taking notes and making pictures, which I explained to use in an anonymous manner in my report. Subsequently, I briefly explained one of the two concepts. Next, I asked if it was okay to put the concept around the participant's wrist, and did so when consent was given. I explained the tested concept further while gathering feedback.

For example, for the Location Watch participants were told 'The home screen includes a watch where you can feel where familiar people are relative to your own location, which is always the middle. Familiar people represent small dots.'; and subsequently asked 'Can you describe what you feel and how would you experience this?' After going through an entire concept, overall questions on that concept were asked, like 'What are your first thoughts on this concept?'; 'Do you think it could be of value to you?' and; 'What do you like and dislike about the concept?'. Dependent on the answers people provided, follow-up questions were asked. For more information on the procedure used during feedback gathering, please consult appendix 8.

During the feedback gathering pictures were taken, which are shown in figure 48, 49, 50, and 51. Notes were taken right after each feedback gathering.

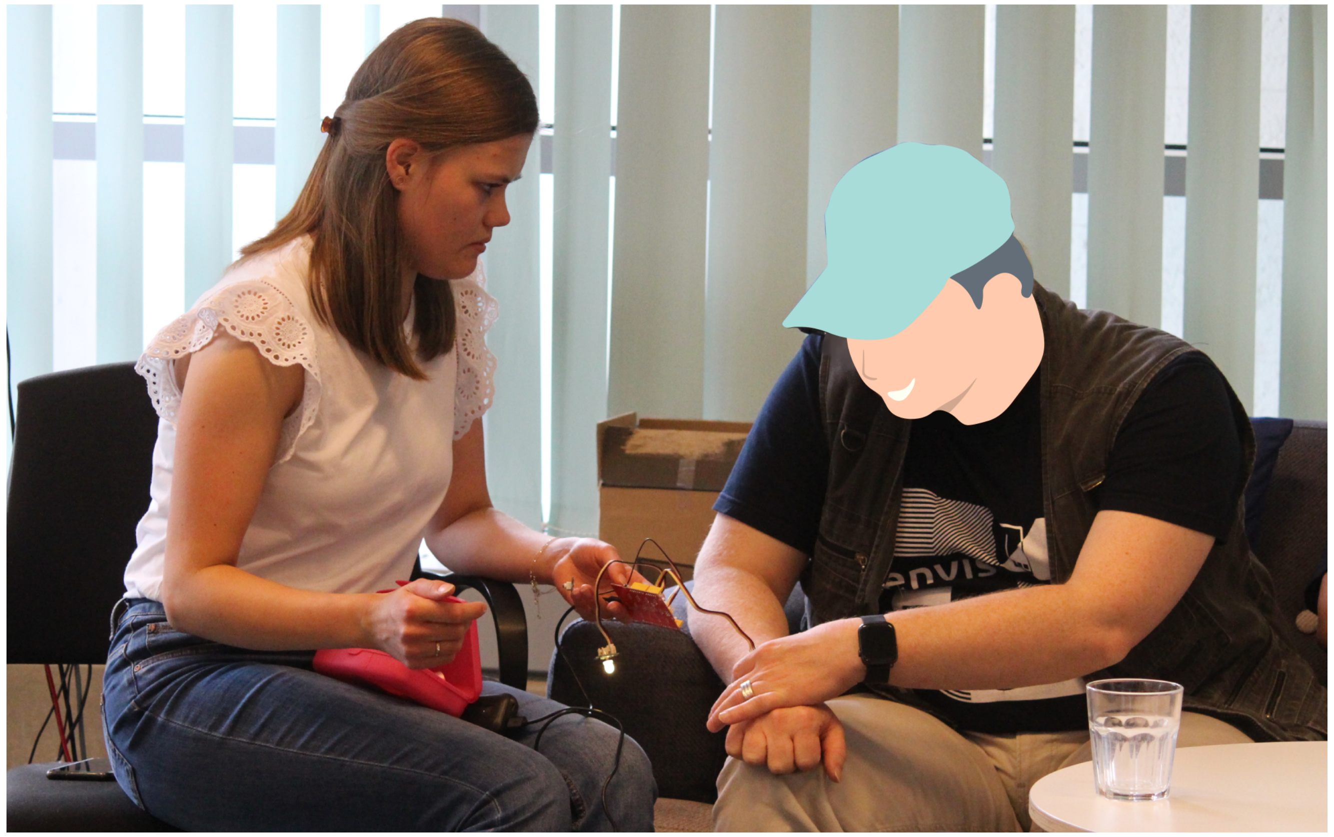


Figure 48: Picture of testing Presence Bracelets prototype with Bjorn at Envision, his exact vision is unknown.

Figure 49: Rick (who is completely blind) testing the Location Watch prototype at Envision

Figure 51: Ruben (his exact vision is unknown) testing the Location Watch prototype at Envision

Figure 50: Jasmin (her exact vision is unknown) testing the Presence Bracelets prototype at Envision

11.3.1 Results

General

- All **PBLV liked the idea** of having something that would help them with social navigation.
- Five PBLV explicitly told that they would prefer to see it **integrated** with an **Apple Watch**, as that is a product they already use. Three people valued the concepts but explained that both concepts were **not worth buying a separate helping device for**. According to two PBLV, it was also an option to integrate the functions in a smartphone.
- Two PBLV that tested both concepts, felt that it was easier and **better to know where people are** via the Location Watch than knowing when someone is nearby. Though one of them still preferred the Vibration bracelet, simply because he liked the electronic system more. However, he suggested making the vibrations more informative by creating directional vibrations.
- Sophie, that tested both concepts, explained that she preferred wearing and interpreting the **Vibration Bracelet** over the Location Watch, as this would be **less noticeable** for others around her. This is interesting, as Alice had the same opinion when testing the haptic communication methods, as explained in chapter 9.2.2. Possibly, this opinion can be related back to the challenge area of stigmatization, and the desire to hide your VI from others, or not stand out.
- Participants had **different opinions** on how **identity could best be shared**, some liked the tactile patterns, and others preferred the vibration patterns. Two people even suggested it might be an option to just provide the identity via audio (like with earphones).
- Participants preferred the idea of **sharing a link with familiar others** over sharing the bracelets. This could be related back to the challenge areas of stigmatization and (in)dependence, in the form of not being a burden to others (asking others to wear a bracelet, pick the bracelet up in advance and bring it back afterward). It could also be related to (in)dependence in the way that sharing a link requires less preparation than handing out the bracelets.

Figure 52: Illustration of guidelines suggestion for the Location Watch

Location Watch

- **Feeling the patterns** and the dots on the map **worked surprisingly well**, even though the tactile imprints were much smaller than for the clay disks described in chapter 9.
- People liked the tactile map a lot, they liked to feel where familiar people are relative to them.
- Though for the map, it would help to have some ***extra guidelines*** on the scale, as visualized in figure 52.
- Participants understood the difference between shortcut- and descriptive patterns. Though one participant noted that the **level of detail needed** for the **descriptive patterns** would **differ per context**. For example, when being in a setting with only colleagues, it doesn't help to read that the familiar person is a colleague, because they will all be. So what the tactile pattern describes should change dependent on either homogeneous or heterogeneous settings.
- An interesting observation was that when PBLV interpreted the tactile information on the watch, they didn't hold it the way I expected them to. Because they often don't have to 'look' at the watch, **they don't position it right in front of them** while interpreting the data.

Presence Bracelet

- Participants **liked the vibrations** and did not find them disturbing or annoying, despite the fact that the vibrations were quite strong.
- As noted earlier, participants felt that knowing when someone is close, is not as useful as knowing where someone is. Therefore one participant, who actually preferred vibrations over tactile information, **suggested creating directional vibrations**.
- As explained in the general results as well, people did **not like the idea of sharing bracelets** with others, because that would include more preparation for the specific event. Furthermore, you would have to ask others to wear something, which the participants would not feel comfortable with. And furthermore, you would have to worry about getting the bracelets back, and charging them on time.

Prototypes

- For the vibration bracelet, the notification distance was set at '1.5 meters' which was considered too close.
- For the Location Watch the size of the screen seemed about right.
- The rubber material used for the bracelets in both concepts was considered very uncomfortable and sweaty.

11.4 Project Takeaways

Although all the insights from the feedback gathering are useful, there are four takeaways that are considered most important:

- People liked the concepts a lot. Though, the most important takeaway is that the concepts were **not considered valuable enough on their own** to be worth buying a separate helping device for. Therefore, it should be considered to integrate the concepts with existing helping devices, such as an Apple Watch.
- For **receiving location** data of familiar people, **using the smartphones** of familiar people (or other smart devices) is preferred. This could be related to being the least of a burden to others (stigmatization and (in)dependence), and limiting the amount of preparation needed ((in)dependence).
- PBLV felt that **knowing where a familiar person is**, has much more value than simply knowing that a familiar other is close. From that perspective, the Location Watch was sometimes preferred over the Presence Bracelets.
- Two advantages of the **Presence Bracelets** were noted: the vibrations are **less noticeable** for others, and this design could more easily be **integrated with an existing helping device** such as the Apple Watch.

Final Design . . . . . .

During the project, a need has been found to design a supporting device that makes PBLV feel more at ease in social situations. After an elaborate study on the social life and corresponding challenges of PBLV, this need was narrowed down to the goal of ***'Designing a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings.'***

Multiple design iterations followed, which made clear that designing a **wearable** that uses **haptics** to communicate **identity** and **location** of-, and helps PBLV to **navigate** to **familiar people**, using **Ultra-Wideband**, would be a suited solution. Based on all these insights, the **final design of Sofi** has been composed, which will be introduced in this section.

First, in chapter 12 the overall concept of Sofi will be explained. Here a brief summary of argumentations will be provided in the boxes at the bottom of each page. The chapters that follow, will go into more detail on the development of the final design.

12. Sofi, the social finder

At a bar with friends, a meeting at work, or just randomly bumping into familiar others on the streets, are just a few examples of situations where people that are blind or have low vision (PBLV) can experience difficulties with social navigation. A visual impairment can make it hard for PBLV to recognize and locate familiar others in social settings. This can be about finding the colleague they are searching for at a conference or recognizing the person talking to them in a crowded social setting.

1 **Sofi**, the social finder (figure 53), is an app and add-on wristband to the Apple Watch. It is designed to help PBLV **socially navigate** themselves. It does so by communicating the identity and location of familiar others nearby **through vibrations**. In addition, it can help PBLV to navigate toward these familiar people. The system uses vibrations to communicate with the user. The **haptic sense** is relatively unused during social interactions. Using

Figure 53: Sofi, the Social Finder

1. The choice to make Sofi an app and add-on to the Apple Watch has been based on the feedback from PBLV in chapter 11.3 to integrate the design with an existing helping device, preferably the Apple Watch.

