esign

For specific users

14/04/2020 - Industrial Design Engineering Module7 - dr. A. Karahanoglu

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Abstract

In the context of this project, Design for Specific users, we tried to make a product that would help a user with specific aspects in their life.

Our specific user, being a highly educated individual that also is on the autism spectrum and has a hearing impairment, was experiencing a lot of stress in her everyday life. After discussing with her what might improve this, we came up with multiple ideas which were presented to her. With her feedback in mind we chose one concept and began refining every aspect.

This concept is called SoundAround. It allows a user with hearing impairment to better understand his/ her environment. It's a necklace the user can wear which will indicate the direction a sound comes from by emitting vibrations. This will be a complement to a hearing aid our user has, as the hearing aid does not allow the user to understand from which direction the sound is coming from, this necklace will resolve this.

A prototype plan was then made with the final design of the product. The prototype could not be produced due to circumstances around the CoVid-19 pandemic.

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1 INTRODUCTION

Introduction

This module the project is centered around ‘Design for specific users’, meaning that we needed to design co-operatively with a user that we had not yet specifically designed for.

Each team could choose their own design challenge, in our case challenge N; A creative maker-space where people on the autism spectrum do various projects, seeks design opportunities for supporting their clients in everyday independence. Specific theme to be further determined together with the intended participant, who, apart from being on the autism spectrum, also holds a degree in product design.

Though, this design challenge has changed and developed over the course of this project.

In this project emphasis was put onto designing with co-design sessions. With the help of these sessions a specific problem could be determined, and a design solution developed.

We thus started out with familiarizing ourselves with the situation of our user and our user herself. With this, specific problems in her life were determined. Then with her help solutions to these problems were found. The solutions that she found most useful were then developed into full fledged concepts from which we chose one to develop into a final design.

Sadly, due to corona virus we were unable to physically involve our specific user in the finalizing of the final concept. But nonetheless this project resulted in a great product and hopefully a solution to a prominent problem in our specific user’s daily life.

2 ANALYSIS

2.1 Literature Research

At the start of the design process, we decided that some research was needed before starting designing the product. The user that we were designing for is a specific user, in our case, someone who is on the autism spectrum and has a hearing problem.

Since the user is on the autism spectrum more in-depth information on autism in general and ways to treat autism was needed. Autism or ASD is a name to indicate a set of neurodevelopment disorders. The cause of it is unknown, but it has a genetical structure. Some of the more common symptoms include difficulties with social interactions and restricted, repetitive patterns of behaviour, interests, or activities.

Besides being on the autistic spectrum our specific user has a hearing problem, therefore a look into the terminology and specifics of hearing problems was needed. Hearing loss exists in two forms; hearing impairment or deafness. These can occur separately or combined, as is the case now. Hearing loss affects a person's daily life, but mainly in conversations.

There are many co-design methods. However, many of them rely on good communication and understanding between the designer and the co-designer. This could cause some difficulty in our situation and therefore research was done what co-design methods exist in different design stages and which would work in our situation.

The complete research can be found in the Appendix (chapter 8.1).

With the findings of this research we had a good overview of what kind of daily problems our specific user would run into and would want to have solved. With this knowledge the questions of the first meeting and the techniques that would be used in the co-design sessions could be determined.

Moreover the research proved in later stages useful as well. During the development of the final product especially with designing the way of use.

2.2 Task analysis

FIGURE 1 - scenario

For the task analysis, a PACT-analysis has been performed. A PACT-analysis consists of the following four components: People, Activities, Context and Technologies. The main function of the PACT is gaining knowledge about all the aspects related to the design challenge. This analysis will help to come up with the requirement specification. Below, the PACT-analysis is briefly summarized. The complete PACT-analysis can be found in the Appendix (chapter 8.2) attached at the end of this report.

People
Our primary user has a combination of impairments which makes her an interesting user. She has autism and furthermore, our she is deaf on one ear and is impaired in hearing with the other. This causes her to have difficulty in having conversations with multiple people at the same time. Furthermore, there are some important stakeholders to consider: for example, caregivers in her home and at her day-care, colleagues, family and friends.

Activities
Our User has a lot of problems with daily life situations. Due to the combination of ASD and Hearing impairment most products don't fit her activities and will not help her. This can also be seen in research; a lot of research can be found on either ASD or Hearing impairment but very little can be found about the combination of the two disabilities. It is thus important to, when designing for this specific user, remember that the product we design keeps into account her over-sensitiveness/ASD AND her Hearing impairment. By doing this we can make a product that will fit her life best.

Context
The information about the different contexts will form restrictions for the design of the product that will be developed. The product needs to for example fit in the rooms that are present at AssortiMens (the day-care facility).

Technologies
There is a huge variety of aiding products on the current market varying from vary simple one-piece product to a High-tech solution. One thing most of these technologies have in common, is that the usage is straightforward, and easy to understand for the user. This is something important we will have to consider ourselves whilst designing our solution.

2.3 Scenario analysis

A spider diagram concerning possible scenarios is shown below. Several scenarios have been written down in different locations. Each line colour has a specific characteristic, these characteristics are shown below:

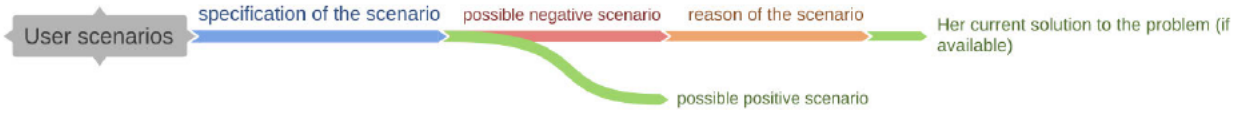


FIGURE 2 – structure scenario diagram

The blue lines represent the locations
The red lines represent an unsolved scenario
The Orange lines represent an elaboration on an unsolved scenario
The Green lines represent a solved scenario, this are the current solutions of the co-designer

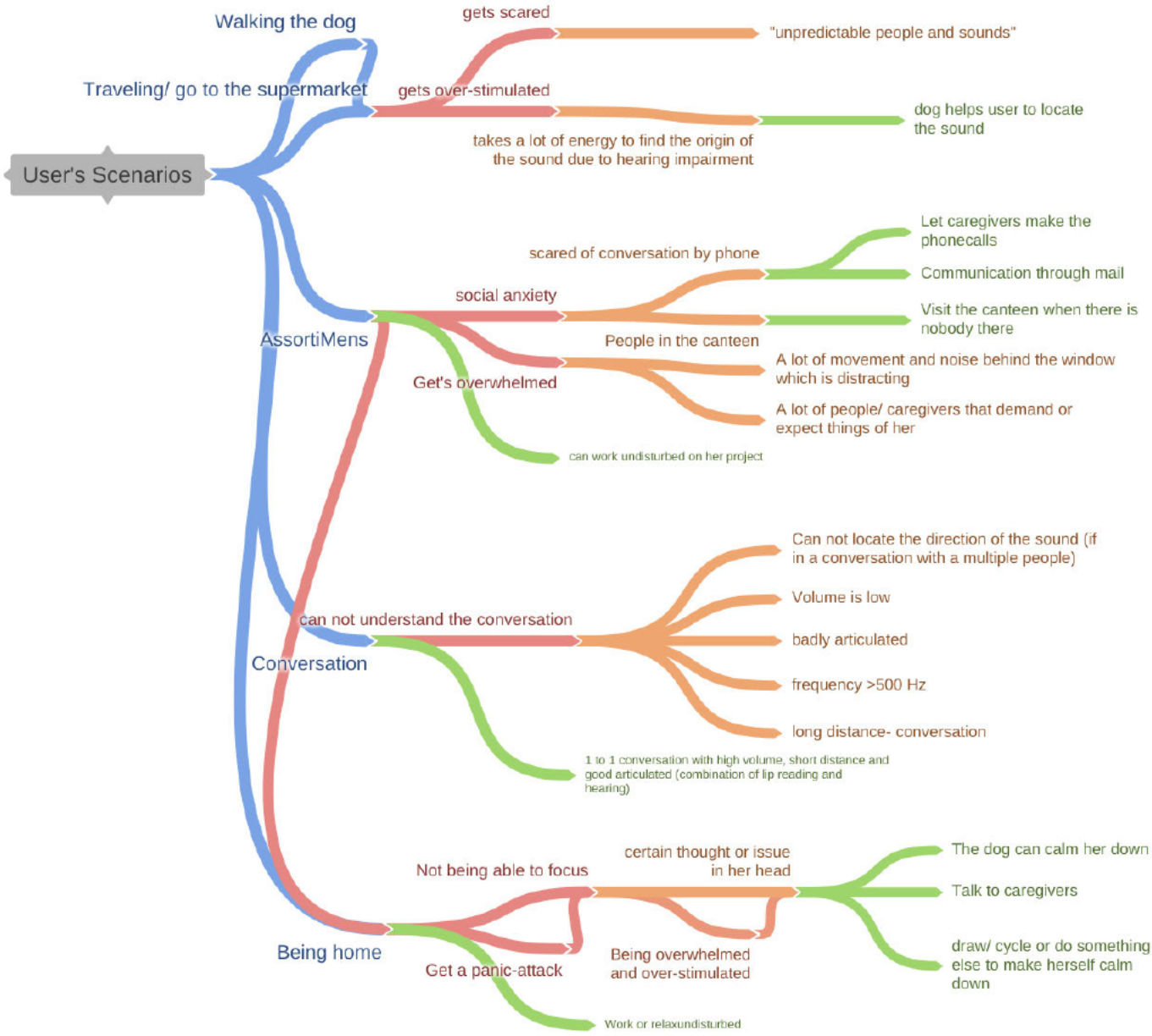


FIGURE 3 – scenario diagram

With this analysis of the scenarios, research can be done to the needs of the user. These problems and solutions to these problems can be taken into account in the requirement specification and design challenge.

2.4 Design Challenge

The design brief has evaluated throughout the project. In this chapter elaboration on the evolution of the design challenge will be explained.

The design challenge received on the beginning of the project:

01

"A creative maker-space for people on the autism spectrum, seeks design opportunities for supporting their clients in everyday independence. Specific themes to be further determined together with the participant, who, apart from being on the spectrum, is also a trained product designer."

When having contact with the contact person, it became clear we had to design something for a specific person. It was decided that we would visit the location as a group and make initial contact with our user to get a visual and better understanding of our project. From the results of the first introduction and problem definition the following design challenge is drawn up:

02

"We aim to help the user in her daily life by creating something that will decrease stress levels, considering the combination of autism and hearing impairment."

This design brief is developed further to make it more specific. It can change, because in the codesign session the possible design challenges became clearer. The co-designer namely experiences a lot of stimuli in public spaces. This causes two happenings that could be improved.
First, if a person passes someone the client in a public space, the person may seem to come out of nowhere for her. This causes the client to get scared.
Second, if the client has a conversation with someone in a space with a lot of noise, she can not understand the things that a person says. There are existing solutions for this. One solution is a mobile phone with a microphone that hears the person talk and transforms this into text. This solution the client does not like because she can then not talk with someone while looking them in the eyes. Another already existing solution which does not have this problem is the google glasses, but the client says she will not wear this because it looks weird. The new design brief, therefore, will become:

03

"We want to make the communication between the caretaker and the outside world easier."

After presenting 9 concepts to our client, she showed the most appreciation for 3 concepts; A device that translates conversation in braille, A bracelet that vibrates at different places to clarify which consonants are used and the third concept is a device that vibrates in the direction the sounds comes from. From this information we defined the following design challenge:

04

"We want to make it easier for the caretaker to process sounds (traffic, conversation or other) that are present around her."

During the research, we found that our user's stress level rises during the day due to the sum of stimuli that she experiences. This is due to her being both autistic and having a hearing impairment. Considering the previous design challenges and further co-design challenges, the following, final, design challenge is formulated:

05

"We aim to decrease the stress levels, not by taking away the stimuli, but by making clear where they come from and what they mean."

A solution to this design challenge both offers a lower stress level as a boost of confidence. When our co-designer will be able to handle more stimuli, her self-confidence will rise, and she will probably be less scared to go to public places. The product will take away the need for an adapted environment. The requirements should provide a basis to the solution for this challenge.

2.5 Co-design results

During the product we had 3 co-design sessions. More sessions were planned but due to the corona virus these were cancelled. The first two sessions will fall into the analysis phase. The first session was an introduction and first acquaintance, we were able to see the organization and get to know our co-designer. The second session was based on defining the problem with the help some co-design techniques. Next, some ideation was done and in co-design session 3 these ideas were presented to and ranked by the co-designer. More about the ideas and results can be found in chapter 3 and 4. Below, the main findings of the codesign sessions are listed. A full explanation of the findings in the sessions can be found in appendix (chapter 8.3).

Session 1: Introduction & First acquaintance

Lonneke has her own office at Assortimens (a workspace for people on the autism spectrum). Next to her autism she has a hearing impairment.

We received a general list of the daytime activities of Lonneke:

- Arrival at AssortiMens during the morning
- Edwin (supervisor) or one of the other supervisors give an assignment (design or programming)
- Back home around 3 p.m. too many incentives for the day
- Continue drawing / programming, cooking etc. at home

She tells us that the choice of working at home or at AssortiMens is difficult to make. People are unpredictable and 'scary'. Especially travelling is very stressful. However, she likes the challenges at Assortimens.

A lot of products which are made for people with hearing disabilities are very annoying and have a lot of stimuli which will interfere with her autism.

Session 2: Define problem(s)

We find out some problems Lonneke encounters in daily life. After this, we did an emotional mapping of her day. This graph is shown below. The ability to handle the stimuli are represented by the blue line. The values are added together. Later in the day, the incentives become more and more annoying and tiresome. The Yellow line shows the amount of energy is costs or gives her. When the line goes up it, the activity gives her positive energy. When it goes down, is costs energy.

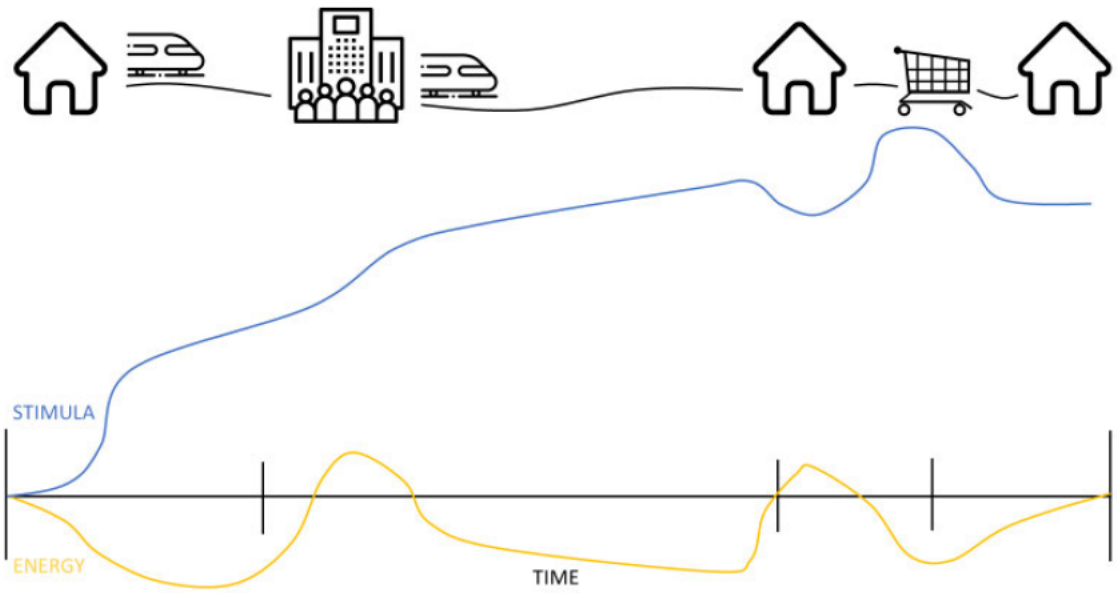


FIGURE 4 – emotional journey

Next, we did some stakeholder mapping. The distance between "I" and the stakeholders stands for how close (psychologically) the people / dog stand to her. The blue notes between them can be a block or a connection. When the lines are perpendicular between the circles, the impairment (written on the block) interferes with the relationship; when the notes are placed the other way around, the limitation on the note is the connection itself (e.g. the connection I-therapist). The impairment is the reason of this connection. She experiences no restrictions or connections between I-friends and I-bailey regarding restrictions.

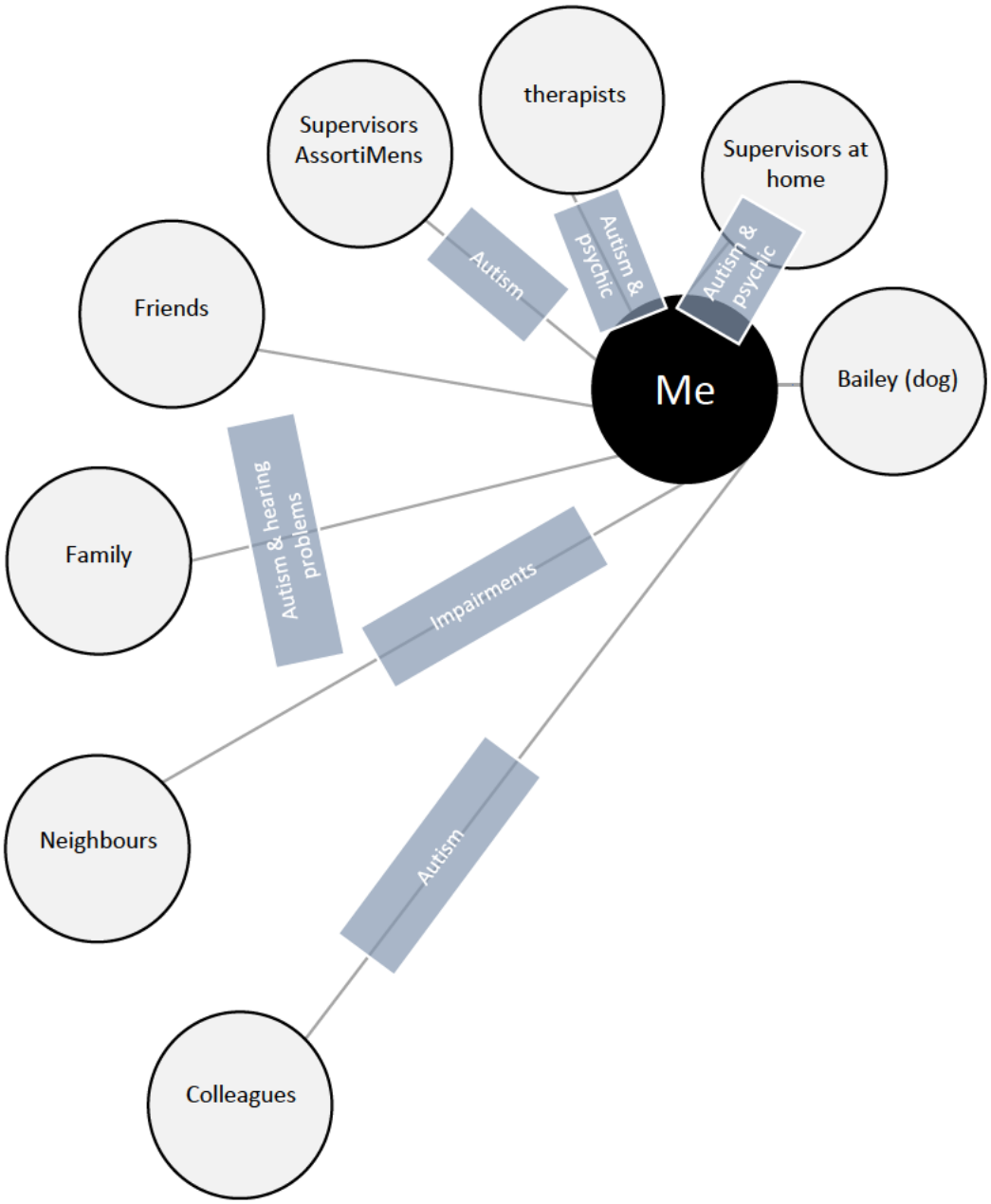


FIGURE 5 – stakeholder mapping

2.6 Requirement specification

The requirement specification is altered during the project. Below, the final requirements are listed. The general requirements set up at the beginning of the project can be found in the appendix (chapter 8.4.1).

1. User requirements

1. The product should stay in position – no rotation*
2. The product should be easy to attach and detach
3. The product should not distract the people/service dog around
4. The product should be unisex*
5. The product should give feedback to the user of the current mode*
6. The product should be comfortable to wear
7. The product should not be noticeable as a helping device, to people around*
8. The user should be able to turn the device on and off
9. The user should be able to change the mode

2. Technical requirements

1. The product should identify the presence of sound
2. The product should identify the direction of the sound
3. The product should be able to operate 12 hours without charging
4. The product should have different modes for different environments*
5. The product should give feedback to the user with a maximum delay of 1 second*
6. The product should have a minimum *Ingress protection rating* (IP-code) of IP56*
7. When a constant sound is around, the product should only give a notification on the beginning of the sound*
8. The product should be able to detect a sound of 80 dB on a distance of 15 meters*

3. Safety requirements

1. Vibrations must be endurable for a long time*
2. The product must not cause choking hazards
3. The product must not have sharp edges
4. The product must not be made from a material that is poisoned or can cause potential allergic reactions*
5. Looking at the iso[1] the product must comply with:
    1. general product safety - applicable to all products *
    2. Chemicals - as the product is usually worn on the skin, the use of hazardous chemicals is restricted
    3. CITES - applicable to a product made from wild plants and animals(Doesn't apply)
    4. Hallmarks – applicable to golden end silver jewellery in some countries (Doesn't apply)

4. Size and weight requirements

1. The product should have a maximum weight of 60 Grams*
2. The product should fit 95% of all users*

5. Wishes

1. The application will give a notification when it notices another environment
2. The product has extra features to make it less noticeable for people around
3. The product should have a battery life of 30-40 hours
4. The product should add as few extra incentives as possible
5. The application will have a mode which anticipates on the environment it is in

*** Elaboration on the Requirements**

Requirements with a * behind it might need some extra explanation and will be elaborated here:

1	User Requirements
1.1	The product should stay in position – no rotation
	When measuring the direction of the sound, the product should stay in the same position to prevent confusion. Next to this, the product should stay located around the neck.
1.4	The product should be unisex
	To make the product attractive for all users, it should be suitable for both male and female
1.5	The product should give feedback to the user of the current mode
	Humans have limited working memory and systems have space and design limitations. The setting of mode is easily forgot which can easily b mistakes.[2] With enough feedback on the current mode, this problem can be helped.
1.7	The product should not be noticeable as a helping device, to people around
	When the product is too visible, it will be stigmatising. Especially for our co-designer, this is an important aspect. Wearing the product, it should not be clear that it is a helping device.

2	Technical Requirements
2.4	The product should have different modes for different environments
	The volumes and distances in different environments change a lot. With different modes, these differences can be included in the software.
2.5	The product should give feedback to the user with a maximum delay of 1 second.
	When we spot or hear something important, we recognise it between 0.15 & 0.45 sec.[2] People with hearing impairments will not have this recognition. To keep it into the range of people with full hearing capabilities, the response time of the device should not be more than twice this time.
2.6	The product should have a minimum Ingress protection rating (IP-code) of IP56
	The product will be worn the whole day, also outside. This means it has to have a level of dust-tightness and water resistance. This is quantified by a so-called Ingress Protection rating. The IP rating measures how well a device is protected of liquids, as well as solid objects. It consists of two numbers: IP_{12}. The first number stands for the protection to solid objects, the second number for the protection to liquids. For the chosen number in this requirement specification this means: **$IP5_X$**: Dust resistant. Some dust may get through, but it won't be enough to damage the product. **IP_X6**: Can resist high-pressure, heavy sprays of water.[3] So the final product should have a minimal object-protection rate of 5 and a minimal water-resistance rate of 6.