2 **vibrations** for communication, allows PBLV to use their audio sense for social interactions and orientation only. This will prevent the user from getting overwhelmed by using Sofi in a social setting.

The design of Sofi will help PBLV to feel more **confident** and **independent** while attending social settings. They can feel more secure about recognizing people on time and will be able to mingle around, instead of having to wait until someone approaches them.

3 Sofi receives the identity and location information of familiar others via **Ultra-Wideband** (UWB). For this to work, the user sends out a **text message** with a link to familiar people in advance (see figure 54). In this link, the user asks familiar people permission for sharing their identity and location with the user via UWB once they are nearby the user (within 15 meters). To reassure consent and create transparency, the familiar people will always receive a notification once their location is shared with the PBLV. For more information on UWB please consult chapter 10.

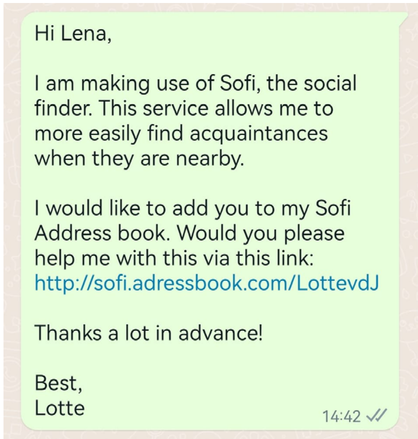


Figure 54: Invite to Address Book

4 When activating the app, Sofi will start scanning the environment for familiar others. During the first seconds of activation, the logo of Sofi will be shown on the screen (see figure 53). This is the only visual interface, during the other operations the **screen will be turned off by default**, to prevent Sofi from attracting attention from others. However, in this chapter sometimes visuals of the interface will be shown to help properly explain the concept.

2. Using haptics for communication, aims to take into account the challenges PBLV experience with processing stimuli (chapter 5). This choice is in line with they findings of Buimer et al. (2018). The choice to use vibrations is based on the research in chapters 9 and 11.

3. Selecting UWB is based on the study of digital positioning systems in chapter 10. The decision to make identity and location sharing possible via smartphones, and asking familiar people permission for this via a text message in advance, is basesd on the feedback gathering in chapter 11.3.

4. Based on the commends by Alice (chapter 9.2) and Sophie (chapter 11.3) that the design should be least noticable to others.

Figure 55: Entry Mode Notification

5 Once activated, users will receive **entry notifications** through short vibrations (see figure 55) when familiar people enter the 15 meters range of the user. The user will also be notified similarly when someone **exits** the range. When the user wants to know who is nearby, they can single-tap the watch, which will turn the watch into identity mode.

6 The **identity mode** consists of an **address book** that the user can scroll through. This mode will communicate the identities of the familiar people around the user via vibrations patterns on the Apple Watch. By default, there will be a set of **ten vibration patterns** that the user can use to describe identity. Five patterns can be used to describe specific identities of people, and five to describe the category the familiar person belongs to for the user (like 'Family').

5. The idea of the entry and exit modes is based on the Presence Bracelets concepts described in chapter 11.2.

6. Using vibration patterns is based on the morse code vibration language in chapter 9.1. The idea of specific and category patterns is based on the design of the identity mode for the Location Watch concept in chapter 11.1. The idea here is to limit the total amount of vibration patterns the user needs to remember.

7 As a **backup option** for the vibration codes, the user can double tap the screen, if doing so the device will speak out the name of the familiar person on a low volume. The identity mode with address book and vibration patterns are further described in figure 56. If the user would want the pattern to be repeated, they can double tap and hold on the screen.

If the user turned the device into identity mode shortly after an entry notification, the address book will start with the familiar person that the user just got notified of. If the identity mode is opened at another moment, the address book will start with the familiar person that is most nearby to the user. In general, the address book structures the familiar people on basis of their distance relative to the user.

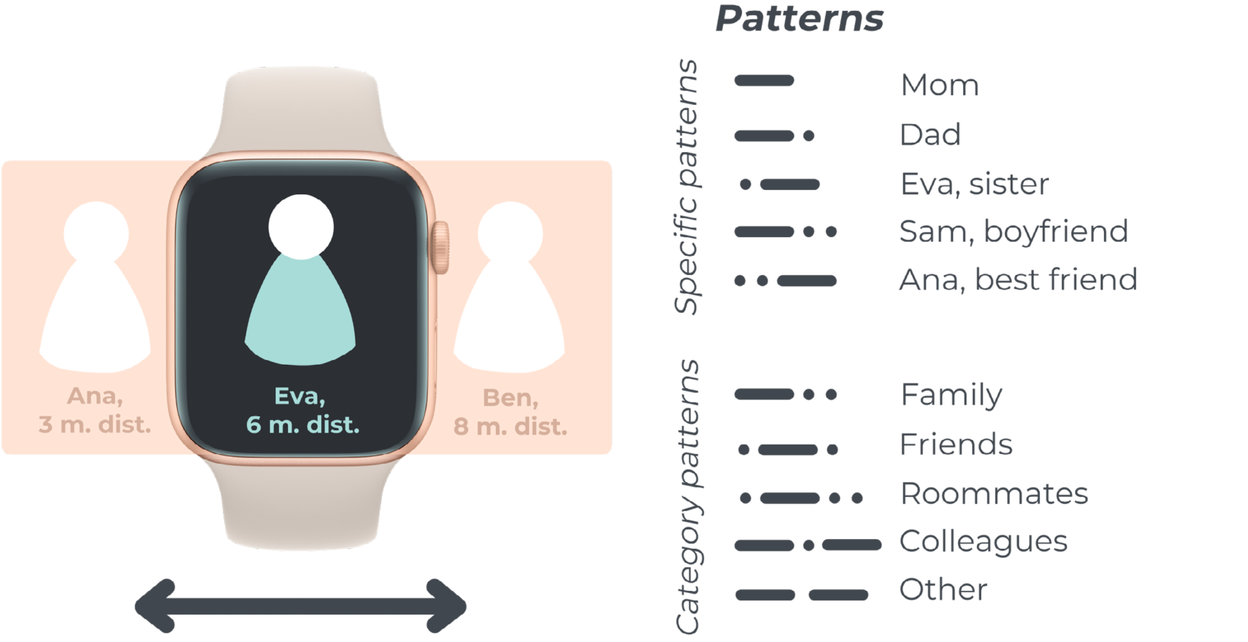


Figure 56: Identity Mode & Address Book

When the user wants to know where a specific familiar person is in their environment, they can turn the device into **location mode**. Therefore, they should tap and hold on to the identity the user wants to know the location from. Sofi will then communicate in which direction and at what distance the familiar person can be found.

7. The audio backup option is based on the expressed need for a reference mode (chapter 15), and on the preference of some PBLV to receive identity information via audio (chapter 11.3).

8 For the Location Mode, **direction** is communicated with **vibrations around the wrist**. By turning on one vibration motor or two simultaneously, the design can provide vibrations in eight different directions around the user's wrist. If the user feels vibrations on top of the wrist, this always communicates that someone is right in front of them. The other directions can be interpreted respectively. Furthermore, the device will vibrate at a certain **pulse frequency** to communicate **distance**. The faster it vibrates, the closer the familiar person is. The direction and distance are communicated for a few seconds. Users can ask for an audio backup signal by double tapping the screen, and ask to repeat the vibration signal via a double tap and hold.

Figure 57 illustrates this mode. When the user wants to know the location of another familiar person present, they can still swipe left and right to navigate through the address book. When doing so, the identity will first be communicated, and afterward the location.

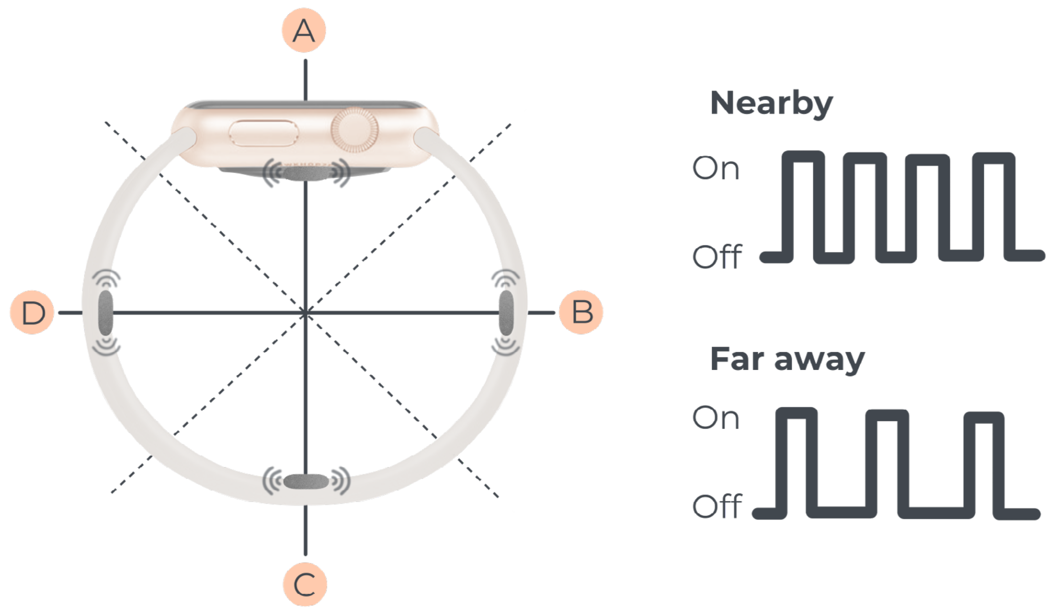


Figure 57: Location Mode

8. The location mode is included because of the need expressed by PBLV to know the relative location of familiar others towards them (chapters 5 and 11.3). The idea to use vibrations around the wrist to communicate direction was proposed by a PBLV during the feedback gathering described in chapter 11.3). The exact design of the Location Mode is based on the research described in chapter 15.2.

9 If the user subsequently wants to navigate towards a specific familiar person, they can turn the device into **guide mode** by swiping up the screen. The guide mode works similarly to the location mode, however now the vibration signal is continuously provided. Furthermore, the vibration signal is adapted when the distance (and direction) between the user and the familiar person changes.

10 To make it more clear if the user is moving in the right or wrong direction, the system will provide two types of vibration pulses. A **fine vibration** pulse is provided when the user moves in the right direction, and a **rough vibration** when moving in the wrong direction. This is visualized in figure 58.

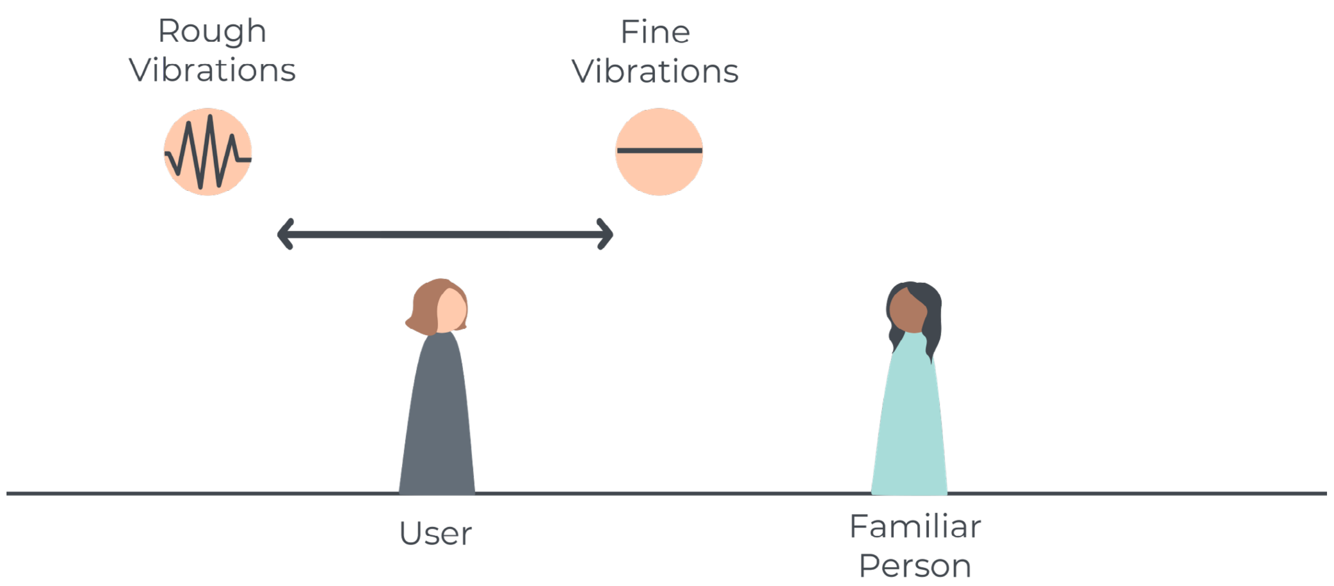


Figure 58: Rough and fine vibrations

9. The guide mode will make PBLV less dependent on others to approach them. Having to wait for others to approach you, was expressed as a challenge in chapter 5.
10. The idea to use rough and fine vibrations originated from testing the guide mode as described in chapter 15.3, and was inspired by a design by Kim et al. (2021).

11 When users want a reference for interpreting the vibrations, they can double-tap on the screen when it is in location or guide mode. This will make the device speak out the direction and distance in which the familiar person can be found at a low volume, or via earphones. As the guide mode provides continuous feedback, the signals are repeated automatically.

Because Sofi is only able to detect the location of familiar others, it is not able to take into account other people present and obstacles in the way when guiding PBLV towards familiar people. Therefore PBLV still need to scan their environment while using the Guide Mode.

With the final design briefly explained above, the next chapters will go into more detail on the design choices made. First of all, the selection of the Apple Watch as the base of the concept will be explained, followed by chapters on the identity mode, and location & guide mode design. The last chapter will present some overall feedback gathered on the concept.

11. This is based on the expressed need for a reference mode by participants that tested the location and guide mode, as described in chapter 15.

13. Selection of Supporting Device, the Apple Watch

During the first design iterations (see chapter 8 and 11) it was often attempted to design a separate supporting device. However, during the feedback gathering on the paper prototypes of the Location Watch and the Identity Bracelet (chapter 11.3), it became clear that PBLV prefer a tool for social navigation to be **integrated with an existing helping device** (that they already use).

A tool for social navigation was considered valuable by the PBLV that provided feedback, however not valuable enough to buy and use a separate supporting device. There are multiple reasons for this, the fact that they often already use quite a lot of helping devices, the stigmatization that comes with using another (visible) helping device, and the costs. This finding is in line with the finding of Hayden (2014) that in order for a user to use the product either the value provided should be high or the inconvenience of wearing it should be low.

There was thus a need to design a tool for social navigation that could be integrated with existing helping devices. In my design, I want to use haptics for communication. A wearable with a complex tactile display is not yet on the market, therefore I tried to find a **helping device** for PBLV that **uses vibrations**. Based on this criteria the wrist wearables **Sunu Band** (https://sunu.io/), **Wayband** (https://www.wear.works/), and **Apple Watch** (http://apple.com/nl/watch) were considered.

Figure 59: Sunu Band (Sunu, n.d.)

Figure 60: Wayband (WearWorks, n.d.)

Figure 61: Render of the Apple Watch (Apple, n.d.)

Based on three arguments, it was concluded that creating a design for the **Apple Watch is most suited** for this project. First of all, since integration with the Apple Watch was **explicitly requested** by five out of eight PBLV during the feedback gathering on the paper prototypes described in chapter 11.3. Secondly, because Apple Watch is a very **versatile device** and therefore already offers a lot of value to the user. So the chance that the Apple watch is worth the value over the inconvenience might be higher than for the Sunu Band or Wayband. Thirdly, a great advantage is that Apple Watch already has a **UWB chip integrated** (Owen, 2020). In addition, it was also observed that many PBLV that visit Envision, already have an Apple Watch.

After deciding to design for the Apple Watch, it was important to consider how a tool for social navigation could be integrated with it. There were **three options** here, to design **only a software tool** for social navigation, to create **software and an add-on product**, or to create a **redesign** of the Apple Watch suited for social navigation. I considered only designing the software to limit my design space too much. In addition, I considered it very unlikely that Apple would ever be interested in a redesign of their Apple Watch specifically for PBLV (and social navigation). Therefore I decided to **design an app and add-on** for the Apple Watch that would help PBLV with social navigation.

An example that shows that it is possible to design an add-on to the Apple Watch is the Wristcam (https://wristcam.com/), a wristband designed for the Apple Watch that includes cameras (see figure 62).

Figure 62: Wristcam, Smart Dual-Camera Band for Apple Watch (Apple MFi Certified) (Wristcam, n.d)

14. Identity Mode design

The **identity mode** has been designed with the **Apple Watch** in mind, and to **use haptics** for communication. Via a small brainstorming, I came up with three ideas: the Braille display, Iconic display, and Vibration codes.

The **Braille display** would be a small **add-on** that could be clicked onto the regular screen of the Apple Watch (figure 63). On this display, **three regular characters** can be communicated via Braille. These three characters could then for example be someone's initials.

Figure 63: The Braille display concept

The next idea, the **Iconic display** did not use Braille to communicate identity but used **tactile icons** to do so (figure 64). For this design, four small cylinders with three tactile icons around each cylinder are integrated into a special wristband design. Each combination of icons would relate to a specific identity.

Figure 64: The Iconic display concept

The last idea, the **Vibration codes**, used the **vibration motor** in the Apple Watch itself to communicate identity (figure 65). To limit the amount of vibration codes the user would have to remember, a set of five vibration codes would be used for specific identities and another set of five would be used to describe the type of familiar person towards the user (e.g. family, friend, colleague, roommate, etc.).

Given the limited time frame of the project, I decided not to prototype and test these concepts, but make a decision based on knowledge gathered throughout the project. Based on a couple of arguments explained below, I decided that the idea that uses **vibrations** to communicate identity seems **most suited**.

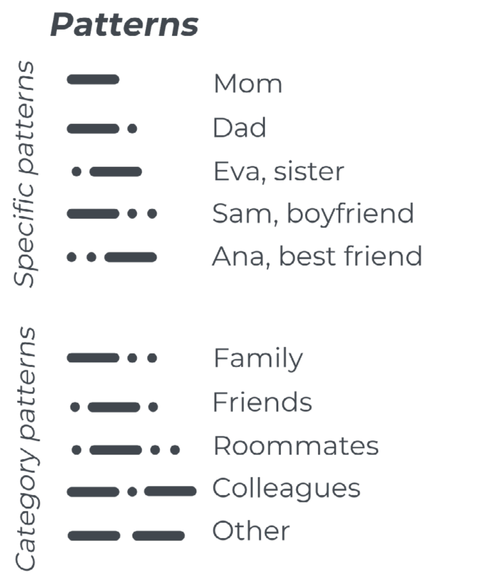


Figure 65: Vibration code examples

First of all, the test on haptic methods described in chapter 9, indicated that vibration patterns might be **easy to learn**.

Secondly, during the feedback gathering on the paper prototypes (chapter 11.3), it was mentioned that an advantage over using vibrations is that you **do not have to scan the watch** for tactile information with your hand. This reduces the time the user has to operate the device.

Thirdly, interpreting vibration signals **attracts less attention** from others than interpreting tactile information (chapters 9.2 and 11.3). Therefore, the vibration idea can work less stigmatizing than the other two. In line with this argument, for the vibration idea, the appearance of the Apple Watch does not change. Therefore, it will probably attract **less stigmatizing** attention over the two other concepts for which different-looking add-ons are needed.

Furthermore, a disadvantage of the **Iconic idea** is that the icons can **solely** be used for **communicating identity** and not for communicating the distance or direction of familiar others. The Braille and vibration ideas both can be used for communicating the location of familiar others as well. With the Braille idea, the location could be communicated by using the characters as abbreviations for direction and distance. With the vibration design, by using one vibration motor, the distance could be communicated via vibration pulse frequencies (the faster it pulses, the closer someone is). With multiple vibration motors directional feedback could be provided as well (which is further explored in chapter 15).

Lastly, the **vibration** idea uses a **technology** that is already **widely spread** on the market and is even already integrated into the Apple Watch itself. Therefore it might be easier to produce and more cost-efficient.

15. Location and Guide Mode design

Next to sharing the identity of familiar others nearby, the other main features of the design are to share the **location of familiar others** and help PBLV **navigate** towards them. This subchapter will explain how the design of the location and guide mode has been composed.

The design of these two modes started with the decision to **use vibrations** for communicating location. During earlier concept generation (chapter 11), a tactile map and vibrations were used to communicate the location of familiar others. With the decision to design an add-on to the Apple Watch (chapter 12.1), continuing with the design that used vibrations is most suited.