2.7	When a constant sound is around, the product should only give a notification on the beginning of the sound
	To prevent a constant vibration caused by a constant sound, a notification of the beginning of this sound should be enough to notify the user. Now, the user will not be bothered with a constant vibration but will be notified to the present and direction of the noise.
2.8	The product should be able to detect a sound of 80 dB on a distance of 15 meters
	The product should be able to detect someone shouting (e.g.) a name on a distance of approximately 15 meters. The average of a screaming baby is 80 dB.

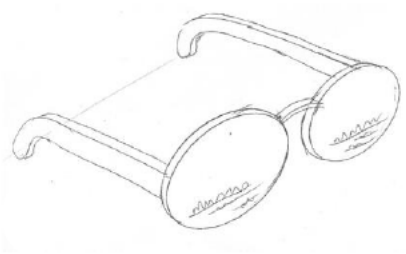
3	Safety Requirements
3	The product must comply with general product safety
	The product shouldn't cause choking hazards or cut the user with sharp edges. The General Product Safety Directive states that all products marketed in the EU must be safe to use and forms a framework for all specific legislation established for specific products and issues
3.1	Vibrations must be endurable for a long time
	Since the product will expose the user to frequent vibrations we need to make sure that this will not harm the user. The product in question is the sound around, a product worn around the neck. We must therefore look into the effects of repeated vibrations on the neck. considering health risks mostly occurs on higher levels of vibrations over the whole body like driving a mining truck[4], given that we only use relatively small vibrations on only the neck it is safe to say that the user of our product won't be risking big health problems by using it.
3.4	The product must not be made from material that is poisons or can cause potential allergic reactions
	As the product is usually worn on the skin, the use of hazardous chemicals[5] is restricted

4	Size and weight Requirements
4.1	The product should have a maximum weight of 60 Grams.
	The 60 grams is derived of the weight of Bluetooth earbuds (with a neckband).[6] This average is around 40-60 grams. The product will have to be in the same range, to prevent pain in the neck and back.
4.2	The product should fit 95% of all users
	95% is the number taken in the design booklet of Introduction to ID: "Product Design" by Arthur Eger.[7] Most products should at least be suitable for 95% of the target group.

3 IDEATION

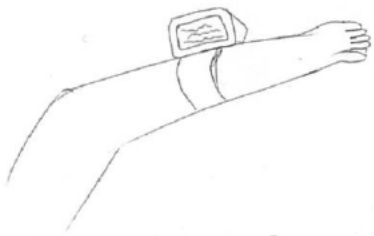
The ideation phase has begun. Based on the design challenge, nine ideas have been generated. This design challenge has been based on the challenges the codesign user encounters. The nine ideas are shown below. The codesign user has given feedback on these ideas and in the end, three concepts will come out of these ideas. The codesign session is described more detailed at Appendix 8.3.3. .

1



This idea is similar to google glasses. This puts text on the screen of the glasses. This will make the conversation easier to understand for the co-designer, while looking the person with whom she is talking in the eyes. The downside is that the co-designer has said she will not use this, however it is a useful design. It only will look too weird according to her.

2



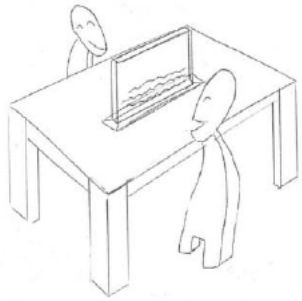
This idea is that the text somebody says (with whom the co-designer is talking) is shown on a screen on her wrist. She does not like this idea, because she then has to look away from the conversation. She wants to look at the person with whom she is talking in the eyes.

3

The idea of the frequency of the speaker changing into a lower frequency is this one. It is based on the thought that the co-designer said she liked low frequency music. This idea however does not work for her, because she does not want the sound coming in to change.

FIGURE 6a,b,c,d,e,f – ideation ideas

4

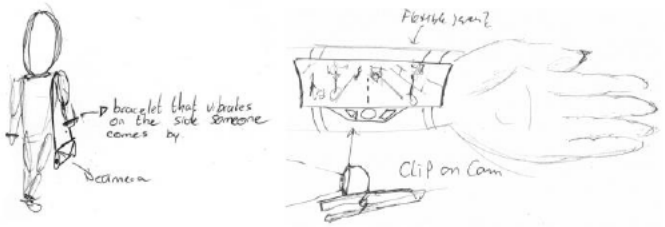


This idea is to make understanding a conversation easier for the co-designer. This will be done by putting the words of the person to whom she is talking in text. This text will be displayed on a screen of glass, therefore she can still look the person to whom she is talking in the eyes. She only said that this design looks too weird and will attract the attention of people.

5

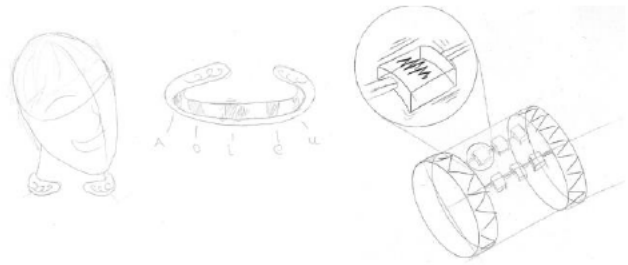
This idea is for in the traffic. The co-designer gets scared if somebody passes her without her knowing beforehand. This idea contains a screen on top of her dog which shows what and if something will pass her in the near future. The co-designer thought this idea was too far away from her to be practical.

6



This idea is to make the co-designer more comfortable in the traffic. In traffic she gets scared because of people passing her in traffic. This idea can take away this scare by letting the co-designer see what is behind her. The problem she has with this idea is that she does not want to use a camera. Then, this idea can also be done with a scanner.

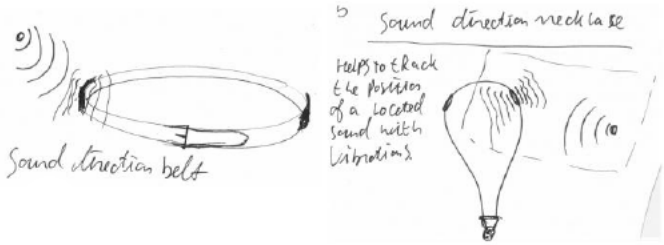
7



The next idea, is to make it easier for the co-designer to understand and follow a conversation. She can already read the lips of the other person with whom she is talking. Sometimes it is hard for the co-designer to see the difference between certain sounds the other person makes. To make it easier for her to follow the conversation, there is this following idea. The sounds that look like each other when lip reading it, are on a bracelet or necklace and if this sound is made, the bracelet or necklace vibrates on a certain spot. This will make lip reading a lot easier for her. The co-designer said some of the consonants are the hardest to separate from each other.

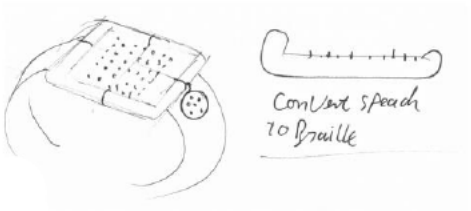
FIGURE64g,h,i – ideation ideas

8



The next idea is to make the co-designer less stressed in both traffic and within conversations. The idea is that she has a necklace of belt that can vibrate at certain spots. A certain spot vibrates if sound is coming from this direction. This will make it easier for her to know where the sound is coming from. Due to her hearing impairment she can not hear where the sound comes from and this makes her stressed.

9



The next idea is designed to help the co-designer to understand the person with whom she is talking better. She already can lip read, but sometimes this is hard. Then there is this design that can convert the words the one with whom she is talking says, to braille. Therefore she has to learn braille. The idea was to make this in a watch, but the co-designer said it could also be a board in front of her where she can read braille from. This has a positive aspect that she can still look the person with whom she is talking in the eyes during the conversation.

FIGURE64g,h,i – ideation ideas

These ideas have been presented to the codesign user. She ranked all the concepts and explained why she ranked them like that. She explained what she did like and what she did not like. Everything about this session is explained in Appendix 8.3.3.

Out of this co-design session came that concepts 6, 7, 8 and 9 are the best once to further develop. The three concepts that are developed are based on these four ideas.

The ideas are:

-6: camera to show what is behind the user

-7: vibrating bracelet when a specific sound is made

-8: vibrating belt/ necklace to indicate where a sound is coming from

-9: braille watch

The choice has been made to let idea 6 of the camera go, because the codesign user told that she did not like the presence of a camera behind her.

4 CONCEPTS

4.1 Concept explanation

4.1.1 Concept 1: SoundAround

4.1.2 Concept 2: Vibracelet

4.1.3 Concept 3: Subfeel

4.2 Concept selection

4.1.1 Soundaround

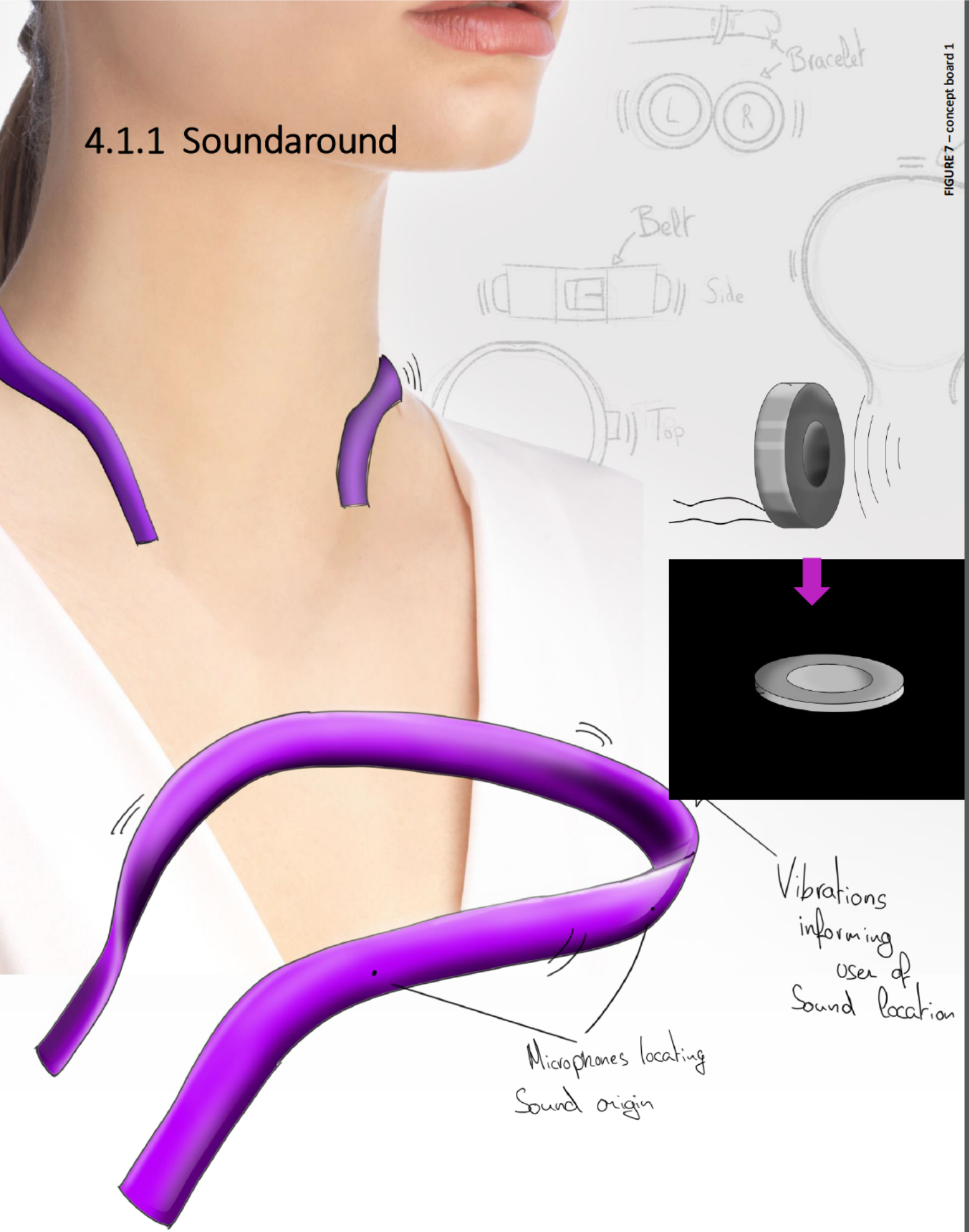
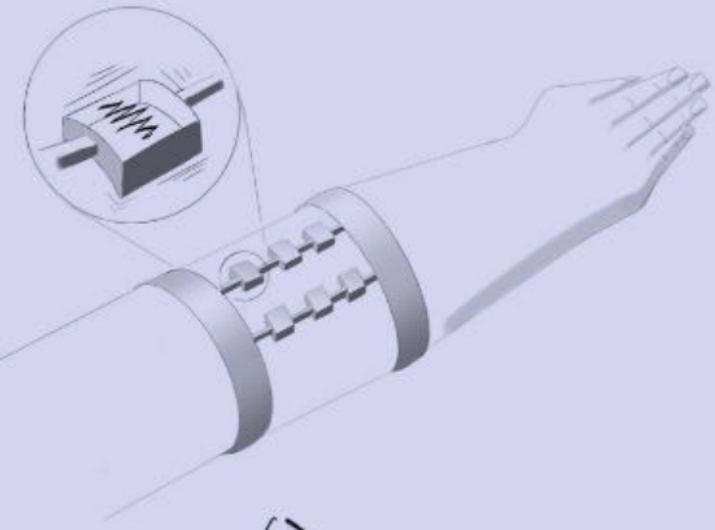


FIGURE 7 – concept board 1

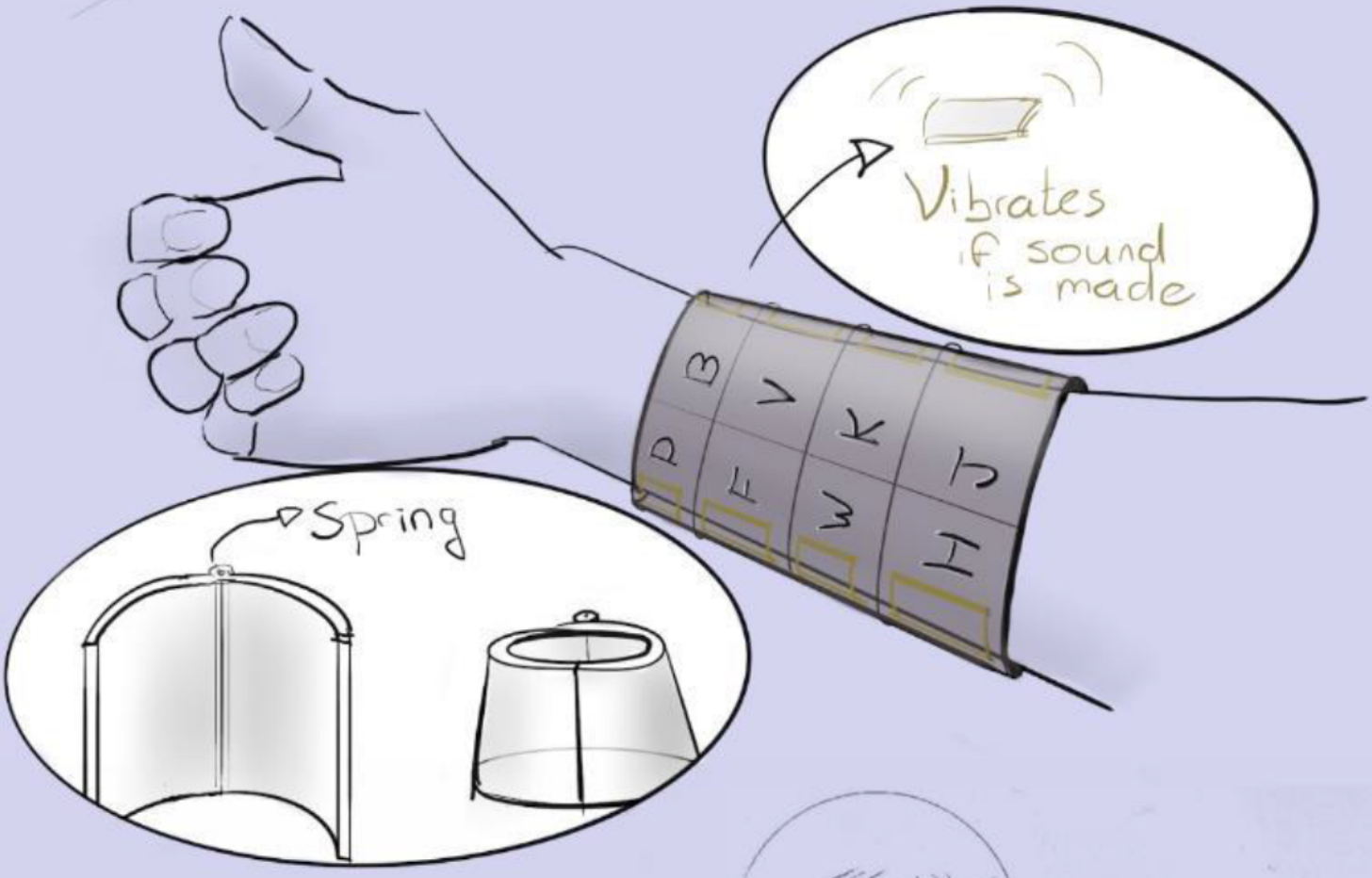
The co-designer has problems with locating the origin of sound in conversation and in traffic. This necklace will inform the user of the location of the sound by means of small vibrations of the corresponding direction. Microphones on the necklace will locate the sound-direction.

4.1.2 Vibracelet



Sometimes it is hard for the co-designer to lip read the difference between certain sounds the other person makes. To make it easier for her to follow the conversation, there is this following idea. The sounds that look like each other when lip-reading, are on a bracelet or necklace and if this sound is made, the bracelet or necklace vibrates on a certain spot. This will make lip reading a lot easier for her. The co-designer said some of the consonants are the hardest to separate from each other.

The sounds are made tangible by a few vibrating blocks. The syllables are the most difficult to differentiate from each other. This is because the syllables are very short. The syllables that are the most similar and therefore will be included in the design of the concept are: 'P', 'B', 'F', 'V', 'W', 'K', 'H' & 'J'. [8]



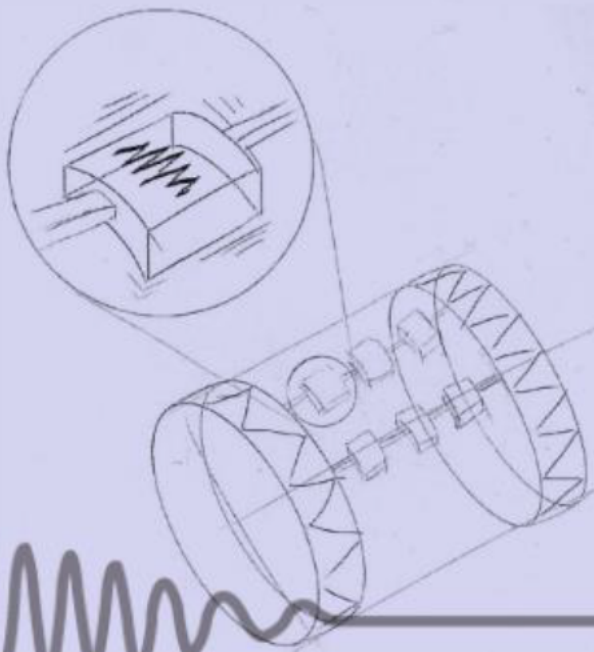


FIGURE 8 – concept board 2

4.1.3 Subfeel

In this concept, a device will provide subtitles to a conversation based on interactive braille. The interactive braille, which can be integrated in, for example, a watch, which will form the just-spoken words of the conversation.
If we will use 3 fingers to detect the letters, the letters (of the regular alphabet) should change every 0,3 seconds. Looking at the possibilities of the interactive braille "blocks", it might be useful to include quick script. This means that fewer characters are needed to give the subtitles to the conversation which will result in fewer changes of the braille characters (>0,3 sec).
In existing interactive braille devices, the movement of the balls will be based on piezoelectric elements or air pressure to push the ball up. The piezoelectric material can have a reaction time of a few microseconds. This means that it should be possible, if given a fast electric system, to have a character-change in the given time.

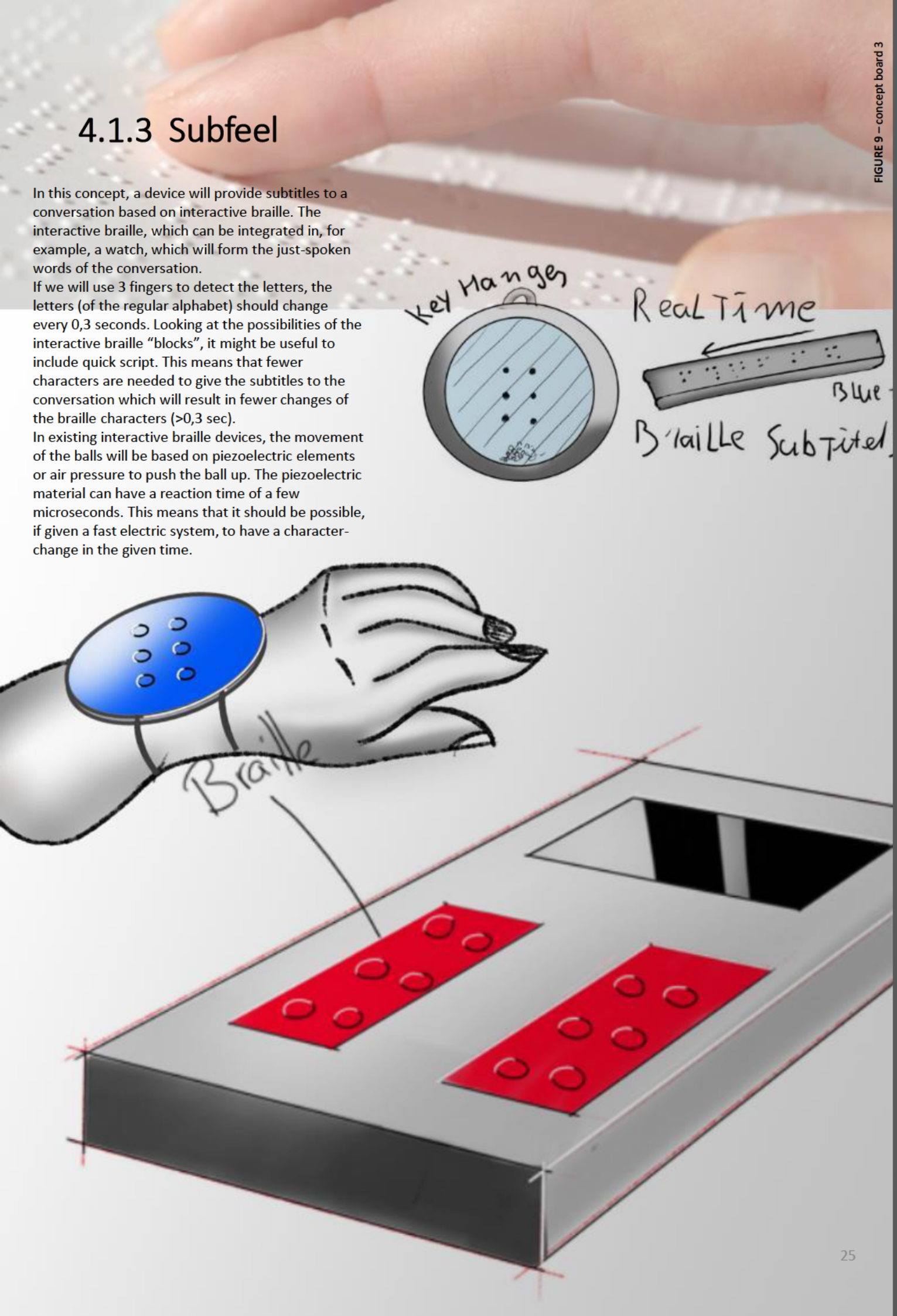


FIGURE 9 – concept board 3

4.2 Concept Selection

Rating:
To find the concept best suited for both our specific user and our design project, all three concepts were assessed on some key factors:

- Is our client willing to try the product?
- How feasible is the product concept?
- Is it possible to develop within this project span?
- How well does it solve our design challenge?