Designing a complex tactile display that could be added to the Apple Watch seems practically impossible. While **adding vibration** motors is likely to be **less complex**. In addition, PBLV explained that interpreting vibration would **not attract attention** from others, which they prefered (chapters 9 and 11). Thus, I decided to **iterate upon the Presence Bracelets** (chapter 11.2). The conclusion from the Identity Mode design (chapter 14) is in line with this decision.

The Presence Bracelet (chapter 11.2) only notified PBLV about the presence of familiar people around them, while PBLV expressed the desire to know the relative location of familiar others (chapter 11.3). Therefore, this chapter will explore how the distance and direction of familiar others can be communicated via vibrations. First, I will address the insights retrieved from studying existing helping devices. This will be followed by explorations into the Location Mode and Guide Mode respectively.

15.1 Inspiration from existing helping devices

Two helping devices on the market that help PBLV with **navigation**, **using vibrations** are Wayband and Sunu Band. These two helping devices have provided some inspiration for the location and guide mode design in this project, as will be explained on the next page.

Wayband (https://www.wear.works/, figure 66) is a design by the company WearWorks that has created a smart wristband that can help PBLV and others with outdoor navigation. It transforms a **route on a map** to a **haptic corridor** the user can 'walk through'. When the user is moving in the right direction, they feel no vibrations at all, when the user gets off-path the device will start vibrating, and vibrate harder the more the user gets off track. The device takes into account fixed obstacles but no changing obstacles like traffic.

Figure 66: Wayband (WearWorks, n.d.)

Sunu Band (https://sunu.io/, figure 67) is a design by the company Sunu, and it is developed to help PBLV **notice obstacles** right in front of them on time, before bumping into them. It does so by scanning the environment around the user via **echolocation**, once there is an obstacle that the user is approaching, the device will start vibrating. The closer the user gets, the more intense and speed up the vibrations are.

Figure 67: Sunu Band (Sunu, n.d.)

What we can learn from these two devices is that we can use **vibration strength and intensity** to communicate distance towards certain objects or deviation from certain paths.

Like with Sunu Band, I want to use vibration to **communicate increasing proximity**. Only my design is about communicating proximity towards a person rather than an object. Sunu Band has more of an alarming function, warning users when bumping into something. Sofi does not. Therefore, I decided to only use speeding-up vibrations for communicating proximity and **leave out increasing vibration intensity**.

For Sofi, it is also desired to communicate the direction of familiar others in addition to distance/proximity. This is hard to do via one vibration motor, therefore in the next section, I will explore if adding vibration motors can help communicate direction. For this design challenge, first, the design of the Location Mode will be explored, because this situation is more static and therefore easier to design for. With the insights gathered from the Location Mode design the Guide Mode design will be further explored.

15.2 Location Mode Design

The feedback gathered on the initial concepts in chapter 11, made me decide to try to communicate the location of familiar others via vibrations. In this subchapter, it will be explored if both the distance and direction of familiar others can be communicated with the use of multiple vibration motors.

First, I explored in what manner multiple vibration motors could be added to the design. One option was to add multiple vibration motors on top of the wrist, and another option was to add multiple vibration motors around the wrist. Rapid prototyping sessions (see figure 68) lead to the conclusion that **around the wrist was best to continue with**.

First of all, it was very hard to distinguish among the four vibration motors in the prototype with the vibration motors on top of the wrist (figure 68, top). Secondly, it would be harder to integrate this idea with the Apple Watch as the vibration motors would have to be added below the watch itself.

In addition, with the surface area of the Apple Watch taken into account, the distance between the four vibration motors would become very small and therefore hard to distinguish. For the prototype with vibration motors around the wrist, it did appear possible to feel vibrations coming from different directions. Furthermore, this idea could be integrated with the Apple Watch by designing a special wristband for the watch.

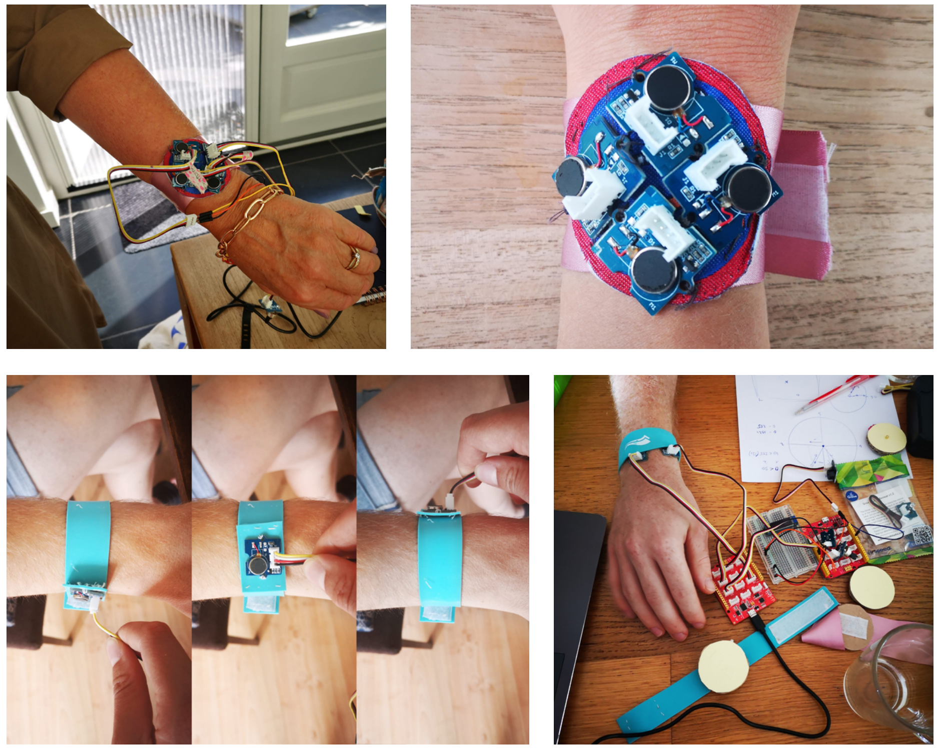


Figure 68: Pictures of the two vibration motor prototypes, top; on top of the wrist, bottom: around the wrist.

15.2.1 Location-Sharing Concepts

With the idea of four vibration motors around the wrist to communicate location, two concepts were created.

Frequency Vibrations

In the first concept, the location would be communicated by **vibrating in eight different directions** around the wrist at **different pulse frequencies**. By turning on one or two vibration motors it is possible to make the user perceive vibrations in eight different directions. The vibrations would be provided as short pulses, the faster the pulses would follow each other, the closer the familiar person is.

With each meter, the pauses between the vibrations would increase by 200 milliseconds, starting at 200 ms at 1 meter, and up to 3000 ms at 15 meters. In total a vibration cycle would take 7 seconds, afterwards, the device would be silent again.

The concept is further explained in figure 69. Thus, to further clarify, if vibration motors A and B would be turned on simultaneously, the user would perceive it as if there is a vibration right in the middle of those two motors.

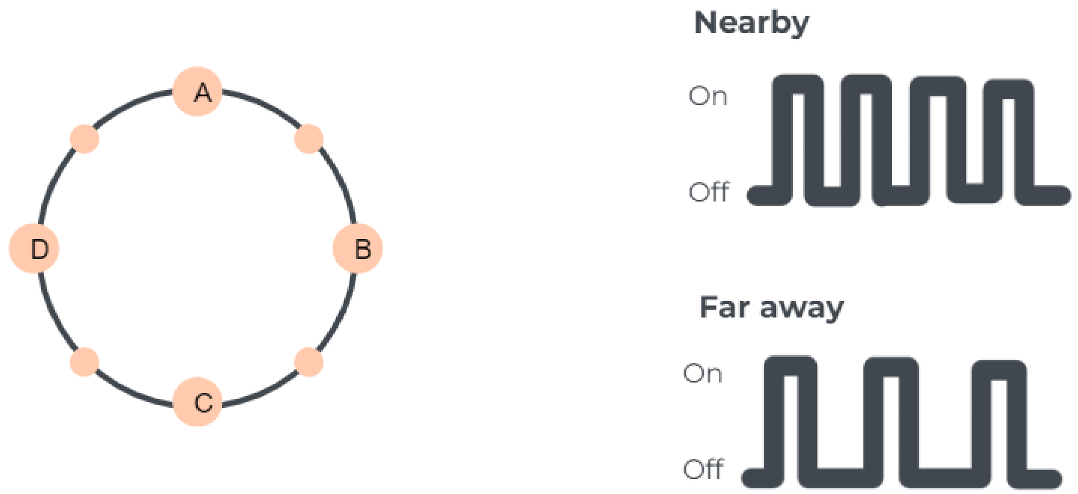


Figure 69: Illustration to explain the frequency vibration concept

Coordinate Vibrations

The second concept follows the principle of using **coordinates to communicate the location** of familiar others. Here the design would first vibrate in the **y-direction**, using the top and bottom vibration motor. It would give a certain amount of vibration pulses which would communicate distance, five pulses from the top vibration motor would correspond with five meters forward from the user. Subsequently, the design would vibrate in the **x-direction**, using the left and right vibration motor, following the same strategy.

The pauses between each vibration pulse take 500 milliseconds. The total duration of the vibration cycle is dependent on the location that is communicated. This concept is further explained in figure 70.

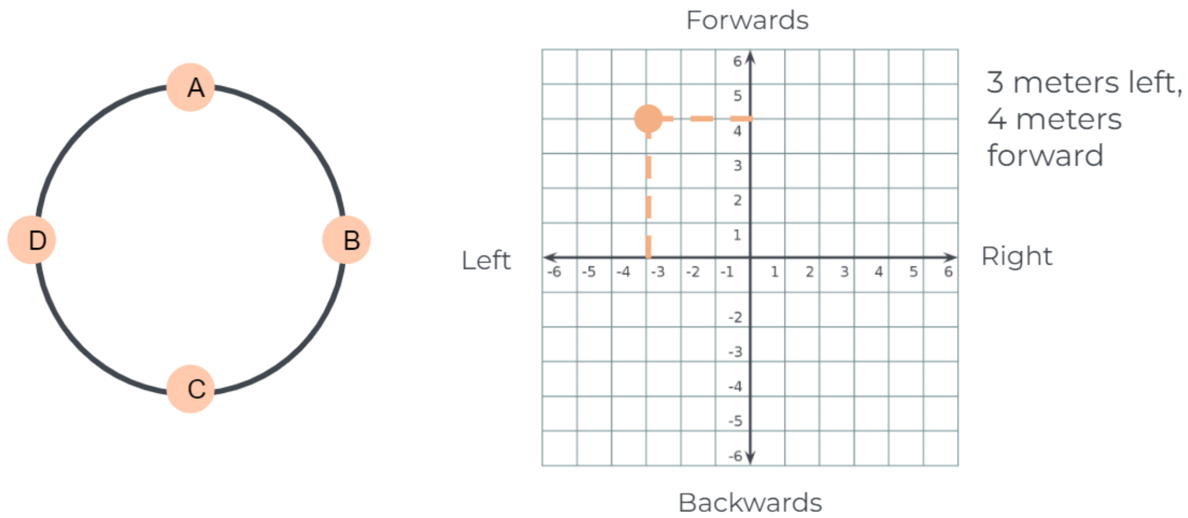


Figure 70: Illustration to explain the coordinate vibration concept

15.2.2 The Prototype

To test these concepts a prototype was created, using a Seeeduino Lotus, **four vibration motors**, and two buttons to control the vibration motors. With the use of velcro tape, the four vibration motors could be attached to two different size wristbands. The prototype is shown in figure 71 on the next page. The prototypes were coded in C++ language, using the Arduino application.

An important development during the coding process was when I started using Pulse Width Modulation (PWM) to control the vibration motors. This allowed me to create much softer vibrations than was possible with regular motor control.

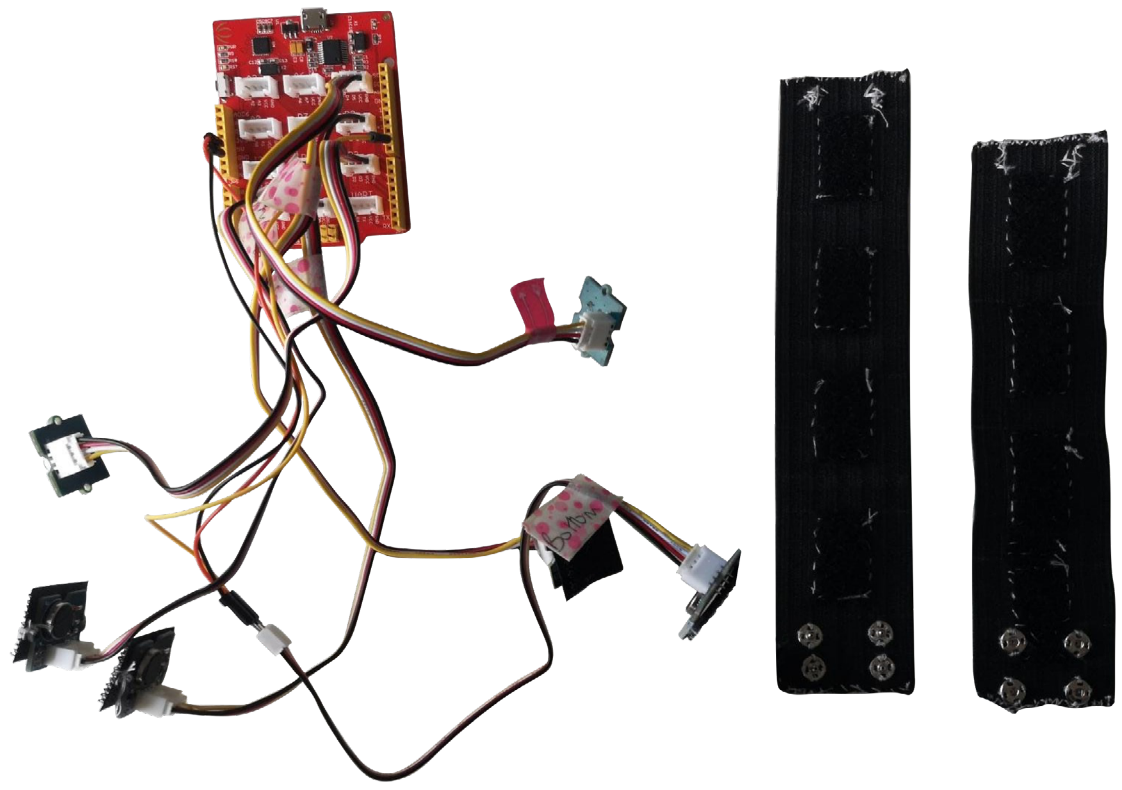


Figure 71: Photo of the prototype to test the two concepts of the location sharing mode

15.2.3 Location Sharing Testing

With the codes and the physical prototype finished, both concepts for location sharing were **tested qualitatively**. Due to time limitations, it was not possible to test elaborately with multiple PBLV. Therefore, I tested the concepts for location sharing with five (blindfolded) sighted people (SP 5, 7, 13, 14, and 15) and one PBLV (Maria). The sighted people were all students and belonged to a young age group, the PBLV is an elderly. The age difference resulted in an affinity difference with digital technologies, by which it took the older PBLV slightly longer to understand the concepts.

During the test, the participants first got introduced to the project, the context (as a PBLV being able to find familiar people around you in social settings), and the test plan. Subsequently, I asked them permission to voice record the session, using the data retrieved from the session and taking pictures during the testing.

The tests with sighted people took place in my student room, where I tried to mimic a cafe setting by putting on cafe background noises and letting participants stand next to a 'bar' (ironing board). The test with the PBLV took place at her home, therefore I could not adjust the test environment. At the start of the test a fitting wristband was put around the wrist of a participant, and the vibration motors were attached.

During each test, both concepts were presented and tested with participants. The order in which the concepts were presented was alternated between participants.

For each concept, six vibration signals were shared with the participants. The relative locations that the signals represented were randomized. During the first two vibrations, no explanation of the concept was given, beyond the fact that they knew the concepts were supposed to share the location of familiar others.

After the first signal, I asked them what their experience was, and what this signal told them about the familiar person nearby. After the second signal, I asked them to tell what they now knew about the location of the familiar person, and point in the direction they thought the familiar person was. Then I explained the concept to them; what the maximum distance between the familiar person and the user was; and how the direction and distance sharing worked.

After the explanation, I presented them with four more signals, and each time asked them to explain where the familiar person was according to the signal they received. Each signal was repeated until the participant had a clue about where the familiar person was, between each vibration cycle there was a few seconds pause before the repetition started. During the test, I was standing in front of a laptop screen where I kept track of the number of cycles participants needed to provide me an answer, and where I could check if that answer was correct or not. After all the signals I asked them some summarizing questions on the comfort of the prototype, the intuitiveness, estimated accuracy, and points for improvement. After having tested both concepts, I asked them which one they felt was most accurate, intuitive, and comfortable, and which one they would prefer to use.

To give a better impression of the test(setting) pictures are provided in figure 72 on the next page. The results of the tests, along with the insights from prototyping are summarized in the next paragraph 'Results of Location Mode development'.

Figure 72: Photo collage of all people that tested the location sharing concepts

Results of Location Mode Testing

Overall concept experiences

- In general, both concepts were perceived positively, people **liked the idea** of communicating location via vibrations to improve social navigation for PBLV.

- All participants felt they could determine the location of a familiar person the most precisely with the **coordinates vibration** concept. As they could simply determine the location by counting the vibrations.

- The answers participants provided during the test are in line with their opinion stated above. Participants were **more** often able to **correctly** determine the location with the **coordinates vibration** than with the frequency vibration. With the frequency concept, determining direction was sometimes hard.

- Although the accuracy in determining location was higher for the coordinates concept, all participants felt that the **frequency vibrations** were **better suited** to use in **real social situations**. This is mostly because they found this concept **more intuitive**. With a little bit of practice, they felt that the user could immediately have a clue about the direction in which the familiar person is and the distance, without having to think about it. Whereas with the coordinates concept, you have to count vibrations, which requires more focus and takes more time.

    - In addition, two participants stressed that it is easy to understand the data of the **coordinates vibration** concept, but **hard to calculate the direct distance** and direction the familiar person has towards the user. Another participant explained that it made her tend to walk in two directions sequentially towards the familiar person, instead of walking directly in the right direction (for example first walk five meters forwards and then two to the left).

- Participants expected that their skills in determining location via vibrations would improve for both concepts with a little **practice**.

    - The PBLV that tested the concepts further suggested implementing a **practice mode**, as this would help her a lot.

- To further improve the user-friendliness of the frequency concept, two participants indicated that it would help to have **reference vibrations** available on demand to compare the minimum and maximum distance vibrations with the actual distance vibration.

General observations

- It was noticed that four participants often **turned their wrists** to better interpret the vibration data. They turned their wrist in a way that the top of their wrist was pointing right in front of them.

- Furthermore, it was observed that three participants (among which the PBLV) sometimes felt the need to **touch the wristband** with their other and to check if their estimation of the vibration direction was correct.

Directional vibration accuracy

Using directional vibrations for describing location seems to have potential, though during the testing participants sometimes struggled with defining where the vibration was coming from. Especially for the frequency vibration concept that vibrated in eight different directions. The **inaccuracy** can be **attributed to** the following factors:

- Due to the fabric layers and the Seeeduino vibration components themselves, the **distance between** the actual **vibrating disk** and the **skin** of the participants was quite large. All the layers between the disk and skin caused a lot of **noise** in the vibrations, making it harder to feel where the vibration was coming from.

- Furthermore, all the **vibration motors** used were relatively **old**, in terms that they have been used many more times before. Therefore, they did **not all vibrate at the same intensity** when they were supposed to do so. Some vibrated harder than others with the same signal provided to them. This especially made it harder to feel the direction of the vibration in the frequency vibration concept. When two motors were turned on simultaneously it could be that one vibrated significantly harder, which influenced the direction perception of the user.

- The **wrist sizes** of the user seem to influence the accuracy with which the user can perceive the vibration direction. For the person with the **largest wrists**, it appeared much **easier** to estimate the direction from which the vibration was coming than for the people with the smaller wrists.

- From the test, it seems that **wrist anatomy** might also influences vibration perception. Motors that were vibrating on top of bone structure, were often experienced more intense than those vibrating on soft tissue. Though vibrations on soft tissue seemed to more easily penetrate through the wrist (during the test top and bottom vibrations were sometimes confused).

In summary, participants seemed to be more accurate in determining direction with the coordinates concept because it was easier for them to distinguish between four directions rather than eight. Nevertheless, **participants advised me to continue developing the frequency vibration concept**. With the inaccuracy factors described above, I think there are enough cues on how to further improve the accuracy of the frequency concept.

I expect to achieve the greatest improvement by placing the vibration motors more directly on top of the skin, as this will greatly decrease the vibration noise. Furthermore, if the vibration motors are placed on top of the skin, the vibrations could also be a made lot softer which will even further reduce the noise. The smaller the vibration noise, the easier it will be to determine direction based on vibrations.