Design challenge:

"We aim to decrease the stress levels, not by taking away the stimuli, but by making clear where they come from and what they mean."

The concepts were on these points and this score was used to make an argumented concept choice. The concepts are rated one to five, one being not true five being true. We used this short-scale for it is hard to explain the difference between a nine and a ten on a ten-step scale, but easier to clarify the difference between a four and a five on a five-step scale as the difference is bigger.

Factor	SoundAround	Vibracelet	Subfeel
Is our client willing to try the product?*	**5**	3	4
How feasible is the product concept?	**4**	2	3
Is it possible to develop within the project span?	3	3	2
How well does it solve the design challenge?	3	3	**4**

* In order to find this out we asked this question to our client.

Requirements score
To get a better understanding of how well the concepts suit our goal, the three concepts are also evaluated against the basic requirements, which can be found in the appendix (chapter 8.4).

SoundAround
The concept of SoundAround overall met the basic requirements. The design is very concealed and due to its sportive looks also unisex. The main difficulties here are the data processing speed and the fact that it needs to fit 95% of our target group. Since this is a wearable it is very body-size dependent, which might cause issues.

Vibracelet
The concept of Vibracelet meets most of the requirements. It is definitively only communicating with the primary user and can be made unisex by making the wrist strap adjustable. The main downsides of this concept are data processing speed and the learning curve it requires before use.

Subfeel
the concept of Subfeel meets most of the requirements. It is solely communicating with the primary user and is definitively unisex. The main difficulties of Subfeel are data processing time, it can be distractive at first, and most of all the long learning curve to master the required braille reading speed.

Conclusion
The concept Soundaround overall scored the best in the first evaluation and matched our requirements the best. Since all the concepts had the data processing speed issue, the main issue of SoundAround would be to make it fit 95% of our target group, which seems possible to solve.
After discussing these outcomes with the client, the choice was made to indeed further develop the concept of SoundAround.

5 FINAL CONCEPT

5.1 Concept Development

The collage below is made by the codesign patient. In this collage she explained what her taste is. So what she finds attractive. This collage has been used to make the product in this style. This is done to make the product fit her taste. Her personal taste is not very useful to use, as the product should be used by people with not only the same taste as hers. However, the collage below shows things that the codesign user would wear and therefore products that are not very noticeable but modern. That is exactly the style that needs to be used. Also, most of the products below are unisex, which the final design also needs to be.
This collage reflects sportive, black, shinny, rounded, bright colours, rubberish material. It is also a combination of geometric rounded forms and organic forms, for example the knots.

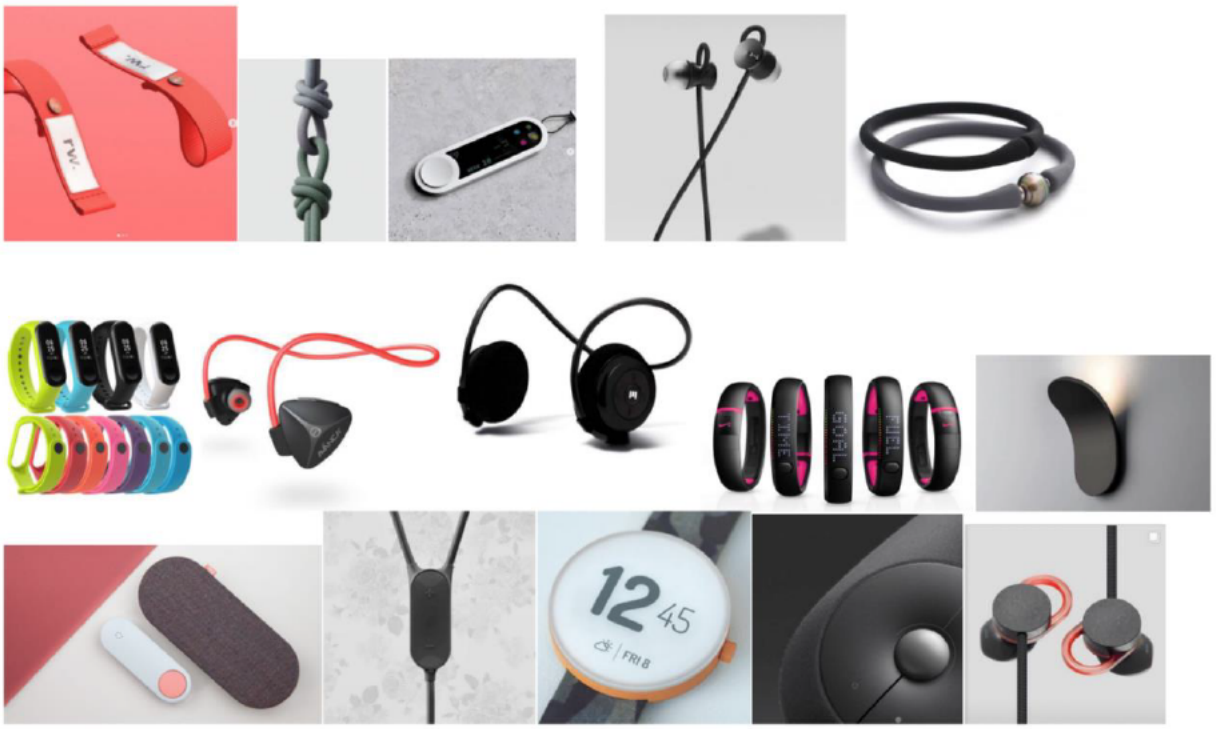


FIGURE 10 – style collage co-designer

This is used in the concept development. The main colour of the SoundAround goes from purple to black. There are some details added in the form of bright colours. Everything is again rounded of.

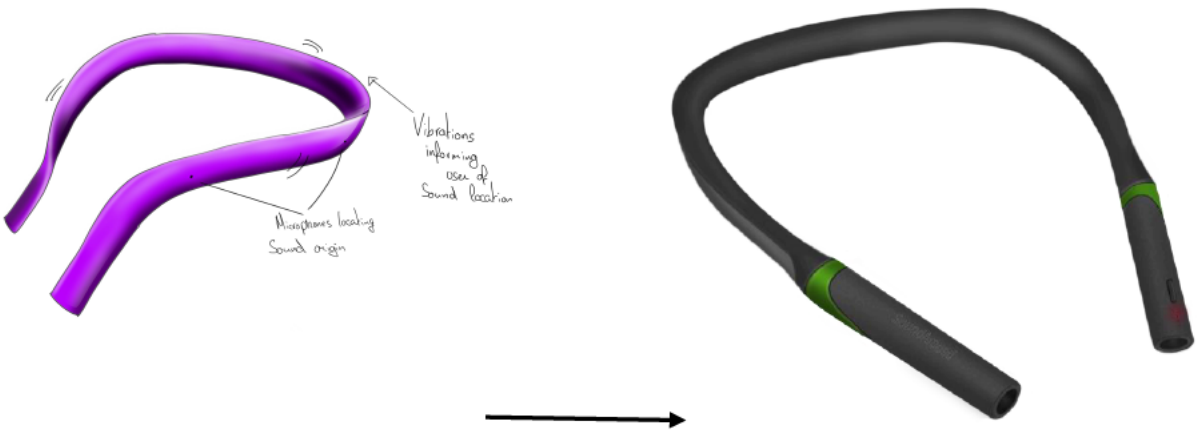


FIGURE 11a,b – concept development

Below is a drawing of the main places we thought of to wear the product, each having its benefits and disadvantages briefly discussed below.[9]

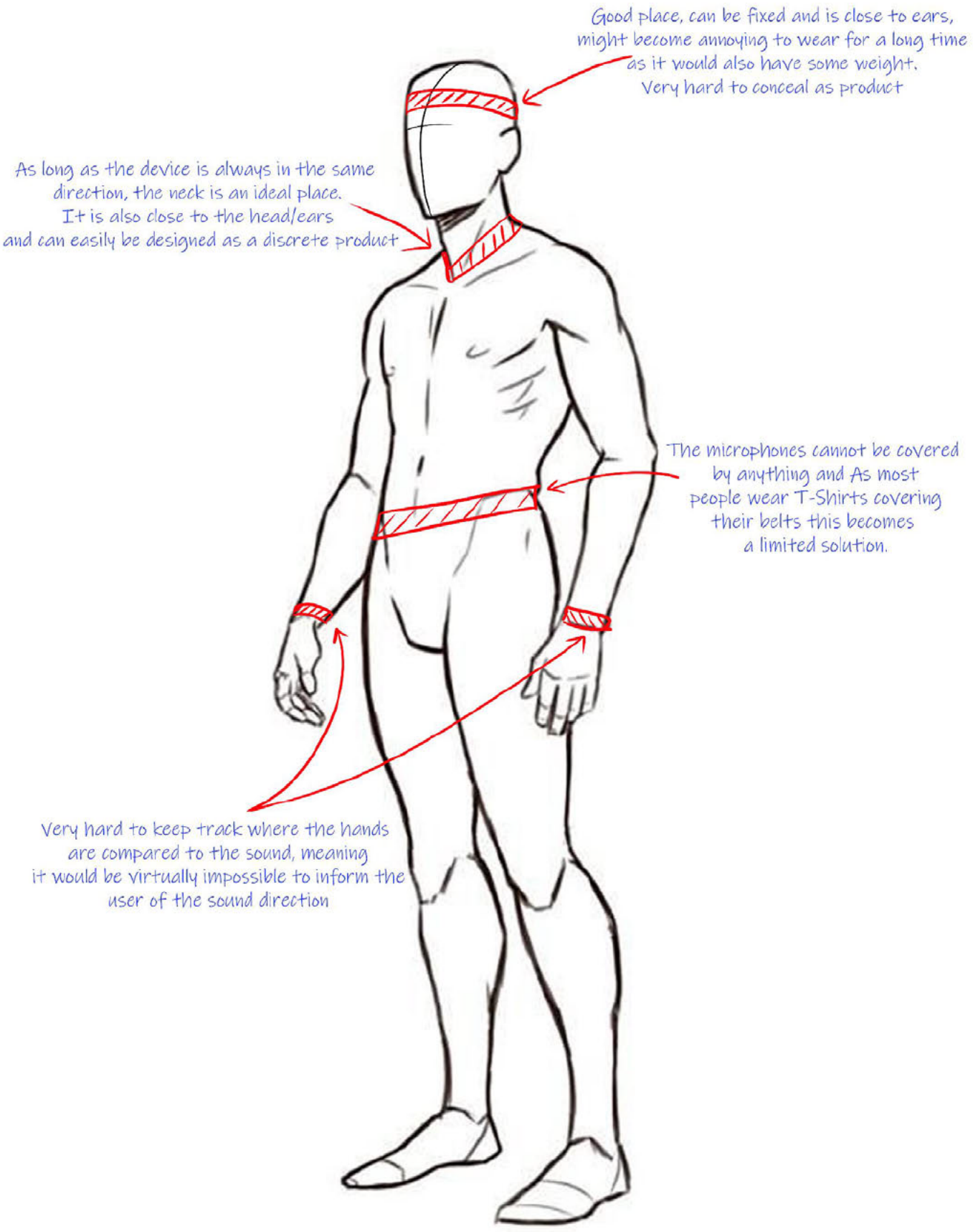


FIGURE 12 – location analysis

Human body drawing reference from: http://getdrawings.com/human-body-drawing-reference#human-body-drawing-reference-64.jpg

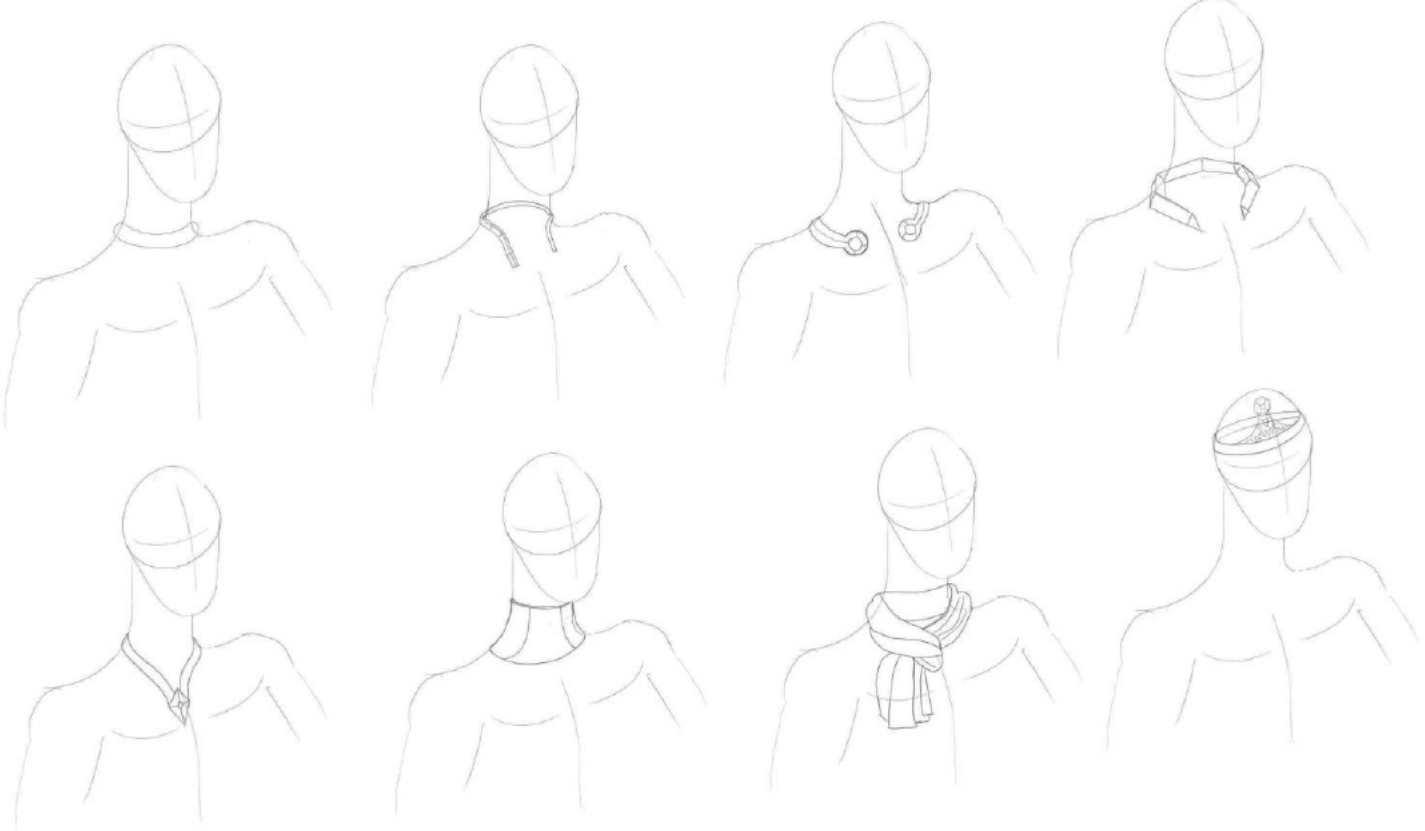


FIGURE 13 – location ideation

After having chosen to develop the first concept of the SoundAround into a final product, some ideation on the shape was needed. Different options of neck accessories were explored as were different styles. Eventually, the decision was made that the shape would resemble that of Bluetooth earbuds. Due to it being unisex and fitting to many style preferences of different people. Besides shape ideation, the vibrations that would be used were also researched. This can be found below.

FIGURE 14 – development ideation

Vibrations

We can either opt for a vibration or a gentle tap that indicates where the sound is located to the user.
The intensity of this indication is dependent on the location of the device. We thought of it being a necklace, a belt or a strap around the chest/waist, much like a bra strap. It is easy to see that the indication can be gentler in the neck than in the waist or chest since that area is more sensitive.
Vibrations could be actuated by using coin vibration motors inside the band. If we opt for the tap, then this can be caused by little linear actuators inside the band.
Moreover, if we choose to use vibration, tests should be conducted in which vibration is used. For instance, one could suffice, or it might become clear that more vibrations in a sequence are better.

5.2 Storyboards

Storyboards can be used to get a better idea of how a product works. And to better get this idea across to other people
A storyboard can help visually predict and explore the user experience with a product. It visualizes how people would interact with a service or app. Therefore we made several storyboards of different scenarios to get the most out of this part of the design process.

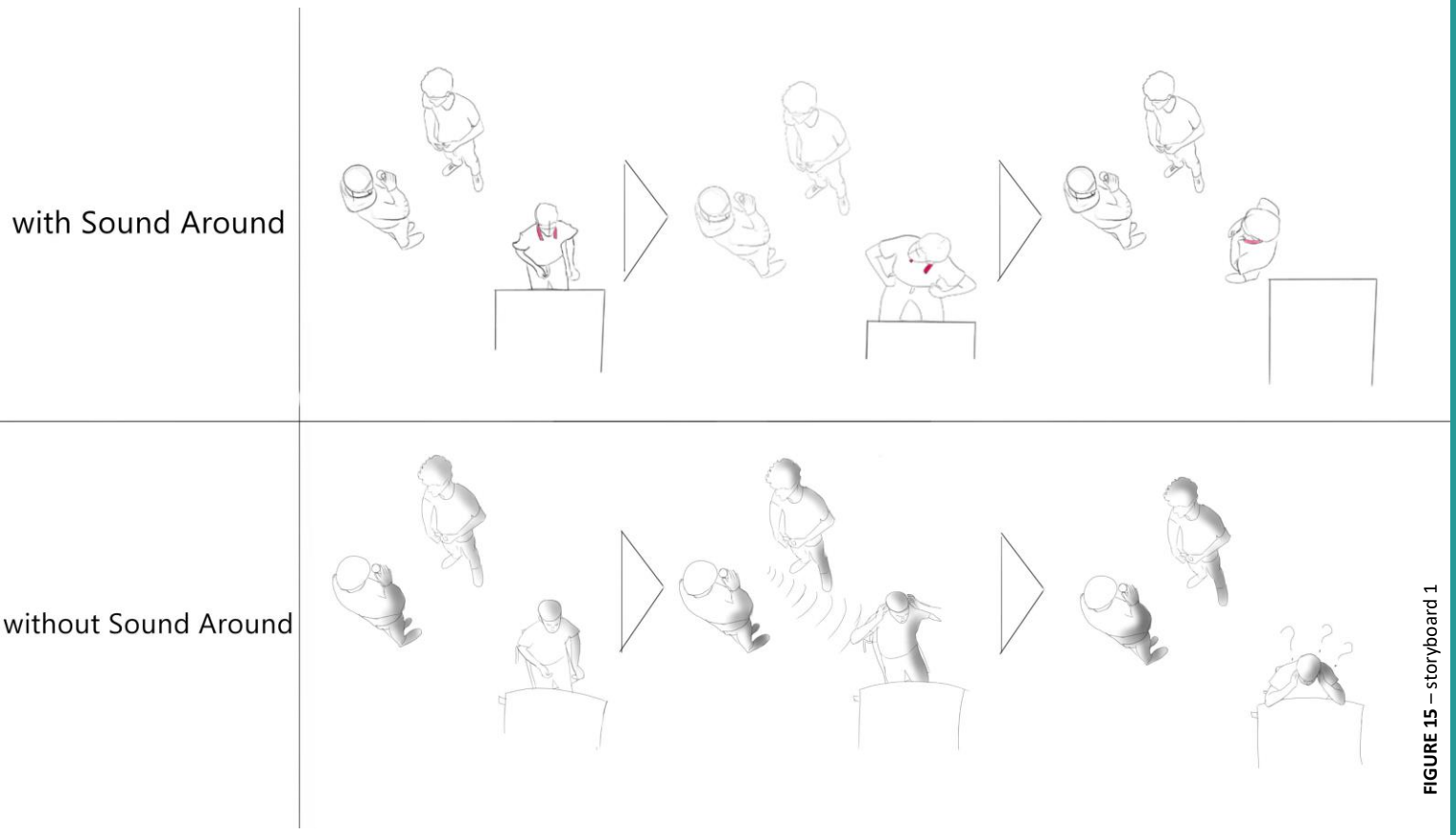


FIGURE 15 – storyboard 1

In this storyboard, two scenarios can be seen. One scenario with the product and one without it. here it becomes clear in what way the Sound Around can be of use. If used properly the Sound Around can help the user identify what is happening around him/her and act accordingly as shown in the top storyboard. Without Sound Around the user can get overwhelmed by the impulses of what is happening around him/her and could result in confusion or anxiety, as shown in the bottom storyboard.

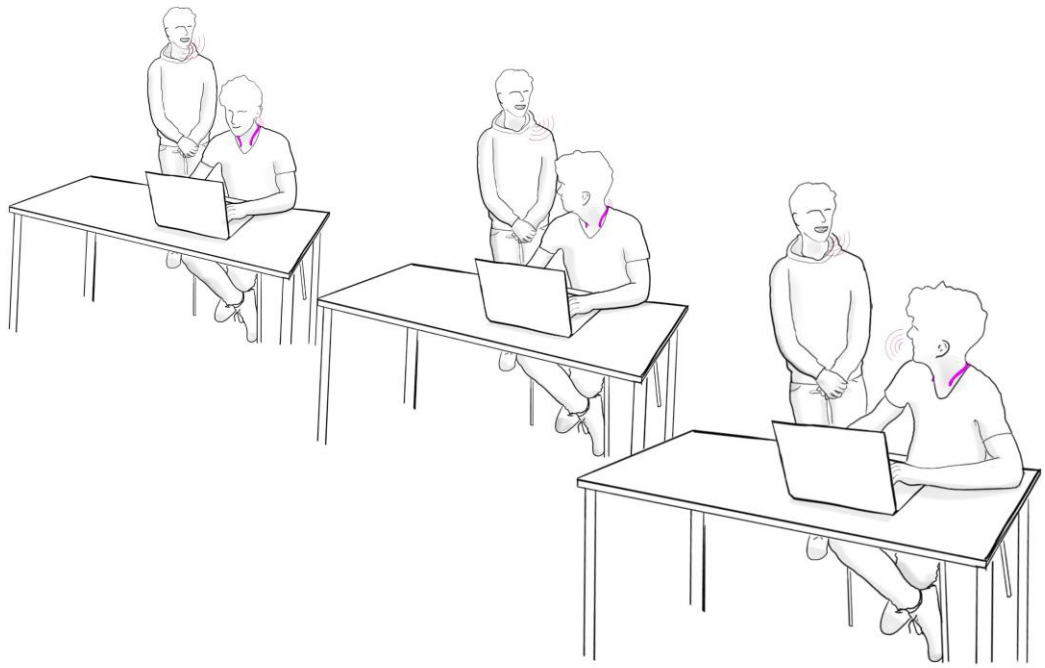


FIGURE 16– storyboard 2

This storyboard shows how the user can notice that someone is approaching, and from which direction, with the help of the Sound Around. With this information, the user can act on this in a normal manner

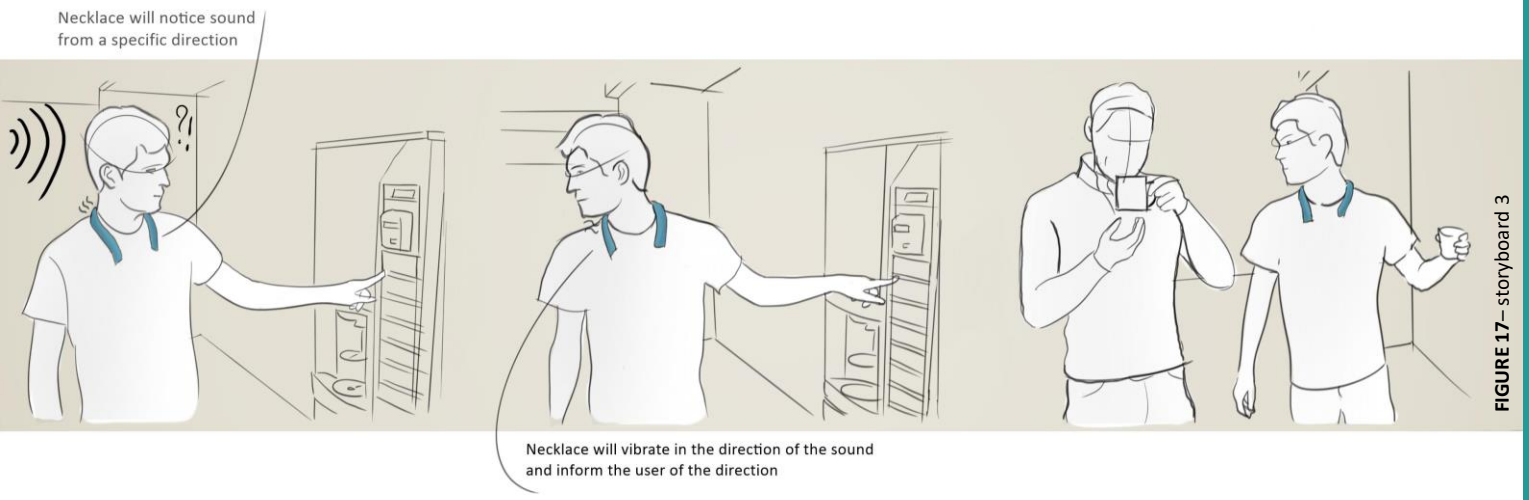


FIGURE 17– storyboard 3

This storyboard is another showcase of how the Sound Around can help the user indicate where a sound is coming from. It shows that the user, with the help of the product, can respond more easily even when focused on something else like getting coffee.

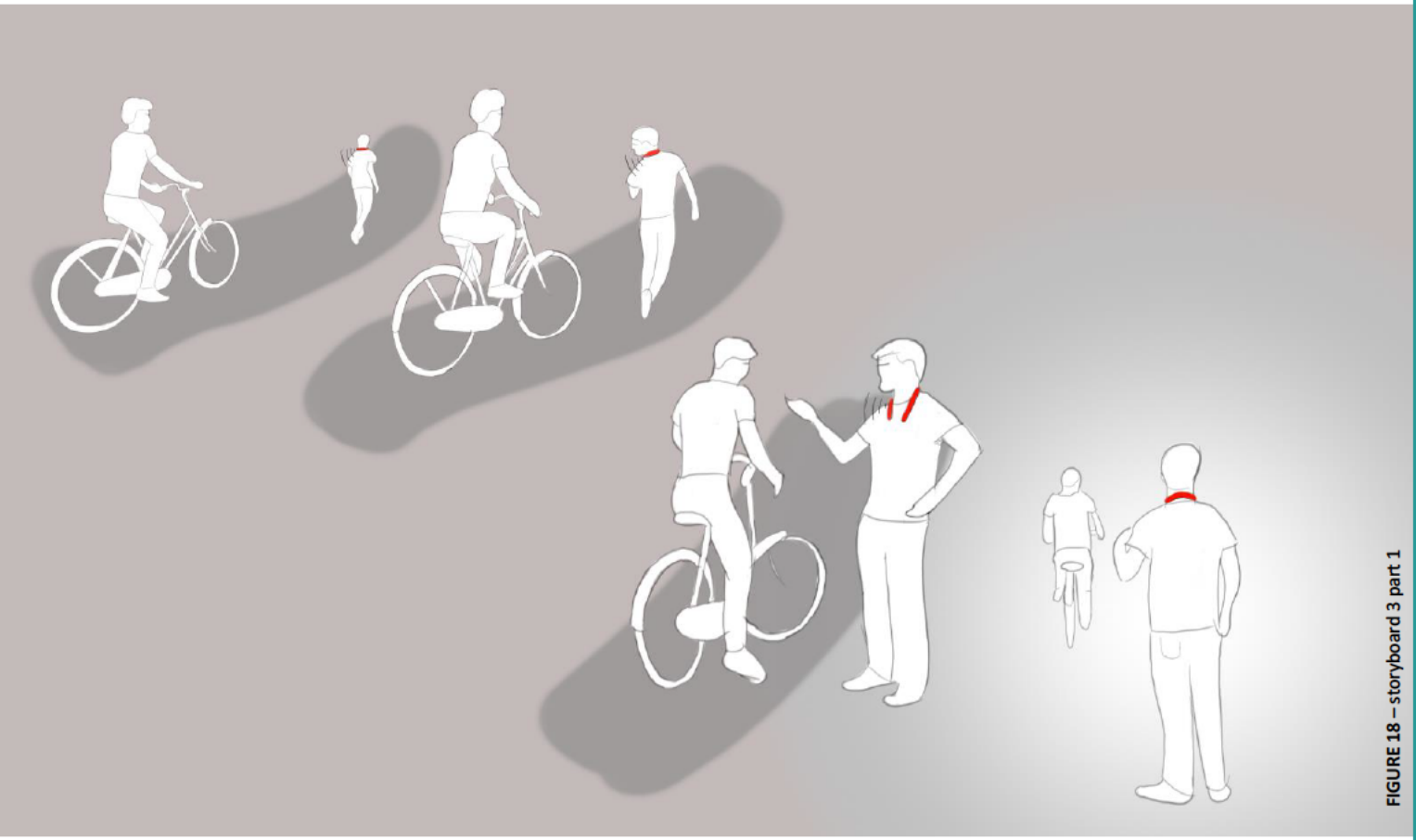


FIGURE 18 – storyboard 3 part 1

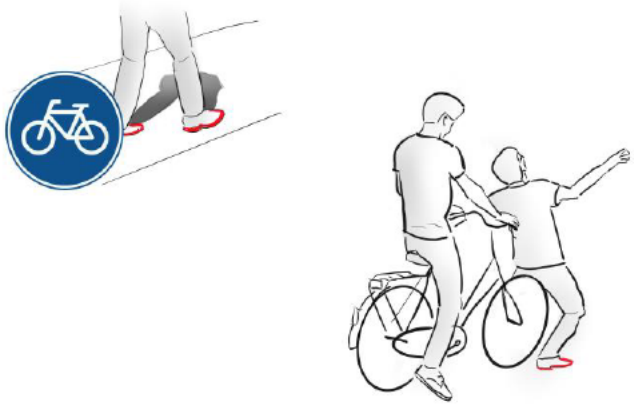


FIGURE 19 – storyboard 3 part 2

Here, two storyboards are used again to show how the use of the Sound Around can influence the user in traffic. The top storyboard shows the scenario with the Sound Around in use. Here the user gets notified by the Sound Around that a biker is approaching from the back. Now knowing where the sound is coming from, they can step out of the way and prevent a collision. In the storyboard below the user didn't have the support of Sound Around which resulted in an accident.

5.3 Final Product

people with hearing impairment, detect the origin of a sound. It
the sounds around them by giving off small vibrations. In order to feel these
product is worn around the neck, like a set of wireless earbuds.

he implementation of three little microphones positioned around
educe its origin by looking at the time difference
origin of the sound, the product will
notifying the user where a
used to change the
different
or
th

n
can

The concep
The user in thi
impairment, also
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h the co-design sess
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wing what she is hear
g a necklace that indi
might take some of that
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ing as she knows it might vib
She argued that the necklace
l the same. The benefit of
inion far outweighs the

oal is to give off one
ferent modes
be limited

SoundAround

The User

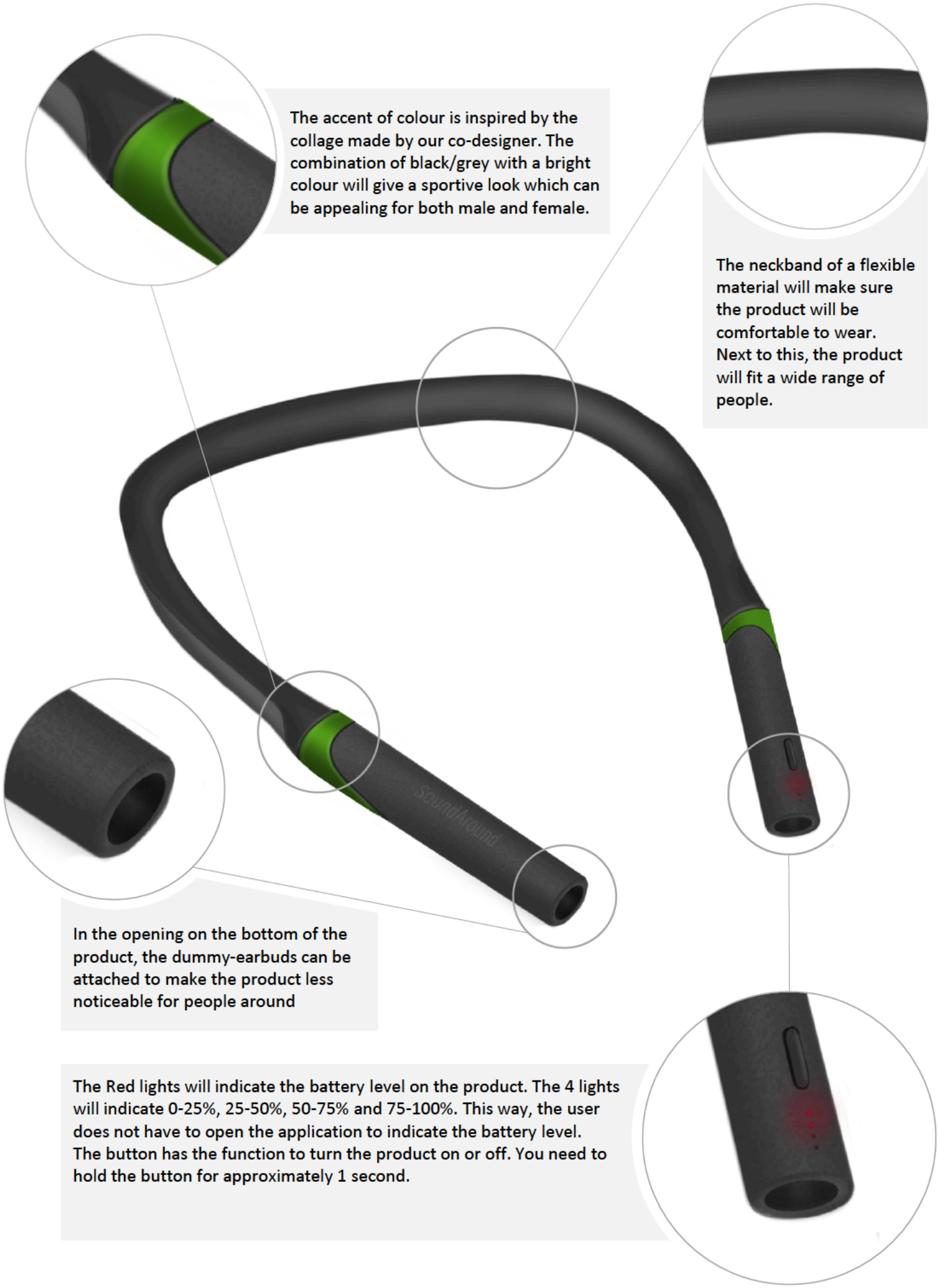
The goal of this project is to design a product that solves a problem a specific user has.
In our case, the specific user is someone who has a hearing impairment and is on the autism spectrum as can be found in the PACA research.

The problem this product solves is the inability to point out the origin of a sound since the hearing aids just amplify any sound and not denote its direction. During the design of the SoundAround, we mainly focused on solving this problem, but also on the product being suitable for people on the autism spectrum.

However, the target audience of this product, if brought on the market, is people with a hearing impairment who have difficulty with pinpointing the direction and origin of a sound.

The accent of colour is inspired by the collage made by our co-designer. The combination of black/grey with a bright colour will give a sportive look which can be appealing for both male and female.

The neckband of a flexible material will make sure the product will be comfortable to wear. Next to this, the product will fit a wide range of people.



In the opening on the bottom of the product, the dummy-earbuds can be attached to make the product less noticeable for people around

The Red lights will indicate the battery level on the product. The 4 lights will indicate 0-25%, 25-50%, 50-75% and 75-100%. This way, the user does not have to open the application to indicate the battery level. The button has the function to turn the product on or off. You need to hold the button for approximately 1 second.

FIGURE 21 – Features SoundAround

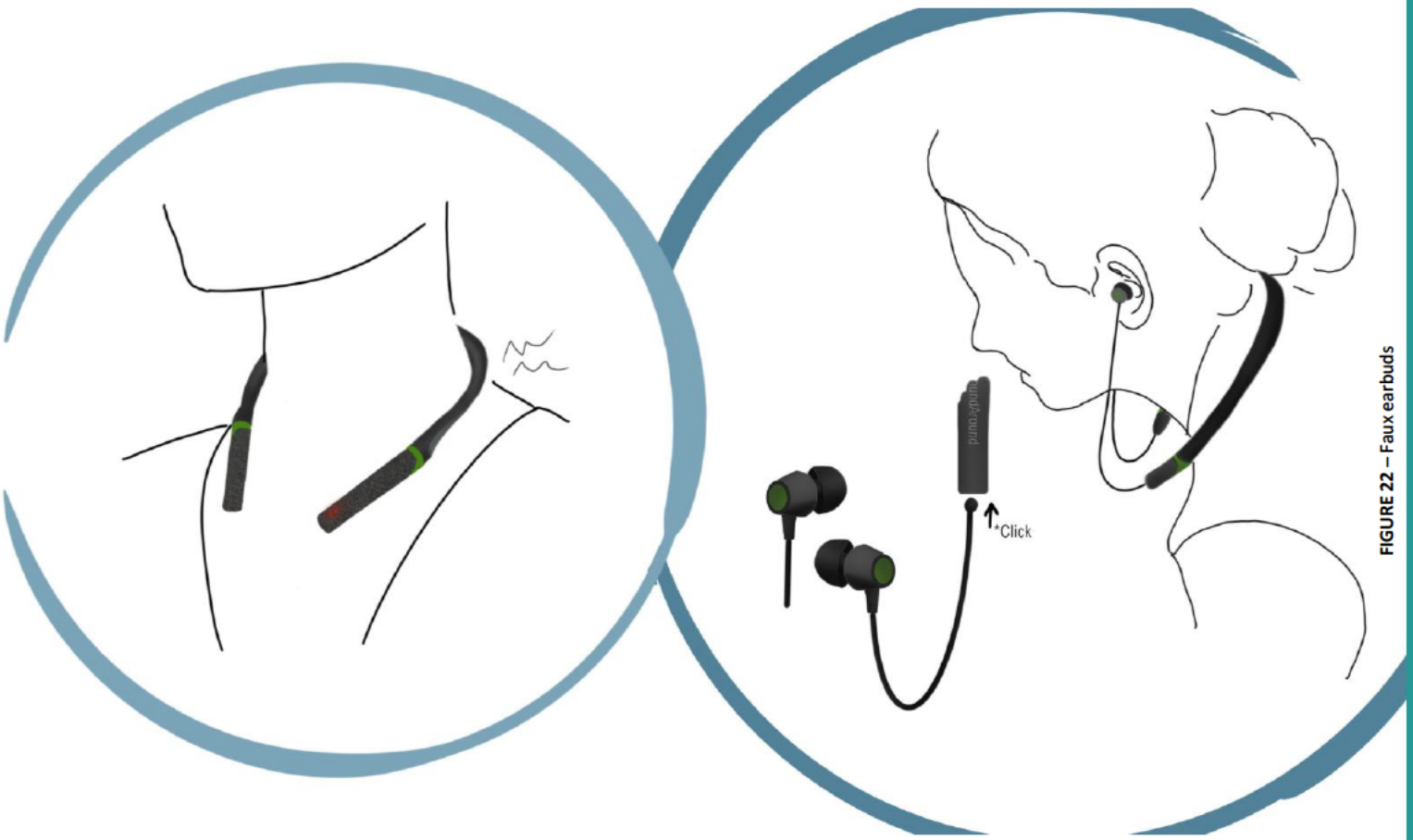


FIGURE 22 – Faux earbuds

In the design of the SoundAround, it was decided to add the option of clicking in faux earbuds that make the product look like Bluetooth earbuds.

This decision has been made due to a remark that our specific user made, namely she indicated that she would feel uncomfortable wearing something that looked out of place and that made it clear to other people that she had an impairment that the product helped her with.

Research shows that a person's appearance indeed influences the perception of people. It also shows that many people do not notice slight changes in appearance right away. Thus we reckon that adding the earbuds will ease the user into wearing the product with confidence. When the user is confident with wearing it, the earbuds could be removed, if that is desired.

The reason the product does not function as headphones as well is quite simple. The target users of this product all have a hearing impairment. They would not need headphones since then they will not be able to hear any sounds, thus making the product unnecessary and the surroundings even more confusing and inexplicable.

5.4 Application

To change the settings, like the mode and intensity, the SoundAround is connected to an application for a mobile phone. In this chapter a walk through this application can be found, including the functions and options. The application can be opened with this link. The evaluation of the application design can be found in the appendix (chapter 8.5).

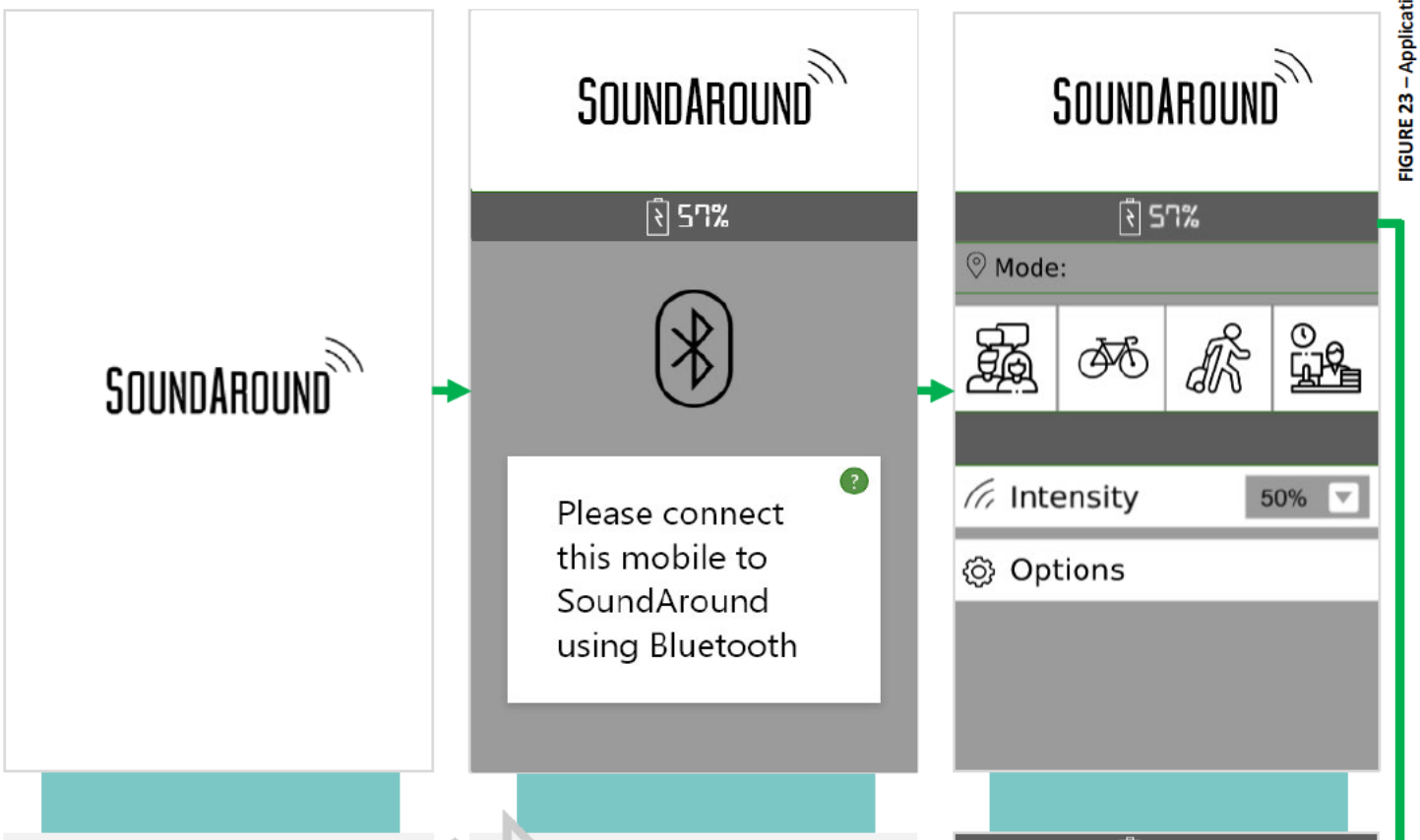


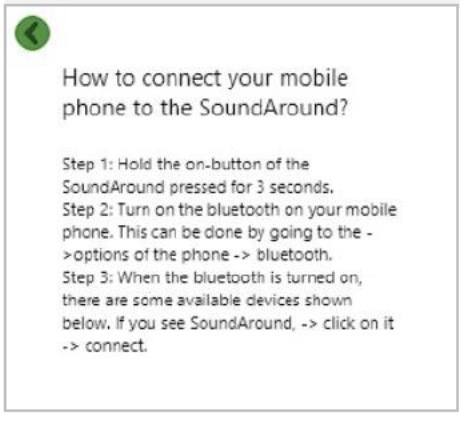
FIGURE 23 – Application walkthrough part 1

START-UP

When the application is loading and started up, this flush screen will be shown. If the product is not yet connected to the mobile phone, the connection page will appear. Other ways the general screen will already be shown.

CONNECTION

After the flush screen, a connection screen will be shown. This screen allows you to connect your device to the Bluetooth of your mobile phone. After connection, the general screen will appear (as shown on the right). When clicking on the question mark, the following message will appear:



BATTERY

The battery level is shown in the app as well as in the general system of the mobile phone where the application is installed. The battery The mobile phone has, next to the battery icon of its battery, a symbol to indicate the battery level of the SoundAround. This icon will be the icon as shown below. The Bluetooth logo will make the two symbols easy to distinguish. This battery level will only be shown if the Sound-Around is connected.

Different modes can be chosen. The selected modes will give feedback of its activation like shown on the right (the icon will light up and the type of mode is shown in text). There are 4 modes: Conversation, cycling and traffic, walking and office. These modes are further explained in chapter 5.5 on the next page.