Based on the results I decided to **continue with the frequency vibration concept**. However, given the limited time frame of this graduation project, I decided to leave improvements on this design (especially for increasing directional accuracy) to further recommendations.

15.3 Guide Mode Design

The **guide mode** of Sofi is similar to the Location Mode design. However, now we are dealing with a **dynamic situation** where the user will move to **navigate** toward the familiar person. Sofi will help PBLV with navigation by providing real-time feedback on the (changing) relative position of the familiar person towards the user.

In the guide mode, the **vibration pulses** will **continuously** be provided to the user until the user has reached a 1-meter distance from the familiar person or turns off the guide mode. The frequency and direction in which the vibrations are provided will be **adapted to the changing location** of the familiar person relative to the user. Based on the insights from studying the Wayband and Sunu Band, I decided to use **confirming vibrations** in this design. This means that the design will start vibrating faster when the user is moving in the right direction.

15.3.1 Guide Mode Prototyping and Testing

To get a better sense of how this guide mode would function and how it would be experienced I created a **simplified prototype** and tested this with three (blindfolded) sighted people (SP 13 and 16). Via prototyping and testing, I wanted to gather insights on navigating through vibrations.

For the prototype, I decided to use just **one vibration motor** to only communicate distance, as I did not yet have time to improve the accuracy of directional vibrations. Furthermore, I replaced the real-time feedback on the familiar person's location with a **potentiometer**, with which I mimicked changing distances.

I put a piece of cardboard behind it where I wrote down which position of the potentiometer related to which distance. The distance range was 1-15 meters, with a step size of 1 meter. For communicating distance the pauses between the vibration pulses were increased by 200 milliseconds per meter, starting at 200 milliseconds at a 1-meter distance. A picture of the prototype is shown in figure 73.

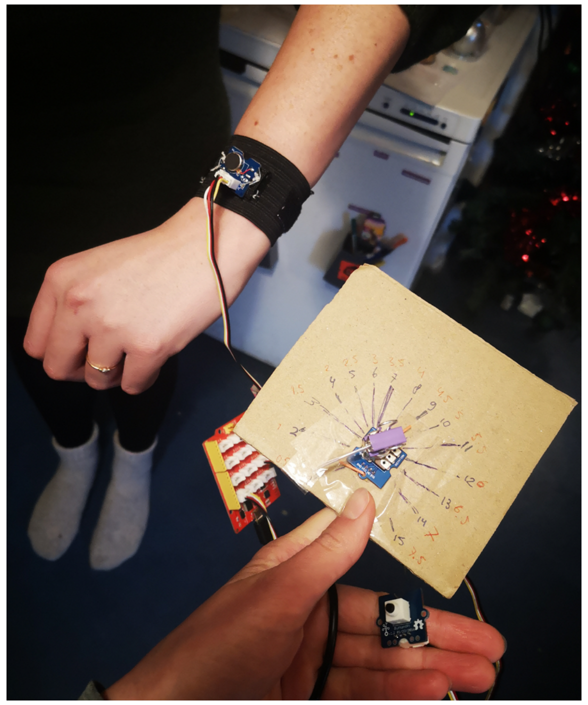


Figure 73: Simplified prototype for testing the Guide Mode concept

It was not possible to conduct a test in a busy social setting where participants had to find 'familiar' people. In addition, it was not possible to test with PBLV. Therefore, for the first test, I let two blindfolded sighted people (SP 13 and 16) try to find three **hidden kitchen rolls** sequentially in the living room, based on the vibration input.

The task of finding hidden kitchen rolls, blindfolded, in a living room served as a replacement for finding people in a busy/complex social setting. As the living room was not 15 meters wide, the range was adapted. Now, the minimum distance from the object was 0.5 meters and the maximum was 7.5 meters, with a stepsize of 0.5 meters. The pause increments were not adapted. Via the vibrations, they would be able to feel if they were getting closer or further away from the specific kitchen roll they tried to find.

The goal was to learn if it is possible to find specific objects (replacements for people) with the use of vibrations. I video-recorded the test, for which I asked permission in advance. A still image from the video recording is shown in figure 74.

Figure 74: Screenshot of videorecording that was taken during the Guide Mode testing

Both participants managed to **find all three kitchen rolls**. Though, for some of the rolls it took them quite some time to find them. This was especially due to the fact that it was **hard for them to feel small changes** in vibration frequency when the distance change towards the kitchen roll they were trying to find was minimal. Furthermore, both expressed the need to feel a **reference vibration** now and then. Feeling either the minimum or maximum vibration speed helped them to estimate their actual distance toward the kitchen roll.

With this feedback, I further iterated on the prototype of the guide mode, trying to make small distance changes more observable.

The first improvement was regarding the pause time between each vibration pulse. In the initial design, the pause time would increase by 200 milliseconds every meter, starting at 200 milliseconds for a 1-meter distance (0.5 meters in the test). With this design, the difference in pause time between 1 and 2 meters was 100% (from 200 ms to 400 ms), and the difference in pause time between 14 and 15 meters was 7% (from 2800 ms to 3000 ms). Thereby it became much harder to recognize differences at larger distances.

The issue was solved by making the **pause increment** not absolute but **percentual**, now the pause time would increase by 30% for each extra meter (the difference is visualized in figure 75).

A quick test on my wrist made clear that this did improve the perception of differences at the larger distances.

However, now became hard to distinguish between 1 and 2-meter distances. To further improve the perception of distance differences across the entire range, I implemented **fine vibrations** when moving in the **right direction** and **rough vibrations** when moving in the **wrong direction** (as visualized in figure 76). The idea of using fine and rough vibrations was inspired by a design by Kim et al.(2021).

With another sighted person (SP 7), I quickly tested if these adaptations had the right effect (see figure 77). During this quick test, she was looking in another direction while I was changing the distance signal. I asked her to notify me when she felt a change and tell me at what distance I set the device. As her performance seemed okay, I decided to continue with a new test round in the living room.

To see if this iteration was an improvement compared to the previous prototype, I repeated the kitchen roll test with the same two sighted people (SP 13 and 16). I did change the positions of the hidden kitchen rolls. Afterward, with one participant we also switched roles, and I was trying to find hidden kitchen rolls blindfolded.

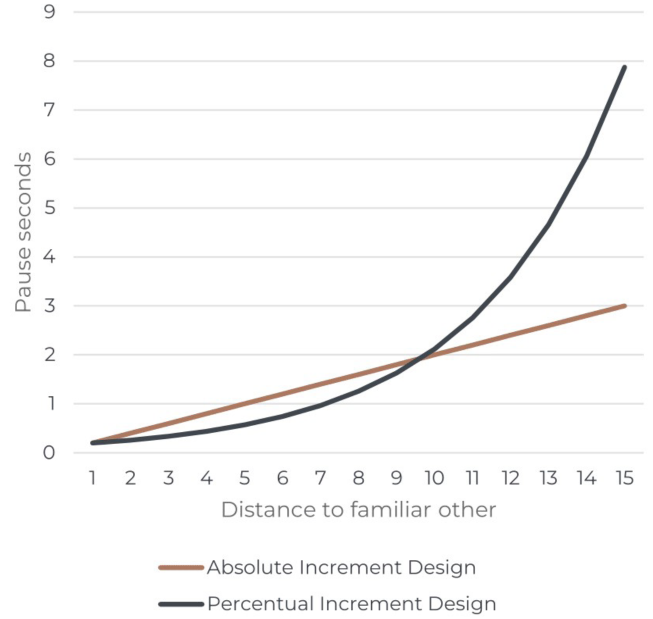


Figure 75: Graph that illustrates the difference between the original linear increment design, and the improved percentual increment design

Figure 76: Explanation of difference between rough and fine vibrations

Figure 77: Quick test to check if adaptations were effective enough

From the second testing round, I concluded that the **iterated prototype** worked indeed **better** than the previous prototype. When participants and I got used to the **two types of vibrations** (rough and fine) it **helped** to more quickly feel if you are moving in the right or wrong direction. It also seemed **easier** to distinguish distance differences with the **iterated increment design**. I noticed, when using the prototype, that I estimated the distance only at the beginning. When starting to walk, I only paid attention to the rough and fine vibrations to know if I was moving in the right direction. Once I got close, I paid attention again to the vibration speed.

Again the two participants suggested a **reference mode**, with maximum and minimum vibration speed, on demand. It would help them to better interpret the data. During the test when a reference was requested, I manually let them feel the minimum and maximum vibration.

Being experienced with the prototype, I felt that it was quite easy for me to interpret the vibrations and move accordingly. Therefore I expect similar **learning curves** for PBLV.

I decided to base the **final design** of the guide mode on the last prototype iteration, thus with **percentual pause increments** and **rough and fine vibrations**. Furthermore, the final design would provide **vibrations in directions around the user's wrist**. This will help the user to directly move in the right direction when navigating to a familiar person.

Also, for the final design, I will add an **audio-based reference mode**. For the reference mode, a user can double tap on the watch which will make the watch speak out the distance and direction in which the familiar person can be found on a low volume. The reason why I chose audio instead of providing the minimum and maximum vibration values is that I expect audio to provide the user with a more secure feeling. Furthermore, hearing the exact location and comparing that with the vibration signal will help users with practicing their interpretation.

15.4 Summary of Location- & Guide mode design

In short, several iterations and small tests have taken place to get to the final design of the location and guide mode the way it is described in chapter 12.

Five decisions are considered the most important. First, place four vibration motors around the wrist instead of on top. Second, use pulse frequency and directional vibrations to describe the distance and direction of a familiar person respectively. Third, to use a percentual increment for the pauses between pulses. Fourth, add rough and fine vibrations for the guide mode. And fifth, add an audio-based reference mode.

16. Feedback on overall design

To gather some overall feedback on my final concept, I presented it to PBLV on another Envisioners day[3]. At that time I **only prototyped the location mode**. With the use of this prototype, I **explained my entire concept** to four PBLV: Iris, Ruben, Sam, and Tanja. I let them experience the vibration signals of the location mode via the prototype and subsequently explained how I envision this concept to be integrated with the Apple Watch and how I planned the identity and guide mode to function.

At the beginning of the session, I asked the PBLV for permission on taking notes, using the data, and video recording the meeting. They all gave me permission to use the data and use video recordings for still images or in my presentation without anonymization. After explaining my entire concept Sofi, I asked them questions about their perception of the received signals, the desirability of the concept, and ideas and suggestions for the identity and guide mode design (that I still had to design at that point).

During the feedback gathering, all the PBLV were very enthusiastic about the project and the design of Sofi. Pictures of the feedback meetings are shown in figure 78 on the next page. The insights from the feedback gathering will be summarized below.