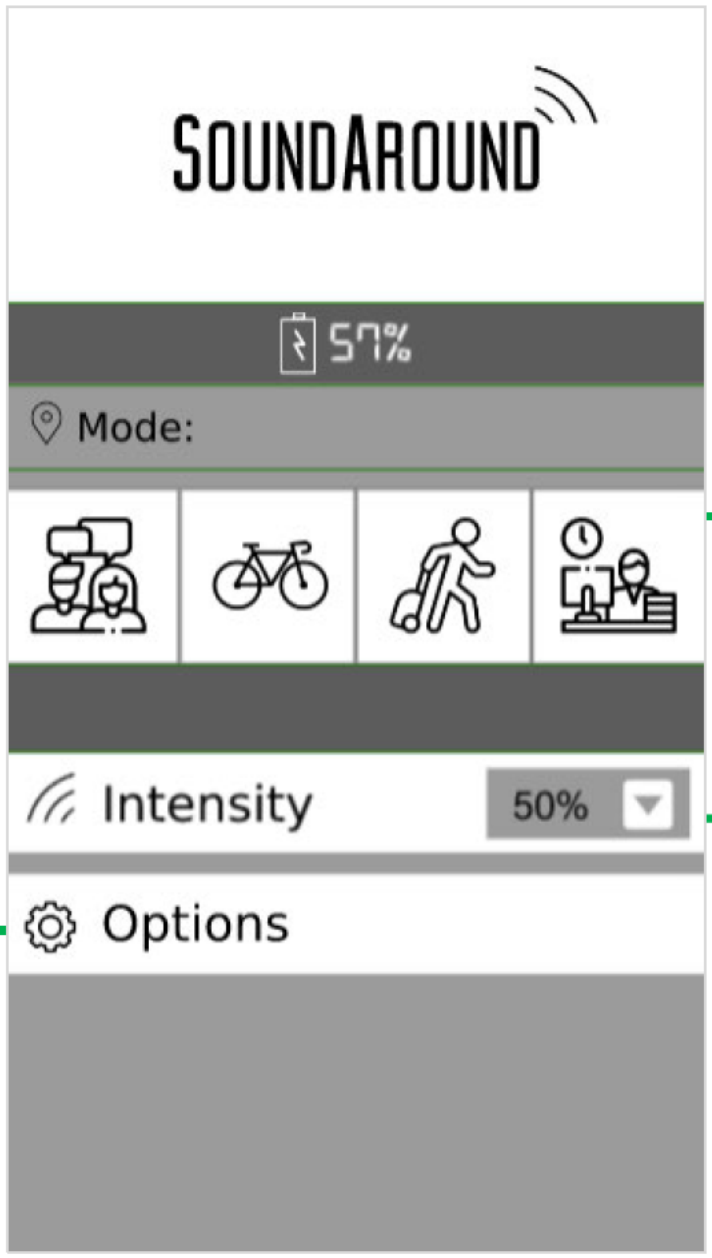
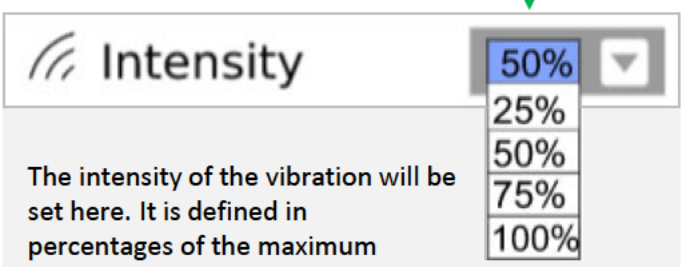


FIGURE 24 – Application walkthrough part 2

The options button will show the general settings of the application. These settings will, for example, be for the preferred language and the notifications.



The intensity of the vibration will be set here. It is defined in percentages of the maximum vibration (25%, 50%, 75% or 100%)

5.5 Modes

The applications main function is to change the mode when the user goes from one situation into a different situation. The SoundAround must react differently in different situations. The modes, therefore, indicate when the SoundAround vibrates, so how many decibels can be caught up without vibrating.
The first situation is in a regular conversation. The SoundAround will especially be helpful when the user is talking with multiple people, then the SoundAround indicates who is talking.
The second situation is when the user is cycling in traffic. The microphones of the SoundAround will catch a lot of noise from the wind when the user is cycling. The barrier, therefore, needs to be quite high. It must be possible for the user to feel it when someone rings the bell of their bicycle.
The third situation is when the user is walking outside. The microphones might catch a lot of wind, but less than cycling. In this situation, it must be possible for the user to feel it when someone is behind him/her talking.
The last situation is when the user is working in the office or is at home. For this situation, the barrier will be quite low, because there is not a lot of noise in an office. It must be possible to feel that someone is behind the user talking or if someone knocks on their door.

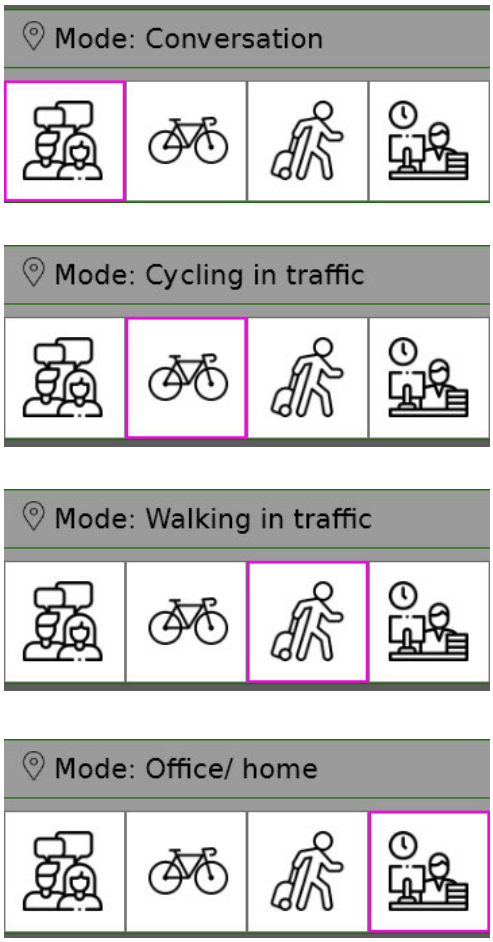


FIGURE 25 – modes application

With all these modes the amount of sound that is received is determined by how long the distance is that the mics can still pick up a conversation. While in-home/office mode the product will detect and process sounds from approximately 5 meters in distance and the intensity of the vibrations will be lowered since this is a surrounding that the user is familiar with. In the cycling in traffic mode, the product will detect and process more sounds, as there is more happening around the user and therefore the vibrations will be more intense if the noise is close (up to 5 meters) and less intense if the origin of the sound is further away (5 up to 20 meters). This in order to assist the user in differentiating between distances in sound. Similar to the last mode, walking in traffic has a relatively high intensity and distance (15 meters). Finally, the conversation mode has the lowest settings, both in the distance of detected sound (1 meter) and intensity of vibrations, to keep the focus on the person in front of the user.

Mode	Distance (m)	Intensity
Home/office	5	low
Walking in traffic	15	high
Cycling in traffic	20	high
conversation	1	low

As presented in the privacy chapter, the phone will only have a information "push" ability. This is because the phone will not be used for the calculations necessary for the product to work. It is only used to change modes, settings and get some information about the product. The app is not a necessity for the product, it can be used without. This also means that the phone doesn't have to always be connected and that the user can walk away from their phone and the product will still function as normally.

5.6 Material choice

In order to find a suitable material to ensure the product will live up the requirements set, we constructed a list of material property requirements. These will be the input requirements for the CES software, which will help us choose our preferred material.

Product requirement	Material requirement
Can be worn in light to moderate rain	Water resistant
Is resistant to sweat	Salt water resistant
Can be worn in sunlight	UV resistant
Provides grip against skin	Has a texture that has grip on skin or can be overmolded with such material
Is flexible enough to flex around the neck	Flexible but not floppy (Young's modulus approx. between 1 and 3 MPa)
Material touches user skin	Should be non toxic

Since most materials with a rubber-like surface texture have a young's modulus of 0.01 GPa, meaning they are very elastic, we chose a base material with a rubber-like overmolding. The positive side to this is we can achieve maximum lifespan and performance since we get the stiffness needed with our base material, and the grip needed from our overmolding. The downside, however, is that it is very hard, or even impossible to recycle overmolded products. Since SoundAround is a product that will not be mass-produced and is likely to be worn every day all day, it is chosen that lifespan and quality go above recyclability, thus overmolding is the preferred process choice. If however recyclability is required, the overmolding could be designed as such that it is removable, like a sleeve or a click-on layer, which would make the product recyclable.

Material selection

The complete material selection process with all graphs and decisions/second options can be found in the appendix (chapter 8.4.2).

Conclusion

In order to select both base material and overmolding, we put our restraints in CES and analyzed the output graphs. From these graphs can be concluded that SoundAround will be constructed from a nylon injection molded body, with a silicone overmolding, to provide the needed stiffness and texture. The nylon ensures the necklace will retain its shape after flexing it around the user's neck, and the friction of the silicone against the skin, together with the shape, will keep the necklace from shifting around.

5.7 Privacy

It is important to also talk about privacy in the context of our product. Our product will contain microphones and will be worn by the user in many contexts. This means that the user should be able to feel at ease about using the product and not feel spied on. This is why we have 2 main options:

1. Make sure that the processing of the sound is done on the product itself, meaning the "computer" processing the position of the sound will have to be placed in the product. The negative side of this solution would be a higher price and higher battery consumption. The positive is that you can ensure that the sound will not be used for anything else. The app connected to the device would only be able to "push" information to the product.
2. In this second situation, the sound would be sent to the mobile phone, processed on the phone and then the correct information for the vibration data would be sent back. The negative side of this solution would be that it is harder to implement security. The advantages would be less battery usage of the product and a cheaper product to produce. It would mean that the app has access to all the data, and this would become more difficult from a privacy standpoint.

For now, we have decided that everything will be included in the product itself as it would be easier to prototype and ensure privacy for the user, as described in point 1.

5.8 Prototype

What are we building:
In order to get clear feedback on the functionality and usability of SoundAround, we plan to construct two physical prototypes.
The first prototype would be a purely visual prototype of how the final product would look and feel when taken into production. This prototype will help us research how willing our target group would be to wear the item, and where the ergonomics of the design can be improved.
Our second prototype would be a purely functional prototype featuring only the essential sensors and actuators to test the way sound directions can be translated to certain vibrations, and the way these vibrations are picked up by the user's brain. We would like to see how our concept influences the sense of direction the user has, and test if these senses are improved by SoundAround.

Production plan:
Visual prototype:

Main requirements	Where they can be found:
- 3D printed with flexible filament (TPE or TPU)	Workplace
- Buttons (3d print or scrapped)	Workplace
- Rubber like substance	Construction Market/Workplace
- Paint	Construction Market/Workplace
- Weights (random objects)	At home

For the visual prototype, we plan to make the main body out of polystyrene foam. For buttons, we will use either 3d printed buttons or buttons scrapped of old products. To make the appearance of the prototype more realistic, we will try to imitate materials. For instance, we would like the part of the neckband touching the user to be made of a rubber-like substance, preventing it from rotating and slipping off. The right feel might be achieved with certain texture paints, shrink tube (usually for electrical appliances) or a spray-on rubber. To make the prototype look and feel real, weight might be added on the right places and small details, like parting lines, will be added. Since the aim of this prototype is purely to test the visual appearance and ergonomics, we will make it as close to the real product as possible.

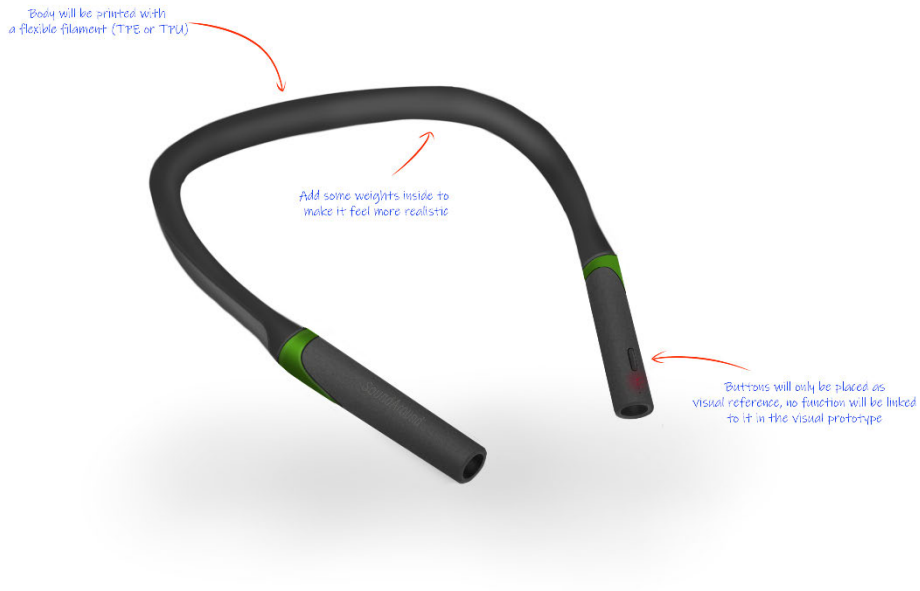


FIGURE 26 – production plan overview

Functional prototype:

Main requirements	Where they can be found:
3 microphones	TinyTronics: MAX4466 Microphone
3 actuators	TinyTronics Vibration DC Motor Module
Wires	TinyTronics
Breadboard	TinyTronics
Arduino or alike	TinyTronics
Power supply	Random external battery from Action
Button	Tinytronics
Potentiometer	Tinytronics
Neckband substitute, 3d printed	Workplace
Small electronics (resistors etc.)	TinyTronics

For our functional prototype, we will focus purely on the working principle of Soundaround. The prototype will be constructed of three microphones and 5 actuators placed on a rough version of our neckless design. These will be wired to an Arduino that will process all received data. The basic working is that we will perform a sound triangulation with the three microphones to trace the direction of the sound source, sending the data to the Arduino, which will return a signal to the actuator on the side of the neck where the origin of the sound is detected.

Below can be found what the diagram would be of the functional prototype with all the components and their relation to each other:

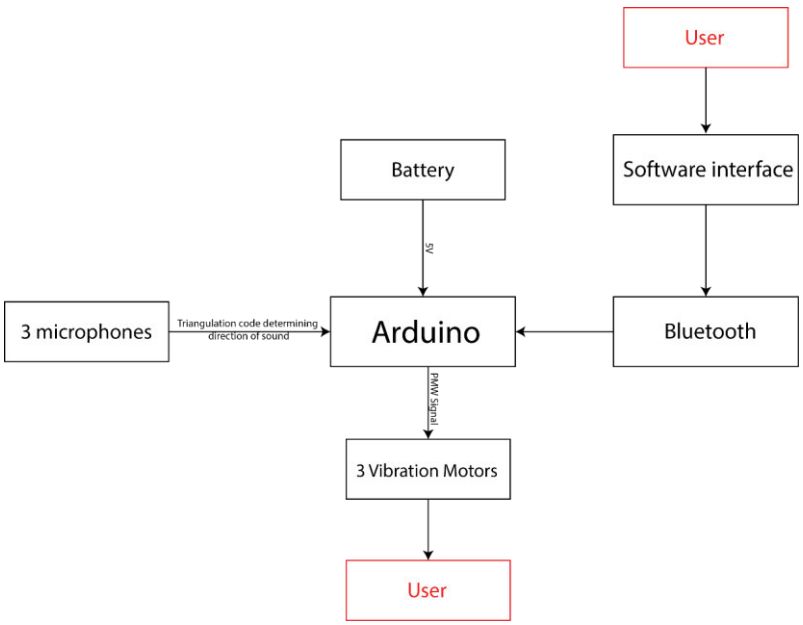


FIGURE 27 – relations prototype

Test plan:

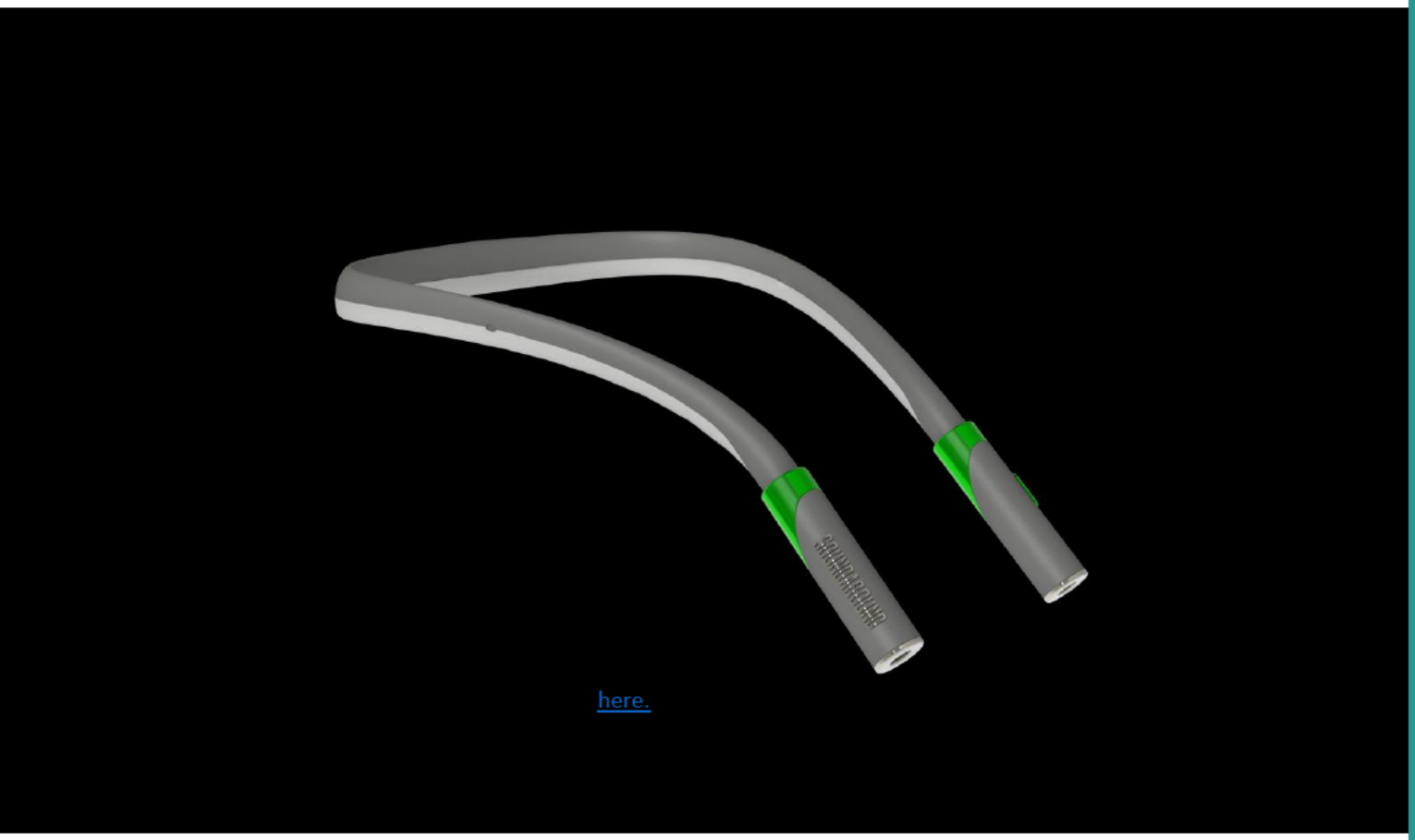
Visual prototype

In order to see what our target group thinks of the final concept, we will a session where we ask the user to turn on the device, wear the device etc. From this, we will conclude what changes need to be made to the design, and what needs to remain the same. The interface and looks of the product are the easiest to modify, but it is essential for good user experience.

Functional prototype

For testing our functional prototype we will start testing with members of our group. We will ask the test person to be blindfolded and wear a pair of noise-canceling headphones. Then we will make noise from a certain direction, and the subject has to point out the direction the sound comes from. If this works as we anticipate, we will start perfecting the concept and alter the intensity of the vibrations until we found a comfortable amount of vibration. When we are sure the technique is safe and comfortable, we will ask our target user to try it, and perform a series of test to see if SoundAround helps our user at all, and how natural this feels. Results of this test will be used to further develop our concept and perfect it to a functional product.

Furthermore we will in this phase also test the application that comes with this device.Test persons will interact with the app and they will be asked to perform a specific task. The time this takes will be noted, just as all the things that are tried before the goal is reached, to see what is clear, and where the app need to be improved.



here.

6 CONCLUSION & EVALUATION

6.1 Conclusion

6.1.1 Adapt to the user needs

6.2 Evaluation

6.2.1 Adapt to the user needs

6.2.2 Prototyping

6.2.3 Mass production & market research

6.1 Conclusion

This project started with meeting our specific user, she was a highly educated person (bachelor of IDE) and has hearing impairments and autism. After researching hearing impairments, autism and understanding what our user's daily struggles were we started to design.
From this process we came to design 3 main ideas that are presented in Chapter 4; SoundAround, Vibracelet and the Subfeel. These were all designed to reduce the amount of stress experienced by our user on a daily basis.

After more co-design sessions, we decided, together with our specific user, to continue developing our concept called SoundAround.

Our product, the SoundAround, has the capabilities to help a lot of people with hearing impairments. By helping them localise sounds around them, it can make them feel less stress in daily life. This is especially the case with someone on the ASD as they have a need to understand everything happening around them constantly.
Thanks to our design that resembles wireless earbuds, this product can be easily worn by both sexes and will not be seen as a stigmatising product.
Even without a prototype being built, we believe that this is a feasible product and could in turn enhance the life of our users.

6.2 Evaluation

6.2.1 Adapt to the user needs

When using the Sound Around product must make direct contact with your skin in order for the user to feel the vibrations. This can however cause some difficulties for ease of use and user needs. Since the microphones need to pick up sounds while using the product, accessories like scarfs or hoodies or maybe even long hair can block the microphones and thus hinder the effectiveness of the Sound Around.

A solution to his problem could be to make the mics detachable or a separate part of the product which can be attached to something else by using clips/pinchers. They can then be attached to the outside of the accessory that is blocking the mics on the neckless. This way it will still be able to perceive sounds around the user while also being able to properly deliver feedback through vibrations on the neck.

FIGURE 29 – clip on

A different solution could be to implement the earpieces as back up mics. Since the user won't be needing them for sound due to their hearing impairment, but still wears them in order to make the Sound Around less noticeable, we can give them a different function. The earpieces will act like back up mics that can be placed somewhere on or around articles of clothing that would otherwise block the normal mics.

FIGURE 30 – earbuds improvement

Finally the Sound Around could be designed in such a way that it could be worn on other parts of the body to circumvent the issue of obscured mics. In this way the Sound Around can for example be worn like a headband while the user is simultaneously wearing a scarf.

6.2.2 Prototyping

The next steps in this project would be to produce our two prototypes, as described in this report, in order to get more feedback from our specific user. This would allow us to tailor the product to her needs and confirm the utility of this device. On top of this, it would also allow us to do multiple studies with material choices and with the application UI/UX development. It would also allow us to confirm the placement of the product, the mechanical specifications the product has to follow, the material, the ergonomics and much more.

6.2.3 Mass production & market research

The next step would be to do more market research, who is interested in the final product? What price are people willing to pay? With this research it would also be important to find out if this product is also viable for people without autism but with hearing impairments, to see if they would also want to use the product. As for the people with hearing impairment and autism it would be important to make sure that more people (not only our specific user) would be okay with vibrations around their neck.

After this is determined, it would be interesting to determine if the product is mass producible, and what needs to be changed in order to mass produce. The cost of production will then also be determined. A profit margin could then be calculated and determined if it is viable to be produced by a company

6.2.4 Application

The application can be developed further. The application now is just an interface, but nothing really works. The application should therefore be connected to the SoundAround and the commands that are in the interface should be working.
The interface of the application itself can also be improved a bit itself. For example the intensity, the user can now choose between 0, 25, 50, 75 and 100%. The user should be able to determine this by itself. The user should be able to adjust the intensity of the vibrations a bit, if it turns out that while using the SoundAround, the vibrations is a bit too much or too less. Therefore this option should be changed in one which the user is more independent. For example this could be a slide bar, as shown in the figure below.

There should also be a text box next to this sliding bar to make sure the user can also precisely adjust the intensity of the vibration.

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8 APPENDIX

8.1 Literature review

8.1.1 What is autism

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8.1 Literature review

8.1.1 What is autism

Autism is a well-known impairment and has been for a long time. Autism spectrum disorder (ASD) is the term used to indicate a set of neurodevelopmental disorders. ASD is the latest term that includes all the other diagnosis from the past, like Asperger's or PDD-NOS, in one all-encompassing diagnosis. Despite more than 60 years of extensive ASD research, its causes are still relatively unknown. [1]

With this said, there are studies that seem to indicate that ASD is genetically structured. As stated in a research article regarding this matter: “Recent research has indicated that autism is not a discrete disorder and that family members of autistic probands have an increased likelihood of exhibiting autistic symptoms with a wide range of severity, often below the threshold for a diagnosis of an autism spectrum disorder.” [3]

It is very hard to produce a universal complete list of traits and symptoms of autism, since people on the autism spectrum all have different traits and intensity of said traits. [4] Rather there are certain scenarios in which people on the autism spectrum generally encounter difficulties. Some of the more common symptoms include difficulties with social interactions, and restricted, repetitive patterns of behaviour, interests, or activities. [1]
Everyone can show to be a little bit on the Autism spectrum, but someone can only be diagnosed with ASD by a person with relevant certifications such as a psychiatrist, when that person determines that the impairment has a severe impact on your daily life, work or relationships. [4]

The way in which someone can be tested for ASD is by using the Autism-Spectrum Quotient (AQ). [2] From using this test came different findings such as the fact that male subjects tend to score higher than female subjects. But the AQ is not to be followed blindly, as stated in an article that aimed to review the AQ; “However, caution is recommended when using the AQ in this way, as the AQ was designed to be a descriptive, rather than a diagnostic, measure of autistic traits.”[2]

SUMMARY

If we relate the information about ASD to the target group of our project it becomes clear that we must take the difficulty's and limitations of people on the Autism spectrum into account in our product. As stated, people with ASD generally undergo difficulty's in social interactions witch is something we might be able to design something to make this less of a struggle. Furthermore, a big change in their daily routine is something that we should avoid. But after all is said and done the things we should take into consideration all depends on where our target group has the most difficulty with and what traits from the spectrum is the most prominent in their life.

8.1.2 Treatments to autism

People with an Autism Spectrum Disorder (ASD) can get a treatment for this disorder. This treatment is not meant to get rid of the ASD, but it is meant for people that suffer from this disorder to cope with it. This therapy has the best results if the person with ASD has therapy and interventions at an early age.
The different sorts of therapy that are generally used are listed below.

- Behavioural management therapy

Behavioural management therapy focuses on reinforcing the wanted behaviour and reducing the unwanted behaviour as much as possible. This is done by for example thinking of why certain behaviour is done.

- Cognitive behaviour therapy

Cognitive behaviour therapy focuses on the connection between thoughts, feelings and behaviour. In this therapy there is a certain goal that will be tried to reach. This is done by identifying and eventually changing thoughts that lead to a certain behaviour.

- Early intervention

Early intervention is a therapy that is done starting with children of the age of two or three. ASD can be noticed at such an early age and it is more practical to than do this therapy, because there can still be things changed in the way of thinking. It is more difficult to manipulate this thinking at a later age.

- Educational and school-based therapies

Educational and school-based therapies are free therapies offered by the government for people with ASD. This can be seen in for example special tools these children have.

- Joint attention therapy

Joint attention therapy focuses on improving joint attention. Joint attention is the ability to focus on both another person and an area or an object. An example of this is following a pointing finger.

- Medication treatment

There is no medication that can cure ASD. Some medication can however make sure that certain symptoms of ASD disappear. An example of this is a medicine that reduces the chance of people from hurting themselves.

- Nutritional therapy

Nutritional therapy is a therapy that focuses on the food people with ASD are getting. Some of these people might not eat everything, because they only like some textures of food for example. This can lead to unhealthy nutrition. Some people also claim that a gluten-free diet is good for people with ASD, to reduce the symptoms of ASD.

- Occupational therapy

Occupational therapy focuses on everyday things that may be difficult for people with ASD. In the therapy, there is tried to find a way in which the task becomes easier for people to get experience with the task.

- Parent-mediated therapy

The parent-mediated therapy lets the parent learn certain therapies from the professional and lets the parents do this therapy with the children with ASD, in this way the child has therapy more often.

- Physical therapy

Physical therapy is therapy in which the people with ASD get trained in their motor skills and improve them. It is also meant to improve the strength, posture and balance.

- Social skills training

The social skills training teaches the people with ASD to communicate with others. An example of things that is taught is handling teasing from other children.

- Speech-language therapy

The speech-language therapy trains people with ASD in the skill to communicate with others in both in a verbal as in a nonverbal way.

By knowing all the different kind of treatments that are generally used, there can be better understood what the caretaker is talking about in for example an interview [5]

8.1.3 Hearing Impairment

Besides being on the autism spectrum, our primary user also has a hearing problem.

Hearing loss can be categorized into two categories; deafness and hearing impairment. [6]
A person is considered to be deaf when there is a hearing loss of over 90 decibels, in all other cases it is called a hearing impairment. [7]

Our primary user is thus classified to be deaf in one ear and hearing impaired in the other. Due to this, she is able to communicate in Dutch with people. However, during the conversation, some difficulties with communication could occur.

When suffering from hearing loss, auditory abilities get worse. These auditory abilities help most humans not suffering from hearing loss in their daily lives. Besides being able to understand spoken language, audition also makes it possible to identify the origin of a sound and to distinguish important environmental sounds [3].

This means that our primary user also has problems with these abilities on a day to day basis.

In particular for most daily tasks the amount of background noise is important in difficulties in information exchange. For instance, a person with hearing loss could be able to have a normal conversation in a room with little background noise, whereas this would be impossible in a noisier environment.

For conversations, in particular, it is also helpful if the visual cues made by the collocutor are clearly visible. Which is most likely in a well-lit room, with a limited amount of collocutors.

Besides the distinction between deafness and hearing impairment, a difference can also be made between people who are born with hearing loss or have gotten it fairly young and people who have acquired it over the years or at a later stage of life.

People who have a hearing loss from a young age often have great difficulty with spoken language. Moreover, there is a reading impact on their reading ability and their level of education. [8] For the other group this is less.

It is unclear when the hearing loss of our primary user originated. Nonetheless, we can safely say that she is able to speak Dutch and that she has had a high education.
However, it is found that hearing loss can cause problems in a person's social life for all subgroups. [8]

8.1.4 Co-design

Co-design (or cooperative design) is mostly used as an umbrella term for open design processes with participatory and co-creation aspects. Co-design changes the relation between client and designer. It enables a wider range of people to have a creative contribution to a design challenge. Designers will take the role of so-called Facilitators. These will provide ways to let people communicate, express their ideas and be creative. People can not only share their insight but can also react to earlier concepts or test out new and existing ideas. [9]

The co-designer of this project has a hearing problem and a form of autism, which can make codesign more difficult. Cognitive impairments such as these can complicate the communication and understanding between the different parties of the design process. Many cognitive impairments, just as autism and hearing problems, are precisely the processes and skills that many participatory and codesign techniques draw upon. For this reason, such techniques might not be useful at all or need to be adjusted. As *K. Sleger* discusses, communication can occur easier in a 'hybrid space' where there is room for mutual learning. This space is the overlapping space between the different worlds with accompanied perspectives. The space is open to differences and can create a discussion, but also a bridge between the world of developers and the end-users. When working with people with sensory impairments, creating this space can be harder than usual. With the proper choice of co-design methods, the design will include both the insights of the designer, co-designer and end-user. [10]

When interacting with the co-designers, *Sanders* distinguishes three approaches: 'say', 'do' and 'make'. 'Say' will most of the time refer to interviews, in which the facilitator can listen to what the co-designer has to say. He or she can also interpret what they express (what they 'do'). Do can also refer to observation of user test or other tests where observation of the users is a key aspect. In, for example, creative workshops people can express their needs and actually "make" their response or solution. Most-codesign methods will be built upon this "make" aspect, it can help to create and organize the joint creativity. [11] [12]

In general, co-design offers benefits for the project, the end-users and the organization itself. The project will have improved idea generation consisting of better ideas, better knowledge about customers' or users' needs, and a better idea generation. It will also improve the possible service connected to this product with a higher quality of service definition and, in general, more successful innovations. The end-users will

experience a better fit between the needs and the product or service and will feel included in the whole design process. The organization will have more input and thus, an improved creativity, an improved focus on the users and a better cooperation between the designers and the end-users. [11]

There are a lot of co-design methods which can be used in different phases of the design process. In this project, the focus will lay on co-design with the end user. In this overview (which will not include all methods) the focus will also lay on co-design methods which are designed to perform on end-users. [13] [14]

RESEARCH

Diary study	Participants are asked to monitor/report or list specific data over a defined period of time. With this information, or even photos and videos, can result in better self-reflection which can be helpful in an in-depth interview.
Emotional Journey	Emotional journey associates the emotional status of the user at different stages of a particular experience. The emotion can be represented in different ways. For example, by adding pictograms or emojis to specific stages, or making a curve to show the level of, for example, frustration, delight, joy or disgust.
Comparison chart	With a comparison chart, an overview of the tools and products will be made to come up with the best concept starting point. The traits of all tools or products will be listed, compared and finally some will be eliminated.
Value session	A value session has the result to explore the common values of the designer and co-designer. Both parties write their main values and after this a discussion will take place to come to five joint values.
Stakeholder map	Find out which stakeholders are dependent on each other and what the influences are on each other with the help of a stakeholder map. The placement of the stakeholders in respect to the main user will express the amount of influence on the user.

Other possible research co-methods are: Interview guide, issue cards, recruiting screener, assumption mapping, golden circle or a SWOT analysis

IDEATION

Issue cards	A specific element of the design challenge is pictured on a card. It is based on a specific need. The cards will be opened one by one and will stimulate conversation and problem-solving between the designer and co-designer. Issue cards can also be used in the research phase
Feasibility creativity matrix	A feasibility and creativity matrix will give insight in already generated ideas and will show if these ideas are creative and feasible enough to develop further. A horizontal and vertical axis will represent the creativity and the feasibility. With plotting the ideas, the ideas with the most potential can be identified.
Lotus Blossom	A idea or question is writing in the middle of a big piece of paper. Things that are associated with this case are written around this starting point. This will go on to form a big “lotus blossom” which can be inspiration for further ideas or concepts.

Other possible ideation co-methods are: Brainstorming, Concept walkthrough, affinity mapping, mash up, crazy 8, dot voting, dark side method, brainwriting or mind mapping.

PROTOTYPING

Role playing	With acting out an exemplificatory scenario of use, a service or product idea can be explained to the user. Prototypes or other materials can be used in this role playing.
Wizard of oz	For testing a complex system before it is fully developed and produced. The user thinks that he/she will use the real system, but the designer will be controlled behind the scenes. The prototype used does not have to be functional.
A/B testing	Find out which of the proposed items is preferred by the user. The user/ co-designer has a limited amount of choices and will choose and explain why he/she chose this item.

Other possible prototyping co-methods are: Concept walkthrough, experience prototypes, rough prototyping, service prototyping, usability testing, video prototyping or paper prototyping.

8.2 PACT analysis

The goal of this research report is to get a better understanding of the user, the human, we are designing for. A common tool is the PACT analysis. This analysis takes four different aspects of human centred design into consideration; People, Activities, Contexts and Technologies. These four aspects are discussed in the following chapters.

8.2.1 People

Primary user

The primary user of our product will be a specific user, who we are designing for and with.
Our specific user is someone who is on the autism spectrum. We do not know what the exact specifications of her case are, but it would be advisable to conduct some research on the general topic of autism. See 8.1.1.

Furthermore, she is deaf in one ear and is impaired in hearing with the other. This causes her to have difficulty in having conversations with multiple people at the same time. She also has problems with hearing indicator sounds in everyday life, like a doorbell or passing by cyclists. This is why some research on hearing impairments has been conducted. See 8.1.3.
Due to the combination of these impairments, she likes to avoid many people at the workplace, and she dislikes leaving her home.
She has done the study Industrial Design at the University of Twente and she has taken some classes in programming. However, due to her impairments, she is unable to work in a normal working environment.

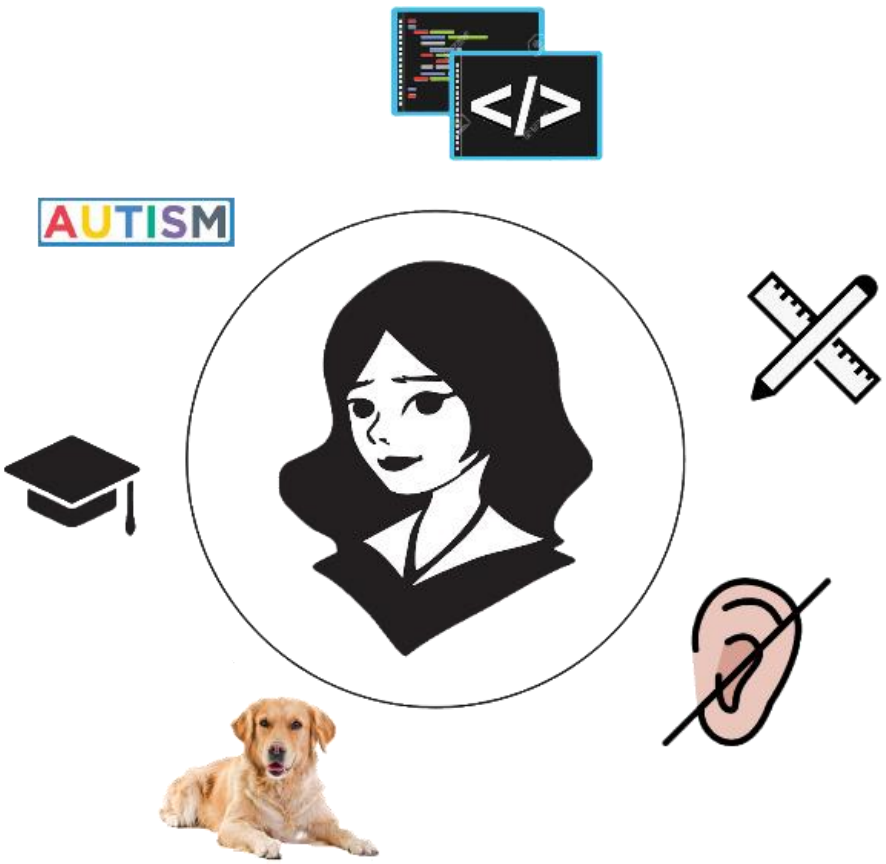


FIGURE A.1 – persona

Secondary users

To our specific user the workplace feels like her real job and thus the other people there, are sort of her colleagues. However, she does not like to interact with them much. All the people working at Assortimens are somewhere on the autistic spectrum, but their specifications differ. Though, most people there are highly educated and do not function (anymore) in a normal working environment.

She and her colleagues are guided and monitored by the staff of Assortimens. The staff makes sure that there is work to do and that the work gets done in time, without making the people there feel like there is work pressure. They also guide in projects that people are working on.

Within the staff, there is one person who is the personal mentor of te specific user at Assortimens. He makes sure she has work to do and that everything goes well with her. He is the person to who she can go with all her problems and he tries to help and guide her as best as he can.

She lives in guided housing. This means that she has her own apartment, but there is staff on hand to help her with things she has problems with.

We did not ask this specifically, but we assume that she also has family and friends that visit her at her house occasionally.

Last but not least, our specific user has a dog that helps her in her daily life. The dog mostly looks up or around when the doorbell rings, there is a knock on her door at work or if there is a cyclist approaching from the back. Do note though, that he does this often, but not all the time. However, the dog is foremost a companion, something that is always there, a constant thing in her life, which gives her comfort.

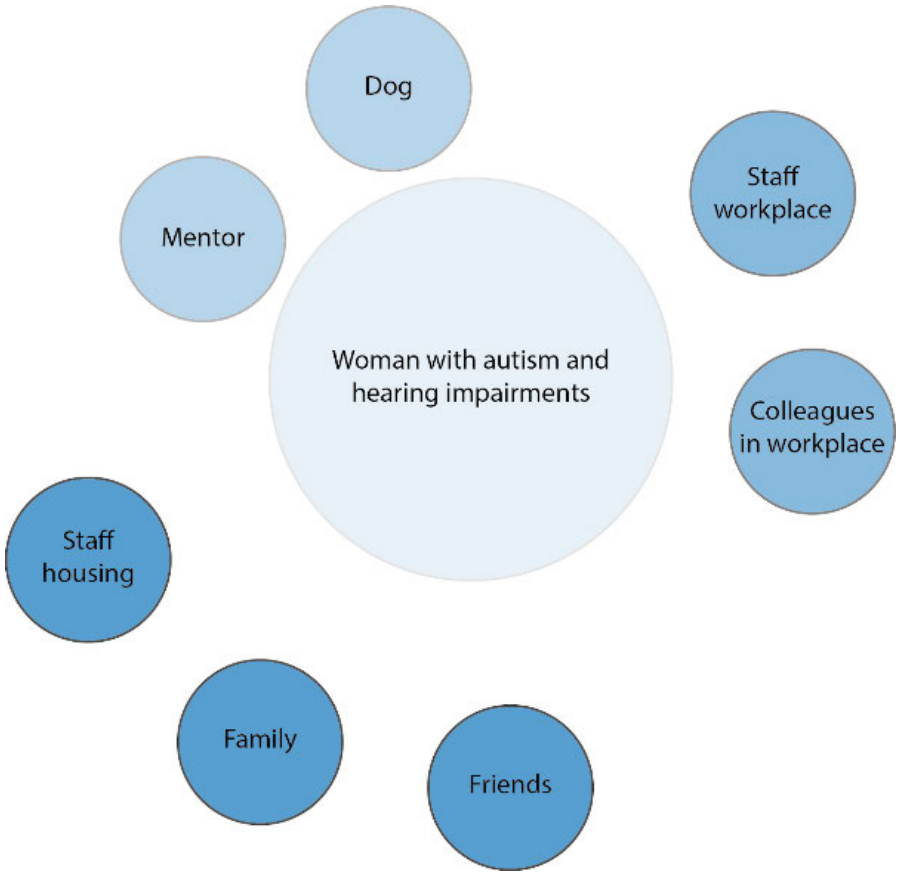


FIGURE A.2 – stakeholders

8.2.2 Activities

The specific user helping us Codesign our product is mainly active in 3 environments: Assortimens (Place of work for people on ASD), Travel (mostly between her home and Assortimens) and Home (where she lives with assistance but in her own apartment). These three environments will be discussed in the following page.

Assortimens
At Assortimens, our primary user works on projects that she has been assigned to from her office. She also goes to the canteen to either search for help ((if needed) or to grab lunch). In her office she programs, and designs products for projects that she is assigned to,
The problems that she encounters are mostly human related, firstly she is distracted by the people walking around that she can see/hear through her office windows, and secondly she has trouble with the social contact that is necessary when going to the canteen, as she is not the only one using that space.
These problems are also described in "Relative Average Look Duration and its Association with Neurophysiological activity in Young Children with Autism Spectrum Disorder". It concludes that children with ASD have more trouble to keep their attention, especially in the context of social interactions (Isaev et al., 2020 [15]).

Travel
Our user mostly travels from home to work by public transport. She used to have to take the bus and it was nearly impossible for her as there was too much happening around her. However now she can take the train and it goes relatively well as there are not too many people. Because of her hearing impairment it is very hard for her to walk in traffic as she doesn't hear anything coming. This is why she has a service dog; the dog will pay attention and try to inform her of any incoming traffic, and this helps her a great deal in her daily life.
> see the next page for a storyboard.

Home
When coming home around 15.00 our user continues to work. She lives in a building with supervision but has her own small apartment. The apartment that she lives in has been adapted for her hearing impairment.
She mentions multiple times that the doorbell, fire alarm and alarm clock have been fitted with lights and the latter with a vibration motor in order to bridge the hearing impairment problem. However, the lights have two big drawbacks, firstly you can only see them from a certain room in the apartment and secondly it is very difficult for her as she is on the ASD.
There is a lot of research about hypersensitivity being linked to ASD, this can be found in "Describing the sensory Abnormalities of Children and Adults with autism"(Leekam, Nieto, Libby, Wing, & Gould, 2007 [16]), "Sensory-Perceptual Abnormalities in Autism: A Case For More Research?" (O'Neill & Jones, 1997 [17]), Unusual Sensory Sensitivities in Autism: A possible crossroads (Talay-Ongan & Wood, 2000 [18]), as well as a first look into a product that tries to describe and resolve this problem in "IoT based assistive companion for hypersensitive individuals (Khullar, Singh, & Bala [19]) with autism spectrum disorder" (Khullar et al., 2019 [20])

SUMMARY

Our User has a lot of problems with daily life situations. Due to the combination of ASD and Hearing impairment most products don't fit her activities and will not help her. This can also be seen in research, a lot of research can be found on either ASD or Hearing impairment but very little can be found about the combination of the two disabilities. It is thus important to, when designing for this specific user, remember that the product we design keeps into account her over-sensitiveness/ASD AND her Hearing impairment. By doing this we can make a product that will fit her life best.

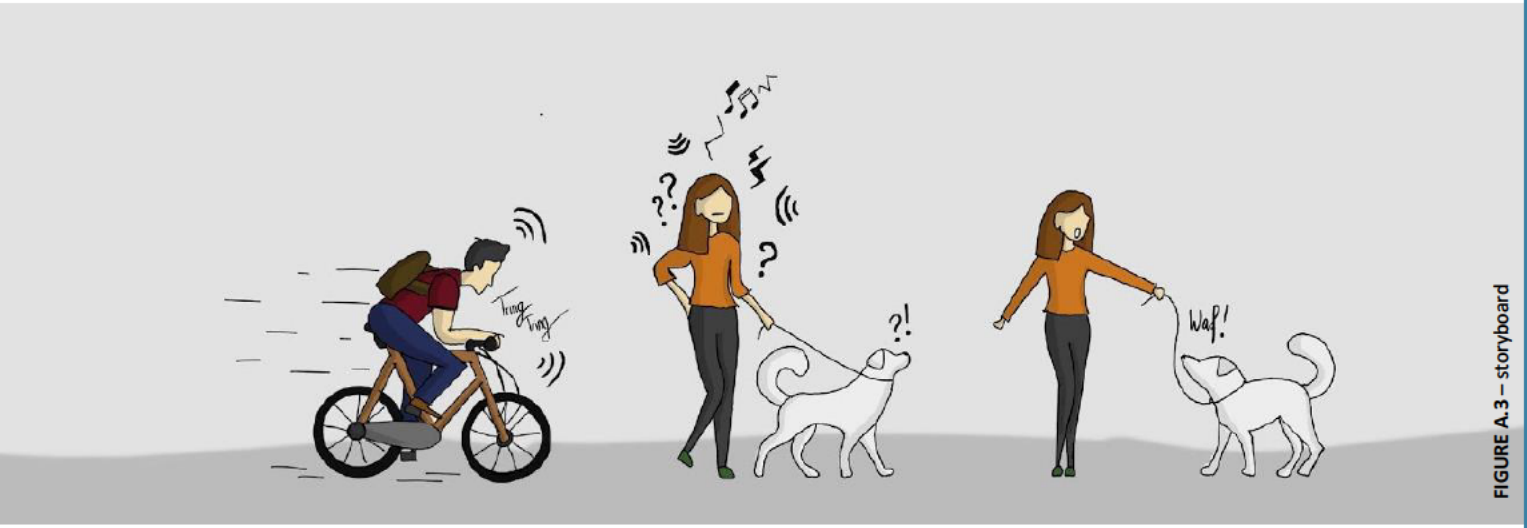


FIGURE A.3 – storyboard

In figure 3, a daily scenario of our co-designer is shown. Because of the hearing problem of our co-designer, walking over street can be stressful. The dog will help her to notice cyclist or other pedestrians on the street.