16. 1 General feedback

All four PBLV were very **enthusiastic** about Sofi, and all of them would **want to buy it**. Tanja explained that she would first want to test it, but the others seemed convinced straight away.

To the question if she would buy Sofi, Iris responded:

> *"Yes, for sure! Yes, it just is very handy, and useful as well... Then you can just know, or at least already walk in the right direction, then the other person will see you. Yes, really very useful, I would buy it and advertise for it!" - Quote by Iris*

To a similar question Sam responded:

> *"Absolutely!! Yes, without a doubt, I would directly do that." And later he continued "Yes, this really means something to me, that these kinds of things are possible..."- Quote by Sam*

3 Envisioners day, is a day organized by Envision, where they invite many PBLV that use their service to come to Envision. During this day, the team can chat with the users and also users can help testing new features of Envision products.

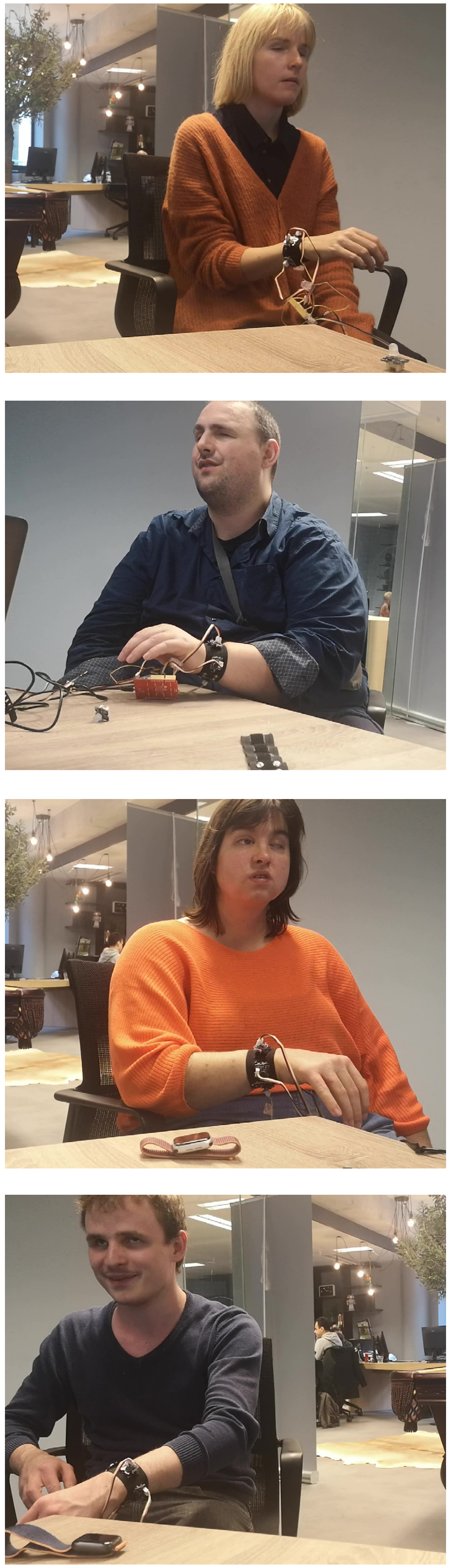


Figure 78: Photo collage of Iris, Rick, Tanja and Sam that provided feedback on the overall concept of Sofi during an Envisioners day. All are completely blind, except for Tanja, she has deteriorating low vision

I also asked them what they would like to **spend on the add-on and app** of Sofi. Their answers were **mixed but positive**. Iris said she would want to spend about 50 euros on it, Ruben at most 200 euros, while Tanja and Sam were both willing to spend 200-300 euros on Sofi as an add-on for the Apple Watch.

Iris further explained that even just knowing which familiar people are around you is already very valuable for her. And explained situations of having lunch with colleagues or at a party where Sofi would be useful. Sam even saw more opportunities for use cases of the Sofi add-on, such as finding your guide dog or finding objects.

Sam suggested that adding a **notification mode**, that would notify the user when a familiar person approaches them, seemed useful to him. In addition, he suggested to add a **'Say Hi' notification** in the guide mode, that would tell you when the person you were navigating towards, is within calling range. Lastly, he mentioned that more research needs to be conducted on the willingness of familiar others to share their location.

All four PBLV would want to be kept up-to-date on any further developments of the concept.

16.2 Identity Mode feedback

For designing a suited identity mode it appeared that **more research is needed**. PBLV did agree that using audio to describe identity could make them feel oversensitized in social settings and that using vibrations instead might therefore be a good solution. But regardless both Ruben and Tanja would prefer to receive identity information via audio anyway. For Iris having audio available as backup seemed suited.

16.3 Location Mode feedback

Feedback on the location mode was predominantly **positive**. Although PBLV agreed that **improving the prototype** was needed, they did **like** the idea of **communicating** the location of a familiar person **through vibrations**.

Ruben explained that he felt this was a very **intuitive** way to do so. Iris also preferred it over using audio, as background noises in social settings like a party would make using audio much harder. Tanja felt that it was very easy to recognize the vibration directions, and expected her skills to even further increase after some practice.

16.4 Guide Mode feedback

In line with the Location Mode design, PBLV liked the idea of being guided through vibrations. Ruben, Iris, and Sam preferred the use of **confirming vibrations** in this mode. Thus receiving stronger vibrations when moving in the right direction, and weaker ones when moving in the wrong direction. Iris explained that if it wouldn't vibrate when moving in the right direction, it would make her wonder if the device was broken.

Sam noted that it could be considered not to use directional vibrations once the user starts moving, but only give feedback if the user is getting closer or further away from the person that they try to find. According to him, this might require less focus than when also having to interpret the direction of the vibration. In contrast, Tanja liked the idea of using directional feedback during guide mode, as this would make it easier for her to start off walking in the right direction. More research will have to be conducted to decide what is the best strategy here.

16.5 Summary

Concluding, the feedback provided by the four PBLV was very **positive**. They were enthusiastic about the concept. They would **love to buy it** if it was on the market and wanted to be kept up to date if there would be any further development.

They agreed about the improvements I suggested making. Furthermore, they agreed with how I planned to design the guidemode (which still had to be done at that time). The feedback from PBLV indicated that more research on the design of the identity mode is needed.

Closure . . . .

With this section, we have come to the end of this report. In this section an overall conclusion and discussion will be presented, followed by a personal reflection.

17. Conclusion

This project contributes to the knowledge of (designing for) the social life challenges for people that are blind or have low vision (PBLV). The focus of the project was to ***'develop a supporting device that makes PBLV feel more at ease in social situations'***. This resulted in the final design of **'Sofi', the social finder**: a tool that helps PBLV to **socially navigate** themselves.

The current project started with exploring what type of challenges PBLV experience in their social life. To answer this question several interviews were conducted, along with observations, and a literature study (chapter 5).

Clustering the insights resulted in a list of eight challenge areas PBLV experience in their social life: challenges with stigmatization; processing stimuli; orientation; (In)dependence; nonverbal perception; nonverbal expression; recognizing others and understanding of others. Furthermore, it was found that the manner in which challenges were experienced was influenced by contextual factors. In total three categories of contextual factors were identified: personal characteristics; audience characteristics; and environmental characteristics.

This study, along with a literature study on existing technologies and design projects for the social life of PBLV (chapter 6), evolved into the design goal to: 'Design a tool that allows PBLV to improve personal social navigation. Helping them to find and identify familiar people around them in social settings.' This design goal covers some of the challenges experienced in recognition, orientation, and (in)dependence.

Concept generation, prototyping, and testing resulted in the final design of **'Sofi'**, the social finder. It is a tool that consists of an application and an add-on wristband for the Apple Watch. It helps PBLV with social navigation by communicating the **identity** and **location** of nearby familiar others **through vibrations**. In addition, it can help them **navigate** toward these familiar people. Sofi receives the identity and location of nearby familiar people (that provided consent in advance) via their mobile devices using **ultra-wideband** (UWB).

Figure 79: The design of Sofi, with the add-on vibration bracelet

The add-on wristband has three integrated vibration motors which, together with the vibration motor in the Apple Watch itself, are used for communication with the user. For sharing the location of familiar others and helping PBLV to navigate towards them, Sofi can give **directional vibration pulses** around the user's wrist, which can indicate in what direction and at what distance a specific familiar person can be found. Sofi uses vibration for communication as the haptic sense is a relatively unused sense during social interactions, and therefore considered available.

Sofi can make it easier for PBLV to find the colleague they are looking for on the work floor, find back their table in a restaurant where they were seated with friends, or allow them to mingle around at a party.

Parts of the design of Sofi have been prototyped, and the location sharing and navigation help have been tested. Based on the prototypes and tests, sharing information on the direction and distance of familiar others via vibrations seems promising. Furthermore, feedback on the concept has been gathered from PBLV. **According to PBLV, Sofi is a valuable and desirable tool that offers potential for further development**. Based on the test and feedback from PBLV, I would advise that the concept is worth looking further into.

Overall the project provides a new perspective on challenges PBLV experience in their social life, and how design could help PBLV tackle these challenges. The research on social challenge areas can be used as topics for consideration while designing for PBLV, and can function as an inspiration for new design projects to tackle the social challenges PBLV experience. Sofi can be used as inspiration on how (directional) vibrations can be used to communicate more complex messages, and on how to design for improved social navigation.

18. Discussion

While this design project has yielded valuable insights into the challenges PBLV experience in social life, and has resulted in a valuable design concept, it has also encountered some limitations. The limitations experienced, along with the limited time frame of this project, left areas for further improvements.

In chapter 18.1 I address the most important limitations that I experienced during my project. Specific limitations of the study into the main challenges of PBLV in social situations are excluded from this list, as they have already been covered in chapter 5.5. In chapter 18.2 I briefly reflect upon the technology readiness of Sofi. And lastly, in chapter 18.3 I recommend a few steps for further development of Sofi if this project is to be continued.

18.1 Limitations

During the entire scope of this project I have experienced some limitations, which will be addressed in this chapter.

- **Limited access to PBLV**
  Although there were many PBLV that helped during the project (20 in total), it was not possible to include PBLV during every step in the project. Sometimes brainstorming sessions or tests had to be executed within a limited time frame (in a week for example), which made it too hard to include PBLV within that time. To account for this limitation all sighted people that helped during the project were always explained about the target group, and the challenges they experience, in advance. Furthermore, during tests, all sighted people were blindfolded as a way to simulate a visual impairment. Nevertheless, testing with and gathering feedback from sighted people cannot be considered the same as from PBLV.