9.2.3 Context

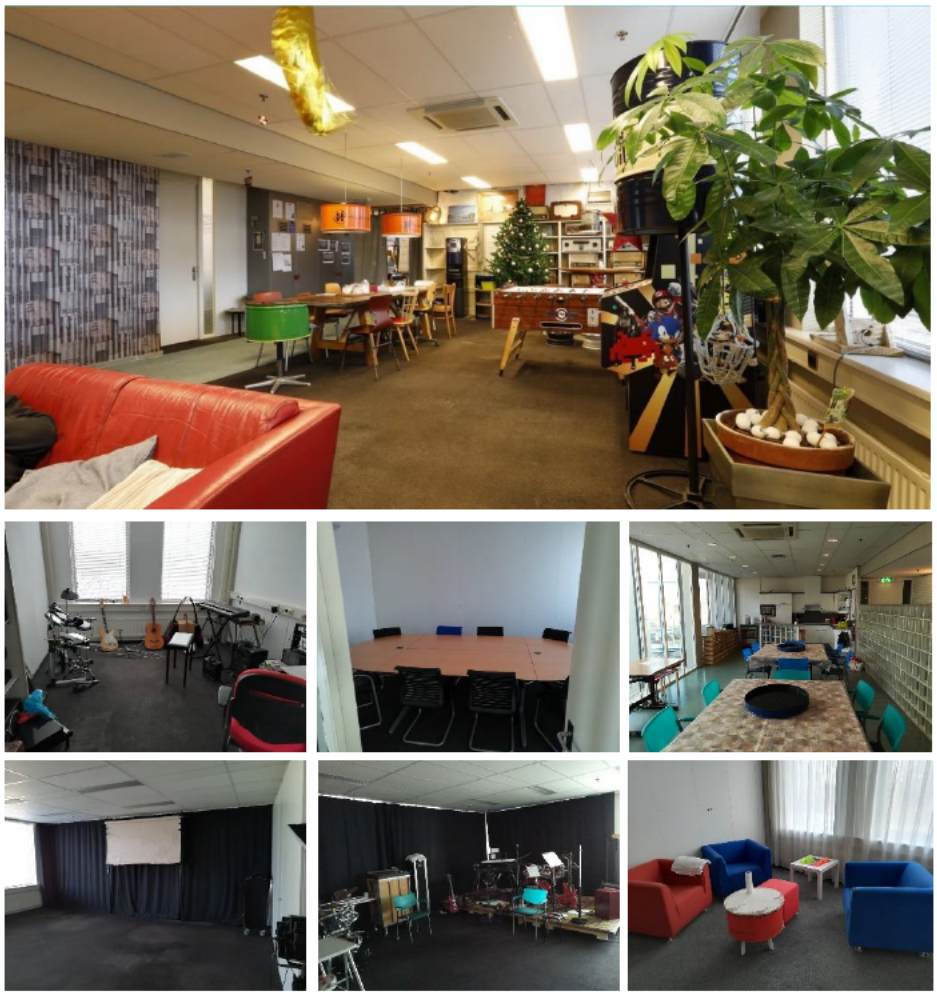


FIGURE A.3 – context assortimens – 21,22

To better understand the different contexts in which the developed product will be used, there is done research into the context. This has been done in physical, social and organizational context.

Physical context
The physical context where the caretaker works is partly shown in figure 4. She works at AssortiMens in Oldenzaal. This is an institution where people with an Autism Spectrum Disorder (ASD) work. They work here, because they cannot function properly in the regular society.
The caretaker works in her own office. This office has windows to the outside and windows to the inside, so that she can see her co-workers and vice versa.
In the building where AssortiMens is located there are also some facilities. There is for example: a music-and photo studio, a kitchen, a rest room without electricity, a few workshops, a few workspaces with desks and a living room.
To get to AssortiMens, the caretaker has to travel by train.

Social context
The social context at AssortiMens is people with an ASD and supervisors/ caregivers. The contact between the caretaker and the caregiver is good, they know each other and speak often. Then there is the contact between the caretaker and the rest of the people with ASD. This contact did not seem smooth. When the project team came to her office, the caregiver asked if she wanted to get coffee and she said no, because it was not 11:00 am. There would therefore still be people in the living room. It seemed to the project team that she was a little bit afraid to get in contact with the other people in the institution.
There are also unknown people on the train. This is hard for Lonneke, because she gets a lot of impulses from this unknown environment. This is because of her ASD.

Organizational context
At AssortiMens there are a few restrictions on those who may participate in the team of AssortiMens. These restrictions are:
The participant has a recognized ASD
The participant has chronical problems in functioning in the daily life
The participant cannot function in regular society
The participant has a valid care indication
The participant is interested in being actively involved
The participant has an average or above average intelligence
The participant is 18 years or older.
There is also a regulation regarding the payment. There is a payment for every four weeks with a minimum of €17,50 depending on the income.

The information about the different contexts will form restrictions for the design of the product that will be developed. The product needs to for example fit in the rooms that are present at AssortiMens, the product therefore can for example not be a cube of 3*3*3 meters.

8.2.4 Technologies

To help people with ASD many products and services have been developed the last few years. To analyse the products on the current market a list of existing technologies is constructed explaining the technology, its influence and its constraints. This is just a small example of all the products that currently exist, made to give an indication of the broadness of the variety of existing products, and to help us in the process of designing a solution for our client. [24] [25]

Desktop & Web technologies
Several programs have been developed to help people with autism practise social behaviour, like emotion recognition and what to reply in certain situations. Examples are:

KidTalk
KidTalk is a program that provides online therapy for individuals with high-functioning autism and Asperger's Syndrome. KidTalk provides rewards for progress in socially appropriate engagement. The software has been

tested with promising results, and is released on 13 Dec 2013.
Influence: This software influences the social interaction of its users and the people around them, by making the user more aware how to act in which situation and at which facial expression.
Constraint: The fact that the software is online, might cause it to be not the most accurate representation of everyday life, leaving its user not knowing how to act to real life situations.

Trocas
Trocas is a system built to improve communication competences of children with autism with a story based game. The game was developed as a research tool, and testing it on three children for 12 weeks showed some improvement in communication competencies, but the software is not released for consumers.
Influence: This game influences its users by teaching them how to act in certain situations.
Constraint: This game will teach children how to behave on a few occasions, but these will rarely occur in real life. Furthermore the software is not released.

Sensor-based and wearable technologies
Wearable products to help people with autism have the benefit that they can easily be taken with them in daily life, and are always there to assist. Examples are:

GOOGLE GLASS
Wearing a device that identifies other people's facial expressions can help children with autism develop better social skills, a Stanford pilot study has demonstrated.

Children with autism were able to improve their social skills by using a smartphone app paired with Google Glass to help them understand the emotions conveyed in people's facial expressions, according to a pilot study by researchers at the Stanford University School of Medicine.

Chewigem Emotion bracelet
With the Chewigem emotion bracelet impulse sensitive children can easily indicate how they feel, so the surrounding can take this into account. [26]

Robots
Generally the interaction between robots and people with autism have been high, and it is even stated that people with autism often prefer robot characteristics above human characteristic. Example of such a robot:

ERSA
ERSA is a robot build to teach people with autism what emotion belongs to which facial expression. The use of the robot can reassure consistent behaviour examples to practise with.
Influence: ERSA influences the user by practising with facial emotion expressions.
Constraint: ERSA doesn't give any directions on how to act on these emotions, and because the expressions of a robot are always the same, this might cause confusion for human expressions are always different.

Home and school environment
In the home and school environment products are used to help people with autism perform better. A few examples:

Concentration screens
concentration screens lessen the amount of distracting impulses like movement and sound, and helps the ones having a hard time concentrating.

De Kleuren Klok (the colour clock)
The colour clock is a clock designed to give a clear indication of time to children, to promote their independent working capability. Because it is hard to read a conventional clock, the colour clock is a colour coded 'stopwatch', to give children an indication of time they still must work on a certain thing. [27]

SUMMARY

There is a huge variety of aiding products on the current market varying from vary simple one-piece product to a High-tech solution. One thing most of these technologies have in common, is that the usage is straightforward, and easy to understand for the user. This is something important we will have to consider ourselves whilst designing our solution.

8.3 Co-design results

8.3.1 Session 1: Introduction & First acquaintance

DATE: 12-02-2020

Daytime activities Lonneke:

- Arrival at AssortiMens during the morning
- Edwin or one of the other supervisors give an assignment (design or programming)
- Back home around 3 p.m. too many incentives for the day
- Continue drawing / programming, cooking etc. at home

She would rather work from a topic / assignment than from nothing (coming up with ideas is difficult). However, she can give good criticism, always something to criticize.

Graduated in programming, but her interest is broader, here at AssortiMens she can do anything. She can bring programming together with design and more.

Not a fan of colour.

With AssortiMens from October 2016. Then it was even smaller and she had a whole floor to herself. That way she had few triggers. Now she has a closed office next to an office garden. The windows do provide more incentives and have tried to shield them. The movement and noise behind the window is distracting.

Difficult choice between working at home or at AssortiMens.

- "Outside the house there are scary things," unpredictable people and sounds. She is stressed when she does not know what people say, do, etc. Good to get out of the house.
- At AssortiMens she likes the assignments but finds it difficult that it is not predictable: she does not know when people have time to help her, when there are people and where they are walking around. (She goes to the canteen when there are as few people as possible). She finds the people and incentives at AssortiMens difficult. In addition, she can place difficult sounds.
- The journey from home to AssortiMens is the hardest part. Due to the poor placement of sound in combination with Autism, traveling by bus is terrible. Lots of noise and way too many impressions and people. She can reach the new location by train. This is only 7 minutes and a quiet route and this is a lot better than the train.
- Her assistance dog gives her sense of security. Someone to walk with and sometimes points her to people cycling past or other things to look out for.

Lonneke lives accompanied but has her own apartment. Because of her hearing problem, she is entitled to an alarm clock, fire alarm and bell that work with vibrations and flashes of light.
The flashes of light are annoying (in connection with her autism) and also very bright. The bell can only be "seen" in a specific room.
She had heard of a vibrating device that could give notifications (could be a solution).

Written contact is the best for Lonneke. Then she has time to think about an answer and her hearing problem does not stand in the way.
Please send the date, time and plan in advance via e-mail (lonneke.kolkman@gmail.com) and also a cc to Edwin Dertien.
Great if there will be contact with the same people (Martijn and Anne Roos)

Suggesting co-design methods: Working with Lego? No she never understood why you would do that!

8.3.2 Session 2: Define Problem(s)

DATE: 26-02-2020

Sounds> 500 Hz cannot be heard (properly) for Lonneke. She therefore also likes music with low tones. (No longer than

15 minutes, otherwise too many incentives.) High tones are unintelligible and irritating. She always has her hearing aid on.

1 on 1 conversation goes well because of the possibility of lip reading and the small distance. On the street, noise gives it stress because it cannot give direction to the noise that causes stress. She also cannot follow communication from a great distance.

She has recently been trying to do shopping once a week because it often fails during the week due to a low energy level. She does the shopping without Bailey, because the groceries have to go in a cart.

A panic attack by Lonneke can have various causes: A peak of stimuli (often at the end of the day), (see graph), can be a cause but also a certain thought or issue in her head can cause an attack. To calm down, she likes to talk to her home or Assortimens. At her home, someone comes quickly after asking for help (eg a whatsapp message), at Assortimens this is unpredictable and can take longer. Bailey (her dog) can also calm her.

She recently visited a center because she is entitled to new products. Now she gets a vibrating block instead of a flash lamp. She also recently has a directional microphone. This can be connected to her hearing aid to help determine where the sound is coming from. This only causes a different sound through her hearing aid which she finds annoying.

What could help is a product that would provide subtitles for a conversation. This is often only via a telephone or other product, which means that she cannot look at the conversation partner. Google glasses or something could be a solution for this. These glasses are only very striking, if they were "more normal", she would be open to this. A device that would make use of a type of braille could also be a solution.

3 things she enjoys / enjoys doing:
- Bailey hugging etc
- Cycling (wants to pick them up again)
- Gaining information (reading, computer) for self-development / related to an ongoing project about all sorts of things but mainly technical subjects such as VR (in which she did a master's)

3 things she doesn't like:
- Passing through traffic, especially difficult when people suddenly cycle or walk past. This makes her scared.
- Places with many people
- Arrange things by phone, she doesn't answer the phone. answering machine says: I do not call, send an e-mail. Much can be arranged via app or email, otherwise her supervisors help her.

Lonneke receives assignments for projects within Assortimens but also assignments from outside the organization.

How was the study with limitations?
Mandatory lectures were of no use, she could not hear them. She never really reported this to the university, otherwise she would have been entitled to a secretary or an extra microphone for the lecturer. She did not dare to admit that she had problems and felt that it was her fault. Regarding the projects, she did not do the tasks concerned with the user. She finds organization structure difficult. She waited until tasks were divided and it was clear what she had to do.

At this moment she is satisfied with her independence. She can sometimes be afraid of being alone and feeling responsible gives her stress.

She finds it difficult to come up with an idea what will really help her. She does say that she can indicate whether or not products would help. For the next session we come up with many ideas and we can discuss the potential of these ideas.

Graphs results Incentives →
Graph: Values are added together. Later in the day, more incentives are annoying.
Energy → gives energy: line goes up, costs energy: line goes down.

Results stakeholder mapping →
The distance between "I" and the stakeholders stands for how close (psychologically) the people / dog stand for her. The blue notes between them can be a block or a connection. When the lines are perpendicular between the circles, the (what is on the note) interferes with the relationship; when the notes are placed the other way around, the limitation on the note is the connection itself (e.g. the connection I-therapist). There are no restrictions or connections between I-friends and I-bailey regarding restrictions.

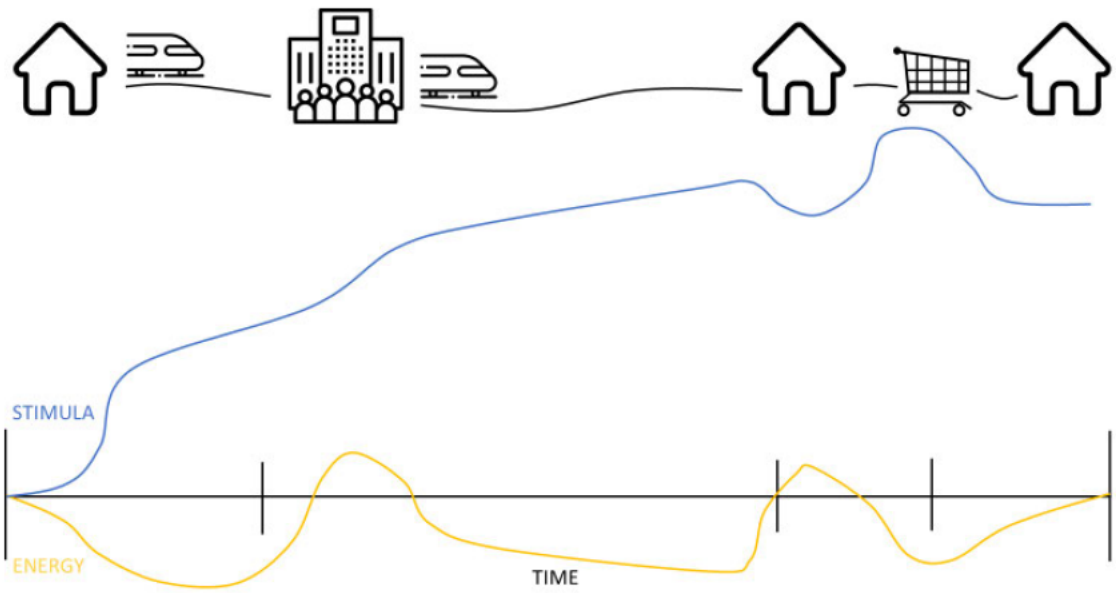


FIGURE A.5 – emotional mapping graph

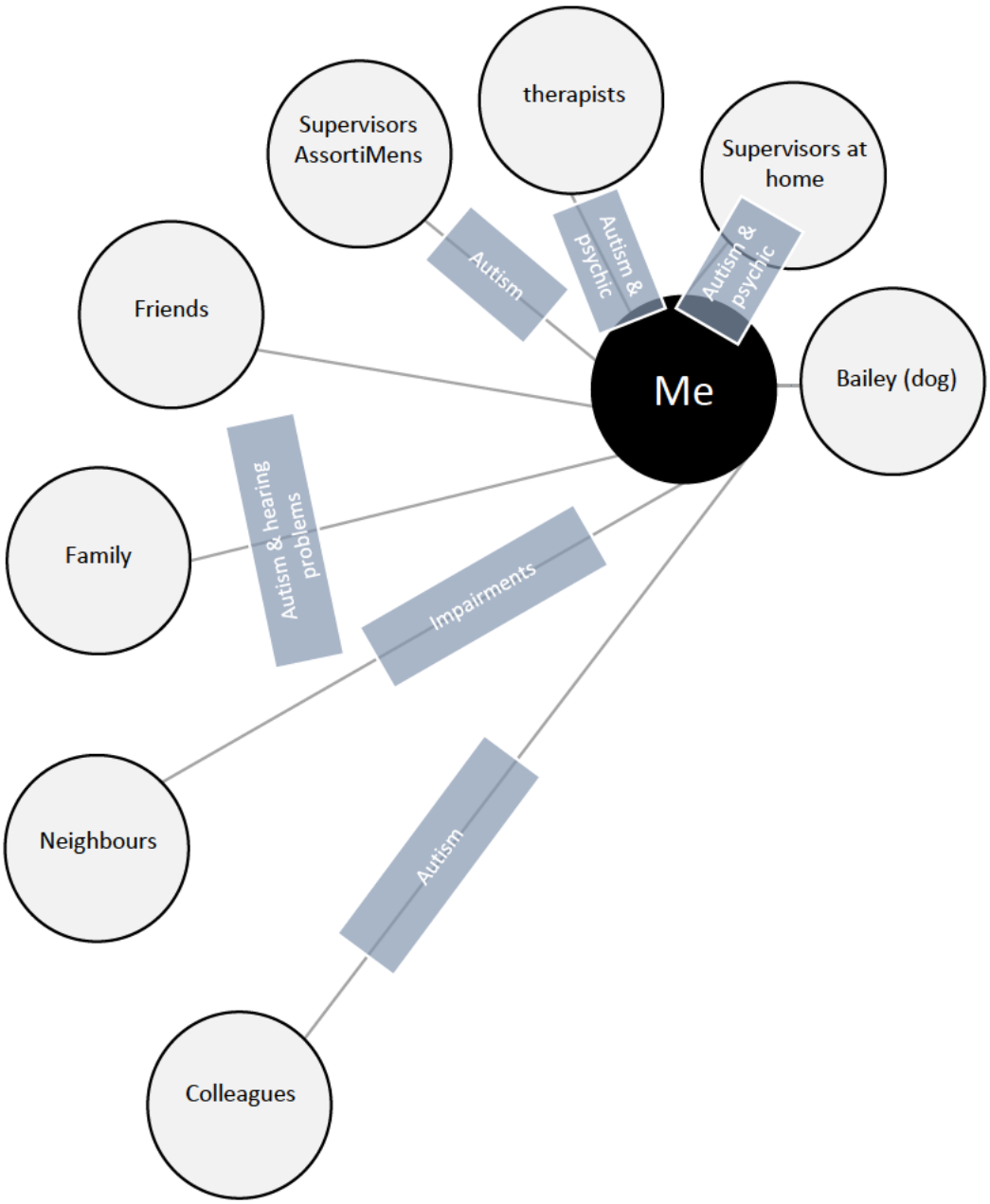


FIGURE A.6 – stakeholder map

8.3.3 Session 3: Ideation reflection

DATE: 04-03-2020

The first question asked to the co-designer is what exactly is her hearing impairment. The reason this question was asked, is that there are ideation ideas that include an improvement of the sound a person makes while talking to her. For example, she said she liked low frequency music. One idea is that the spoken frequency of the speaker is transferred to low frequencies, so that she could hear this.

She answered that the cilia in her spiral casing are damaged.

Then, there were already a few ideation sketches for different solutions for both the problem in the traffic and the problem during the conversations. These ideas have been explained and the co-designer put them on a graph with one axis representing the willingness to use and the other axis representing the usefulness. These axis have been chosen, because while hearing the problem in the previous co-design session, the solution of google glasses came up. She said she has considered this but does not want to wear them. Therefore, the google glasses should not score high in the graph.

All the ideation sketches are shown in the report at 'Ideation'.

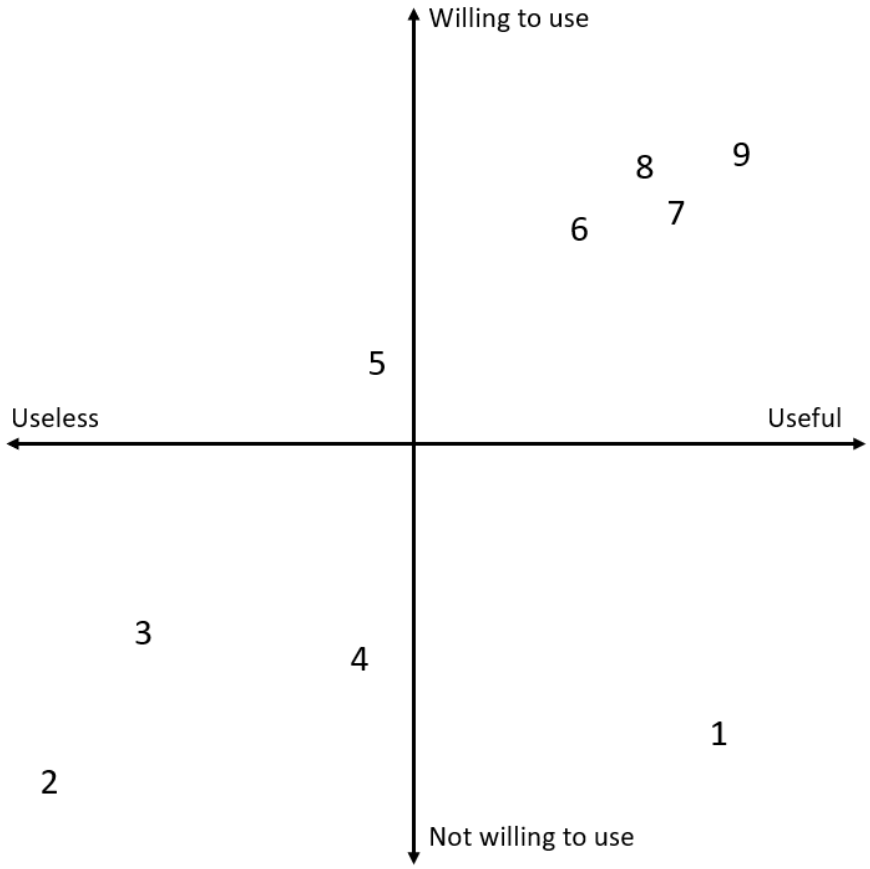


FIGURE A.7 – matrix

FIGURE A.8a – idea 1

8.4 Product development

8.4.1 General requirement specifications

User requirements	**Specification**
The product should be easy to use.	Product should require less then 15 minutes to understand basic use.
The product should not distract the people/service dog around.	Product should communicate only to the primary user.
The product should be appealing to male and female.	The design should be unisex.
The product should be comfortable to use.	The product should be understood
The product should not be noticeable for people around.	The product should blend in with its surroundings.
The user should be able to turn the device on and off.	Product should have an on/off button.
Safety requirements	
The product must not cause choking hazards.	The product should not contain small loose parts.
The product must not have sharp edges.	All edged must be rounded.
The product must not be made from material that is toxic or can cause potential allergic reactions.	The used materials should be non-toxic.
Technical requirements	
The product should be able to operate 12 hours without charging if battery's are required.	Battery's should be sufficient to last at least 12 hours.
If the product gives feedback to the user it must be in real time.	Responsive delay caused by data processing may not exceed 1 second.
Product should fulfill the IP requirements.	The product should have a minimum *Ingress protection rating* (IP-code) of IP56
Size and weight requirements	
The product should fit 95% of all users.	Sizes should be determined such that 95 percent of the target group fits the design.
Wishes	
The product has extra features to make it less noticeable for people around.	Product should blend in with surroundings.
The product should add as few extra incentives as possible .	Product should not be distractive.