- **Focus on PBLV perspective**
  This entire project has been approached from a PBLV perspective, thinking about how they experienced certain challenges in their social life. The design Sofi that has been proposed in chapter 12, is likewise designed from the PBLV perspective. However, in social interactions, other people beyond the user are part of the situation as well. Therefore, to some extent, their perspective should be considered.

  For example, to assess if the design of Sofi won't evoke stigmatization, the opinions of both famliar people and strangers need to be considered.

Furthermore, for Sofi, it is important to consider if familiar people feel comfortable sharing their location with PBLV. Their perspective on the location sharing has so far been left out of consideration but would need to be included for further development, as will be addressed in chapter 18.3.

- **Incomplete prototyping, testing, and evaluation**
  The design of Sofi has been based on several studies and tests throughout the project. Nevertheless, not all elements of Sofi have been prototyped and tested. Regarding the prototype, for example, due to the limited time scope I decided not to prototype the identity mode (and focus on the location- and guide mode), not to include real-time location sharing via UWB, not to further iterate on the vibration motor design for the location and guide mode, and not to create a mock-up of the concept on the Apple Watch. Regarding the testing, it has not yet been possible to test Sofi in a real-life situation; and the final feedback gathering from PBLV (chapter 16) has been based on the prototype of the location mode (chapter 15.2) along with an explanation of the entire concept.

  Although all of these decisions are well considered, the results of the tests are promising, and the feedback from PBLV on the unfinished prototype was highly positive, I can still imagine that the decisions might have influenced the outcomes of the project. Therefore, although I think Sofi has the potential to be a success, this cannot be guaranteed.

- **Business perspective**
  For the design of Sofi, many business aspects have been left out of consideration so far. Some thoughts have been spent on making Sofi an add-on to the Apple Watch, to increase desirability; and not to merge it with the design of the Apple Watch. However, business considerations like regulations for developing an add-on for the Apple Watch, or marketing considerations have not been included in this project. Therefore it cannot yet be assessed if it is feasible further to develop Sofi for the current helping device market.

With the above-stated limitations, the design of Sofi should be seen as an inspiring proposal for helping PBLV with social navigation, rather than a finished product. More steps are needed to decide if and how Sofi will become ready to market. Some of these steps will be described in the next section 18.3 on recommendations.

18.2 Brief reflection on Technology Readiness

In this project, existing technologies are put together in a new way to form a design called 'Sofi', which helps PBLV with social navigation.

As Sofi only uses existing and used technologies, I consider Sofi to be a feasible design, both in the short term and long term.

During the project, several studies, prototyping sessions, and tests have been conducted. In terms of technology readiness of the design, an experimental proof of the entire concept has been achieved. In addition, I validated the elements of the location and guide mode in a 'lab' setting.

To get Sofi market-ready on the short term, two points need to be addressed. First, I would advise only designing the software of Sofi, and therefore using just one vibration motor. This would make it possible to get Sofi on the Apple Watch without any complex hardware considerations. The trade-off here is that Sofi would solely be able to communicate distance, rather than relative distance and direction of familiar others. Second, as the UWB system used by Apple is currently only able to communicate with other Apple devices, a current version of Sofi would become an Apple-only service. This would limit the familiar people that users can add to the system, as those can only be added when they use Apple mobile devices.

In the long term, with more steps involved (as described in chapter 18.3), I consider it feasible to get Sofi ready to market as the version which is described in chapter 12. It would be important to take enough time here to design the add-on wristband. It is likely that in the long-term UWB will have become widely used among different brands of mobile devices (see chapter 10 for argumentation).

Steps I consider important to get Sofi ready to market, are further discussed in chapter 18.3.

18.3 Recommendations

In addition to the design proposal of Sofi, this project ends with areas to continue with. In this chapter, I will propose a few steps which I consider important to focus on if Sofi were to be further developed. I present them in the order I would approach them if I were to continue with this project.

1. Including outsider's perspective

As explained in chapter 18.1, during this project I have focused on designing for PBLV and approached every test and feedback session from their perspective. Although PBLV are definitely the most important stakeholder in this project, perspectives of familiar people and strangers in social settings should be considered as well.

One important thing that should be studied when further developing this concept is the willingness of familiar people to share their location (along with identity information) with PBLV via UWB once nearby. How does this make them feel? And, how to take into account their need for privacy? I expect a proper explanation of the goal and transparency on the location sharing will help create acceptance and willingness from outsiders, however, this shouldn't be taken for granted.

2. Further exploration of the identity mode

As has been explained in chapter 14, I haven't been able to prototype and test the identity mode (with PBLV). The current identity mode concept is based on gathered knowledge described in chapters 9 and 11. It includes a set of five specific vibration patterns, and five category patterns to describe identity. I advise prototyping and testing this concept with PBLV. I would also consider variations of the design (such as using rhythmic vibration patterns, or using multiple vibration motors). For testing with PBLV, I would test both short and long term learning capabilities.

Furthermore, I would explore how the identity mode could best function in heterogeneous and homogeneous environments. Possibly in homogeneous settings additional information needs to be provided for the identity category patterns (communicating that a familiar person that is nearby is a colleague might not be sufficient in the work environment).

3. Creating an improved prototype

After having further explored and iterated on the identity mode, I advise creating a more advanced and complete prototype.

For this prototype, the type and positioning of the vibration motors on the wristband should be improved. They should be properly distributed and directly in touch with the user's skin. In advance, I would advise studying the autonomy of the wrist. Based on this, it should be decided whether the symmetrical distribution of the four vibration motors makes the most sense, or if because of bone structure and soft tissue, the distribution could best be different.

Next to integrating both the identity, location, and guide mode into this improved prototype, it is also desirable to integrate a UWB system. This will allow for testing the concept in real life with real-time feedback (as will be explained in discussion point four). I would advise integrating a UWB chip into the prototype, along with a couple of separate UWB modules that can be provided to 'familiar others' during testing (to mimic the UWB sharing via mobile phones and smart devices). Another possibility could be to create a simplified mock-up on the Apple Watch. This prototype would only use the one vibration motor present in the Apple Watch and could therefore be used to communicate the identity and distance of familiar others (rather than distance and direction). This simplified prototype could possibly use Apple Airtags to receive location from, to mimic receiving the location of familiar others via their smart devices.

4. Testing in real context

With the improved prototype(s) created, I consider the next important step to test the concept in a (simulated) real-life situation: A PBLV that attends a busy social setting where they try to identify, locate and navigate towards familiar people nearby.

This type of testing will among others allow gathering insights on

- Is the design operable in parallel with engaging in a social situation and social interactions? Thus can the device be used in social settings without limiting the user's social capabilities.
- Accuracy of directional vibrations using the improved prototype with four vibration motors
- Accuracy of UWB system to receive location from familiar others in a social context with obstacles (walls, other people, etc.).
- How do PBLV experience navigation towards familiar others with the help of Sofi? How do they deal with the obstacles that will be in the way, like other people, walls, or furniture?
- What happens when a PBLV navigates to a familiar person who moves around simultaneously?

Furthermore, Sofi must be tested in different contexts. During earlier research (chapter 5.4), it was learned that the challenges and needs of PBLV can change dependent on the context. By testing in different contexts, it could be assessed if the behavior of Sofi needs to change depending on the context.

5. Design Reflection

Based on the test results, I would advise conducting another reflection on the design of Sofi. One important consideration is regarding the value of the vibration wristband. Is the accuracy of direction vibrations indeed improved compared to the prototype described in chapter 15? How did PBLV experience the directional vibrations during the test with navigation as described in step 4? Do PBLV consider it to serve enough value to be sold as an add-on for the Apple Watch?

Furthermore, it is important to assess the general value of Sofi according to PBLV. It is helpful to let PBLV which tested the concept, as described in step 4, assess Sofi's value. I would advise asking if they would want to use Sofi while attending social situations, and also ask how much they would be willing to spend on a service like Sofi (and the accessory add-on).

Based on the design reflection, it should be decided whether or not to continue developing Sofi, or a similar concept.

Furthermore, it should be decided if it is worth developing the add-on for the Apple Watch with the directional vibration capabilities, or if it might be better to create a simplified concept that does not need this add-on. For this consideration, an indication of the costs involved in developing this add-on should be created and compared with what PBLV would be willing to spend on such an add-on. Also, it should be checked if any legal regulations (for example on location tracking) should be taken into account when designing an add-on for the Apple Watch.

6. Technical detailing of Sofi

After the decision has been made to continue (or discontinue) the project, I would suggest elaborating on some technical details of Sofi. Details that could be considered are:

- Which vibration motors to use in the add-on?
- How to calibrate the vibration motors in the add-on with the vibration motor in the Apple Watch?
- How to design a wristband that properly distributes the vibration motors around the user's wrist, taking into account wrist size variations.
- How to supply the wristband with energy?
- Which perspective to use while communicating the location of familiar others and helping PBLV to navigate? The main issue here is that the positioning of the user's wrist is not always aligned with the position of the user's body (the top of the wrist is not always parallel to the front of the user's body). Should the device provide feedback on location and navigation from the perspective of the user's wrist, or is there a way in which Sofi can determine the position of the user's body relative to their wrist?

7. Making Sofi ready to market, and far future suggestions

Above I described the steps I considered important to elaborate on when further developing the design of Sofi. After conducting these steps there will still be work left before Sofi is ready to market. Such steps could include making a first high-fidelity mock-up of the add-on, regulatory actions, adding the business perspective, and detailing software, hardware, and production of the add-on. Providing advice on how to approach these steps, is currently beyond my knowledge. A plan for these steps should be created at that point in time. For this plan it could be an option to start with a simplified Apple-only version, as described in chapter 18.2.

Imaging the 'ideal scenario', where Sofi has been developed into a real product for PBLV, there are a few ideas in my mind on how to further increase the value Sofi can offer:

- Adding a notification mode, that notifies PBLV when a familiar person is approaching them, so they can respond adequately.
- Adding a 'Say Hi'/arrival notification, that communicates to the user when they are within 'calling' range of the familiar person they were navigating towards.
- Adding a 'Smart Silent' mode, that detects when PBLV are interacting with others, and puts itself on silent mode during these interactions.
- Check if it is possible to make Sofi compatible with different types of smartwatches.
- Check if there are additional market opportunities for Sofi, such as opportunities in regular navigation (like using google maps), or using directional vibrations for communicating more complex messages through vibrations.

The above-described steps give an indication of how Sofi could be further developed. Which closes up the current project. In the last chapter that will follow, I will provide a personal reflection on the project, the process, and my personal development throughout the project.

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