8.4.2 material selection

In order to find a suitable material to ensure the product will live up the requirements set, we constructed a list of material property requirements. These will be the input requirements for the CES software, which will help us choose our preferred material.

Product requirement	Material requirement
Can be worn in light to moderate rain	Water resistant
Is resistant to sweat	Salt water resistant
Can be worn in sunlight	Is UV resistant
Provides grip against skin	Has a texture that has grip on skin or can be overmolded with such material
Is flexible enough to flex around the neck	Flexible (Young's modulus approx. between 1 and 3 MPa)
Material touches user skin	Should be non toxic

Since most materials with a rubber like surface texture have a young's modulus of 0.01 GPa, meaning they are very elastic, we chose to opt for a base material with a rubber-like overmolding. Positive side to this is we can achieve maximum lifespan and performance since we get the stiffness needed with our base material, and the grip needed from our overmolding. The downside however is that it is very hard, or even impossible to recycle overmolded products. Since SoundAround is a product that will not be mass produced and is likely to be worn every day all day, it is chosen that lifespan and quality go above recyclability, thus overmolding is the preferred process choice. If however recyclability is required, the overmolding could be designed as such that it is removable, like a sleeve or a click-on layer, which would make the product recyclable.

Overmolding

For the material of the overmolding CES software was used in combination with the constraints given above to select usable materials. The program is allowed only to pick from elastomers that suffice our requirements, visualizing these materials in graphs (see below). From these graphs can be read that performance wise a silicone elastomer overmolding would be most resistant against UV radiation, as well as being excellent salt- and freshwater resistant, featuring a wide band of possible young's modules so the material can be fine-tuned to the desired surface feeling. This material however is quite costly featuring between 3,82 and 5,68 euro/kg. If price would be a big influence on the choice, butyl rubber might also be considered for it is the second-best scoring material on the list, and less than half the price of silicone. Considering the small amounts needed for the overmolding, we will however choose the overmolding te be made from a silicone elastomer.

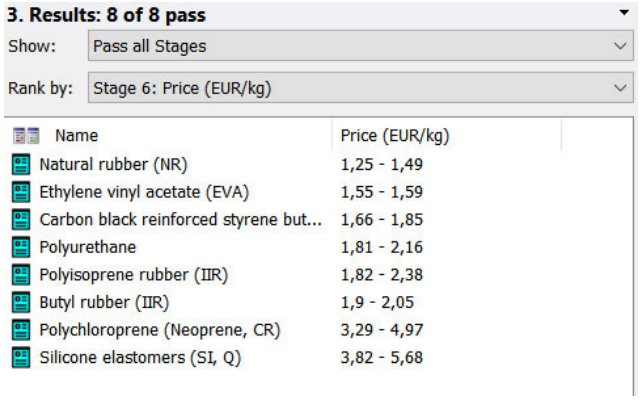


FIGURE A.9 – material choice

Graphs used:

Graph showing UV-radiation resistance vs Young's modulus.

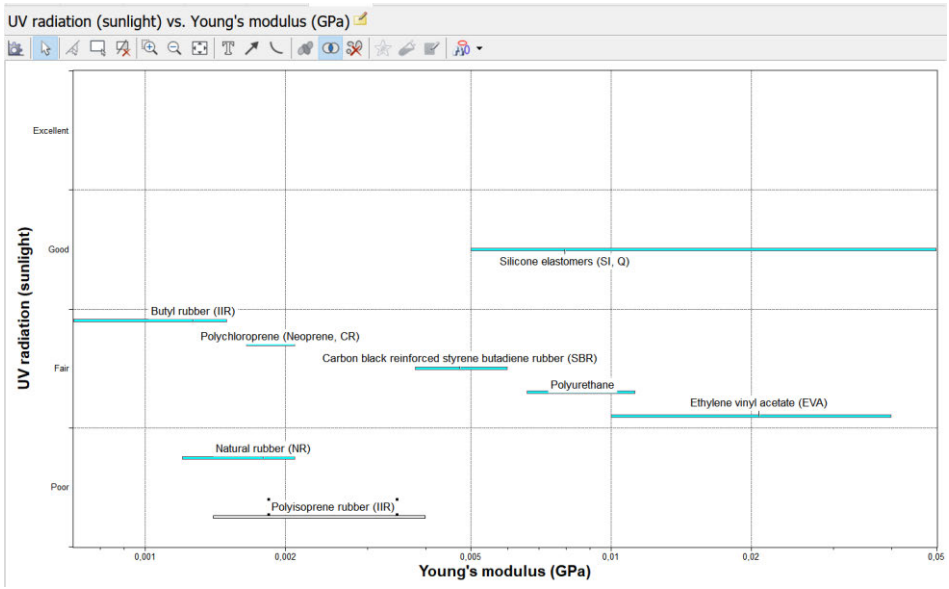


FIGURE A.10 – UV vs Young's modulus

Graph showing saltwater resistance vs Young's modulus.

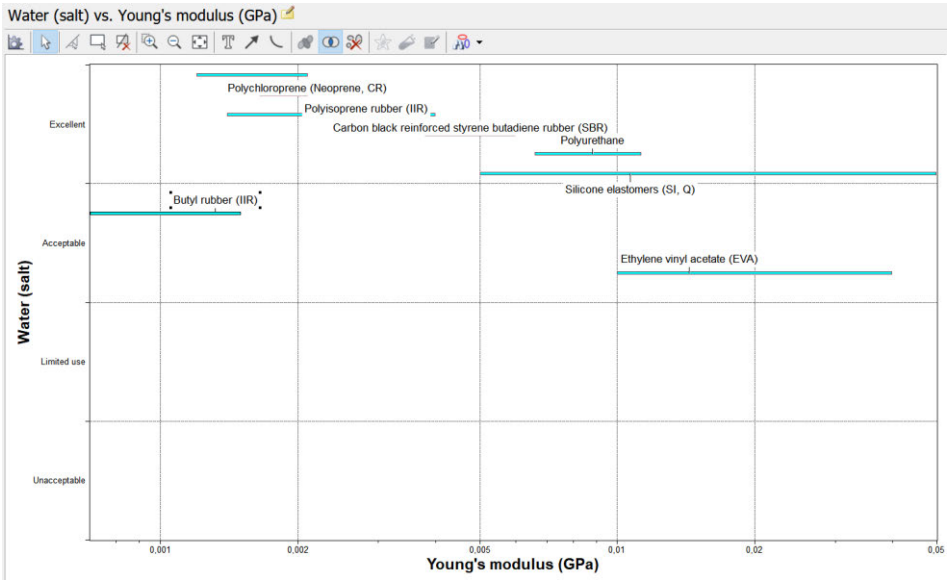


FIGURE A.11 – saltwater vs Young's modulus

Graph showing freshwater resistance vs Young's modulus.

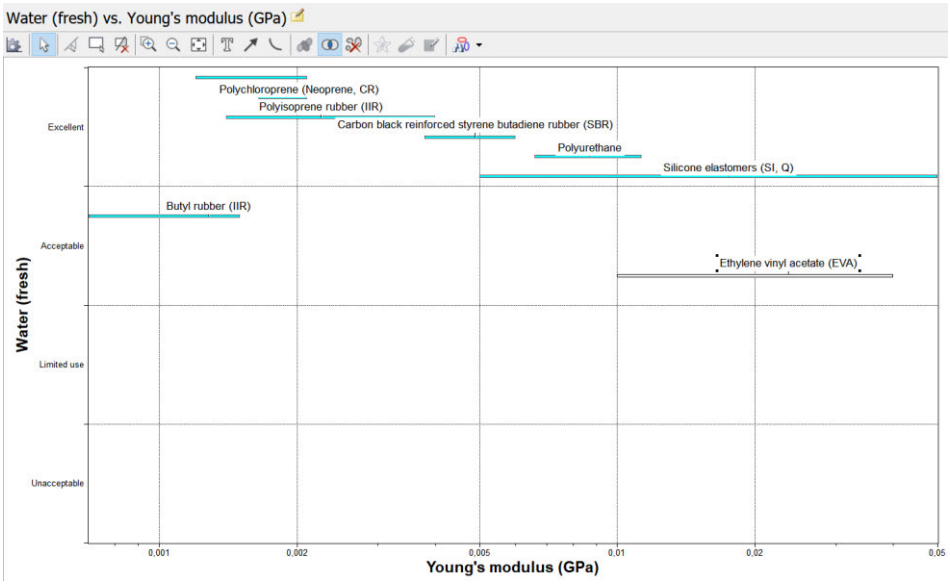


FIGURE A.12 – freshwater vs Young's modulus

Base material

For the base material of SoundAround we conducted a similar research. For this material we tried the flexibility of different materials we could find around the house and estimated a young's modulus similar to abs would be sufficiently flexible to comfortably put the necklace around the user's neck. For further development this must be calculated and simulated in larger extent, but for now we will use this estimate to determine our material choice. The young's modulus of ABS is between 1.19 en 2.9 GPa, so this is the range where the base material of SoundAround has to be located.
the UV radiation is less important for this part, for it is encased in a shell of silicone rubber, so only poor UV resistivity is filtered out.

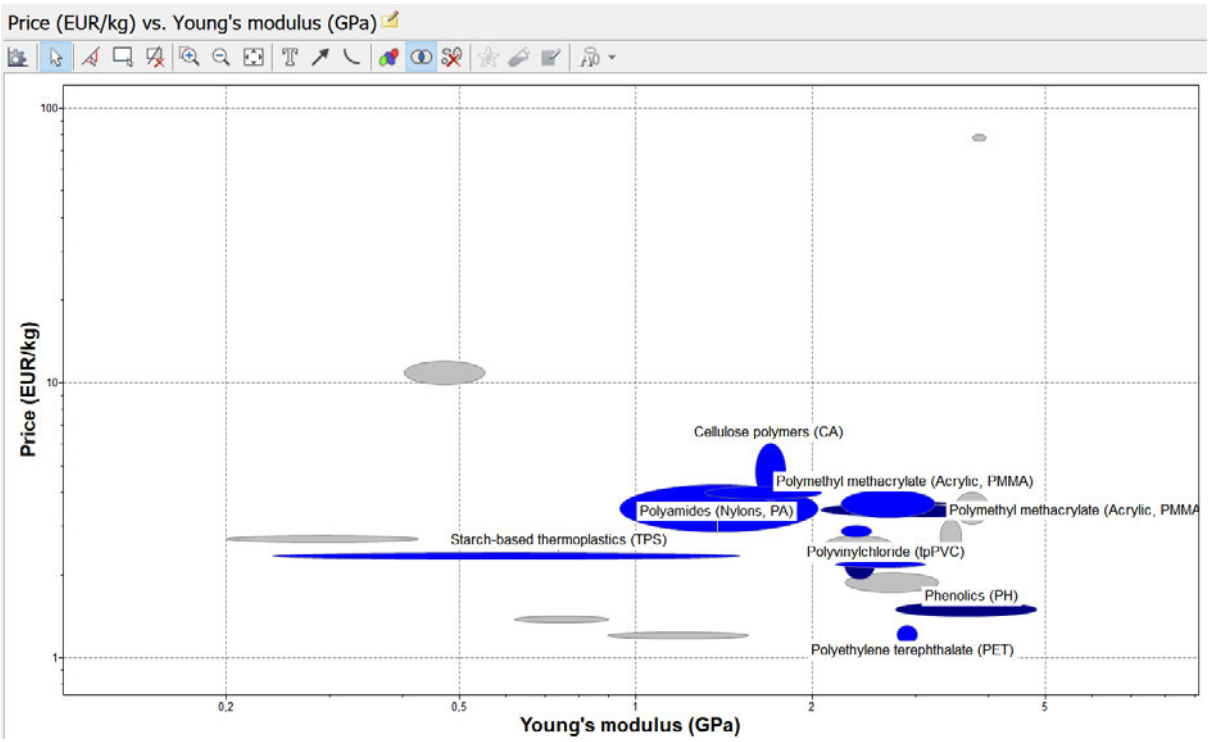


FIGURE A.13 – price vs Young's modulus

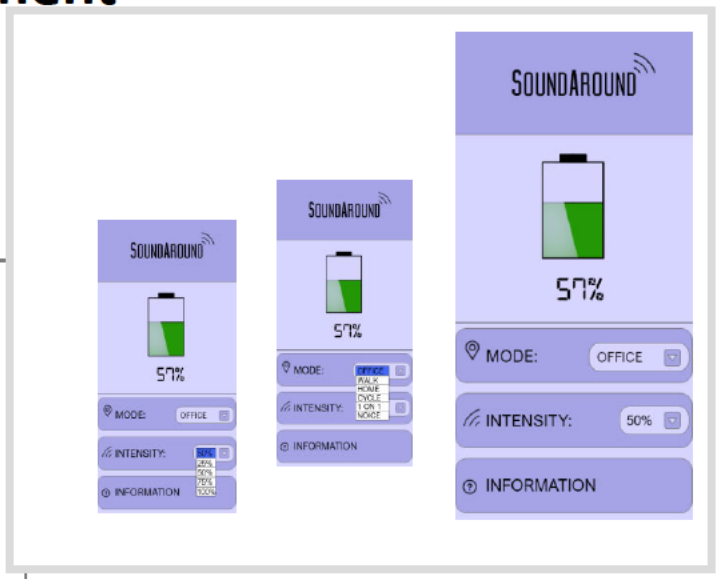
All materials depicted in blue are saltwater, freshwater and UV resistant and non-toxic. the material that fits this case the best would be Polyamides, also known as Nylons. This is a very moldable material that is readily available and recyclable. If our estimate of flexibility is too high, TPS (starch-based thermoplastics) might also be suitable for this is also a very well moldable polymer that has a wide range of possible young's modulus and is recyclable.

Conclusion

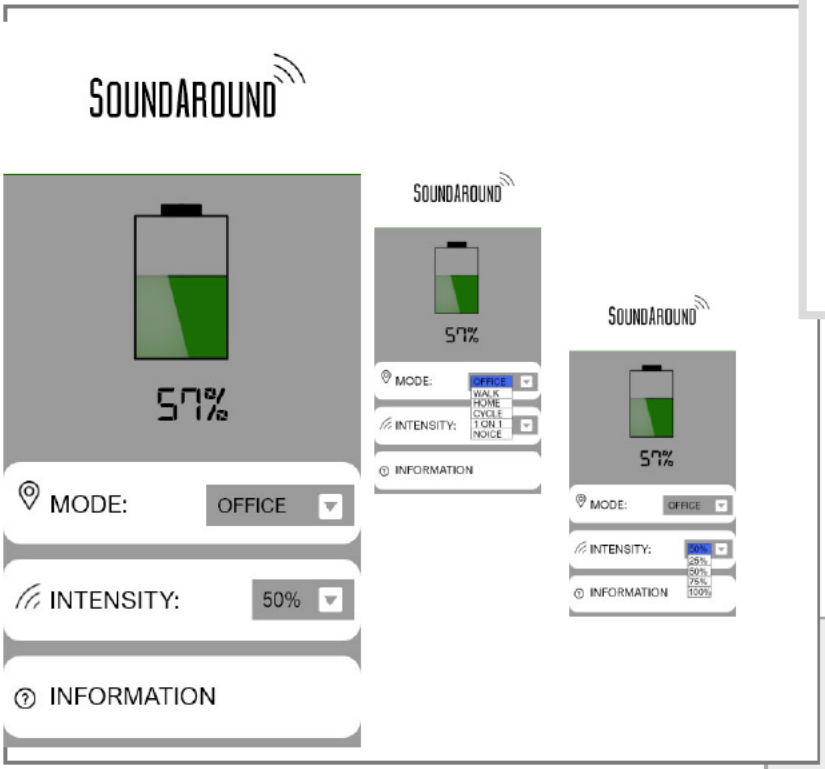
SoundAround will be constructed from a nylon injection molded body, with a silicone overmolding to provide the needed stiffness and texture. The nylon reinsures the necklace will retain its shape after putting it around the neck, and the friction of the silicone against the skin, together with the shape, will keep the necklace from shifting around.

8.5 Application development

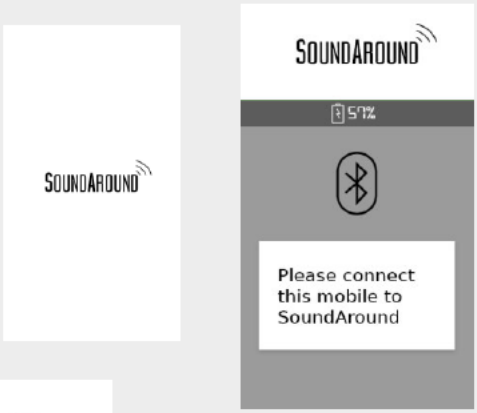
This page shows the evolvement of the application through time. A little explanation is given to point out the reasoning behind the changes.

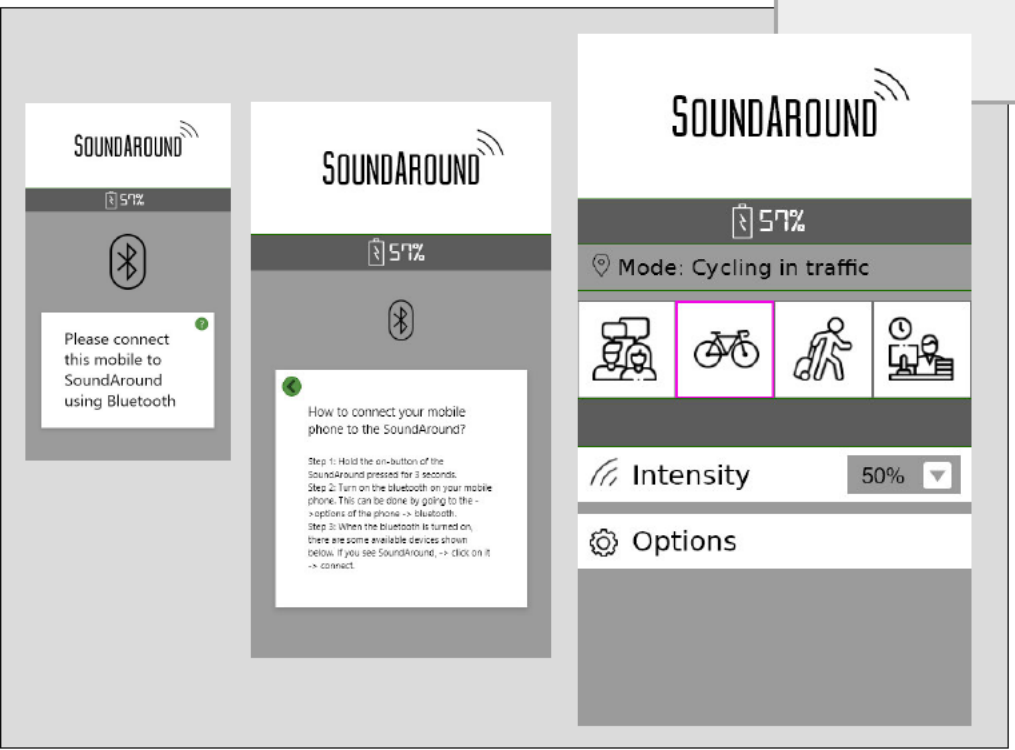


The first draft of the application showed all the functions the application should have. However it does not look like a modern application, this is tried to solve by changing the colours.



The application now does not have a loading screen and does not work if the mobile phone is not connected with the SoundAround





The modes are now shown in images, because that is the main function of the app, to change the mode.
The battery is a lot smaller, because it is not that important.
There is also added an explanation on how to connect the mobile phone to the Bluetooth.

FIGURE A.14a,b,c,d – application development

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TOESTEMMINGSFORMULIER

Voor het verzamelen en verwerken van persoonsgegevens.

Project: DesigningforSpecificUsers
Onderzoekers: Rik, Martijn, Floris, Gijs, Vera, Anne Roos

Bedankt voor uw medewerking aan dit project van de Universiteit Twente. Tijdens het onderzoek zullen de onderzoekers relevante persoonlijke gegevens verzamelen en verwerken. Hiervoor dient u dit toestemmingsformulier in te vullen.

1.1 Geldende afspraken:

- U heeft ten alle tijden de mogelijkheid om vragen te stellen aan de onderzoekers.
- Uw deelname is vrijwillig en u heeft het recht om zich op elk moment terug te trekken zonder opgave van reden.
- Al uw gegevens zullen anoniem worden gemaakt.
- Als uwgegevens niet meer nodig zijn, zullen de verantwoordelijke onderzoekers deze verwijderen.
- U kunt uw toestemming om gegevens te gebruiken intrekken.
- Uw gegevens worden niet met derden gedeeld.

1.2. Gebruik persoonsgegevens

Het volgende onderdeel gaat in op het verzamelen en gebruiken van uw gegevens tijdens sessies met de onderzoekers. Hierbij kunt u per stelling aangeven of u hier toestemming voor geeft. Hou er rekening mee dat de genoemde opnames zeer belangrijk zijn voor de onderzoekers en dat al uw gegevens anoniem worden gemaakt.

Vraagstelling	Graag aankruisen
Audio-opnames	X
Ik geef toestemming geluidsopnames te maken van de sessies.	X
Ik geef toestemming (delen van) de opgenomen audio te gebruiken in presentaties.	X
Ik geef toestemming de transcripties van de opgenomen audio te gebruiken in publicaties.	X
Foto/Video-opnames	
Ik geef toestemming foto's te maken van de sessies.	X
Ik geef toestemming de foto's te gebruiken in presentaties, waarbij gezichten onherkenbaar zijn gemaakt.	X
Ik geef toestemming video-opnames te maken van sessies.	X
Ik geef toestemming (delen van) de opgenomen video te gebruiken in presentaties, waarbij gezichten onherkenbaar zijn gemaakt.	x

1.3. Uw gegevens& handtekening:

Door het plaatsen van uw handtekening hieronder, gaat u akkoord met deelname aan het onderzoek, onder de geldende afspraken in 1.1. Daarnaast geeft u toestemming voor anoniem gebruik van de persoonlijke informatie die u met de onderzoekers deelt. Hierbij gelden de voorwaarden van gebruik zoals door u aangegeven in 1.2.

Voor- en achternaam: Lonneke Kolkman

Geboortedatum: 04-10-1990

Handtekening:

Datum: 7-4-2020 **Plaats:** Hengelo Ov