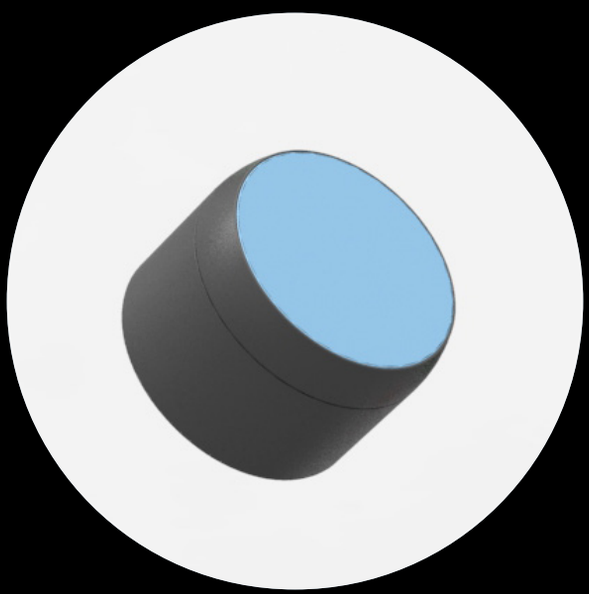

DESIGN FOR USHER AND BEYOND

A master thesis by Job van Dongen
4522915

USHERSYNDROOM
reaching out for sight and sound

TU Delft

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Industrial Design Engineering
Landbergstraat 15
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Abstract

Assignment

The Usher Syndrome is a hereditary disorder, where people's sight and hearing degenerates over time. As a result, being socially involved with other people can be challenging, especially in rooms that are low-lit and that include background noise. The project was initiated to help people with Usher Syndrome to still be able to socially involved, regardless of such challenges. Hence, the project assignment is stated:

"To design a non-stigmatizing, portable and affordable product for people with Usher syndrome, that offers enhanced control over lighting and/or acoustics, with the goal of improving their sense of involvement in social contexts."

Methods

Methods used in tackling this assignment are the classic design cycle by Roozenburg and Eekels, accompanied by the diamond model of Buijs. The design cycle entails evey step of the innovation process where in every step - by using the diamond model - information is gathered (diverging) and narrowed down subsequently (converging), steering many options to a single defined design outcome. Important steps are evaluating ideas and validating concepts with end-users, to ensure a meaningful product is realized.

Results

As a result of the deficits caused by Usher, having conversations with other people can be challenging. Especially, in a dark and noisy context like a bar or pub: the design context in this project. In understanding a conversation, speech contains the most information. By aiding the sense of hearing, speech intelligibility can be improved and in turn the sense of social involvement.

Important functions to for a design for people with Usher is this context is separating speech from background noise, reducing the distance between the speech source and person with Usher, allow volume control over the speech source and enable a connection with the hearing aid(s) and/or cochlear implant(s) of the person with Usher. Current products do not offer such functionalities.

Functions and requirements are ultimately translated into a design proposal: a microphone system called Micall. Micall is a system of small microphones that can be divided among friends/family. These Mics can pickup sounds from each person individually rather than capturing an entire scene like current microphone aids do. Speech is now separated from background noise and is made more intelligible. Feedback received from validation tests shows that the project assignment is validated: Micall is a non-stigmatising, portable product with enhanced control over acoustics and improving sense of involvement in social contexts.

Conclusions

After a full design project has been performed, a solution is found to the project assignment: Micall.
Micall proves to assess the main functionalities as stated in the project assignment by the validation of the end-users.

Discussion

A realisable design proposal is made, which can be developed in the near-future. However, more focus is needed on the sound engineering and manufacturing sides. With more advanced models deeper use insights can be gained. Also, investment models should be researched in order to come up with viable ways of developing, producing and selling the product.

Table of contents

I would like to thank the following people for their support throughout the thesis.

Ivonne Bressers for inspiring the project subject, for your perseverance, enthusiasm, optimism, energy and empathy. Your attitude makes the world a better place.

Wilfred van der Vegte and **Bob Groeneveld**, for coaching me throughout the project, being critical and honest, for asking the right questions and for the opportunity to graduate within this team.

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Giulia Frigo for your friendship, tranquility, understanding and encouragements.

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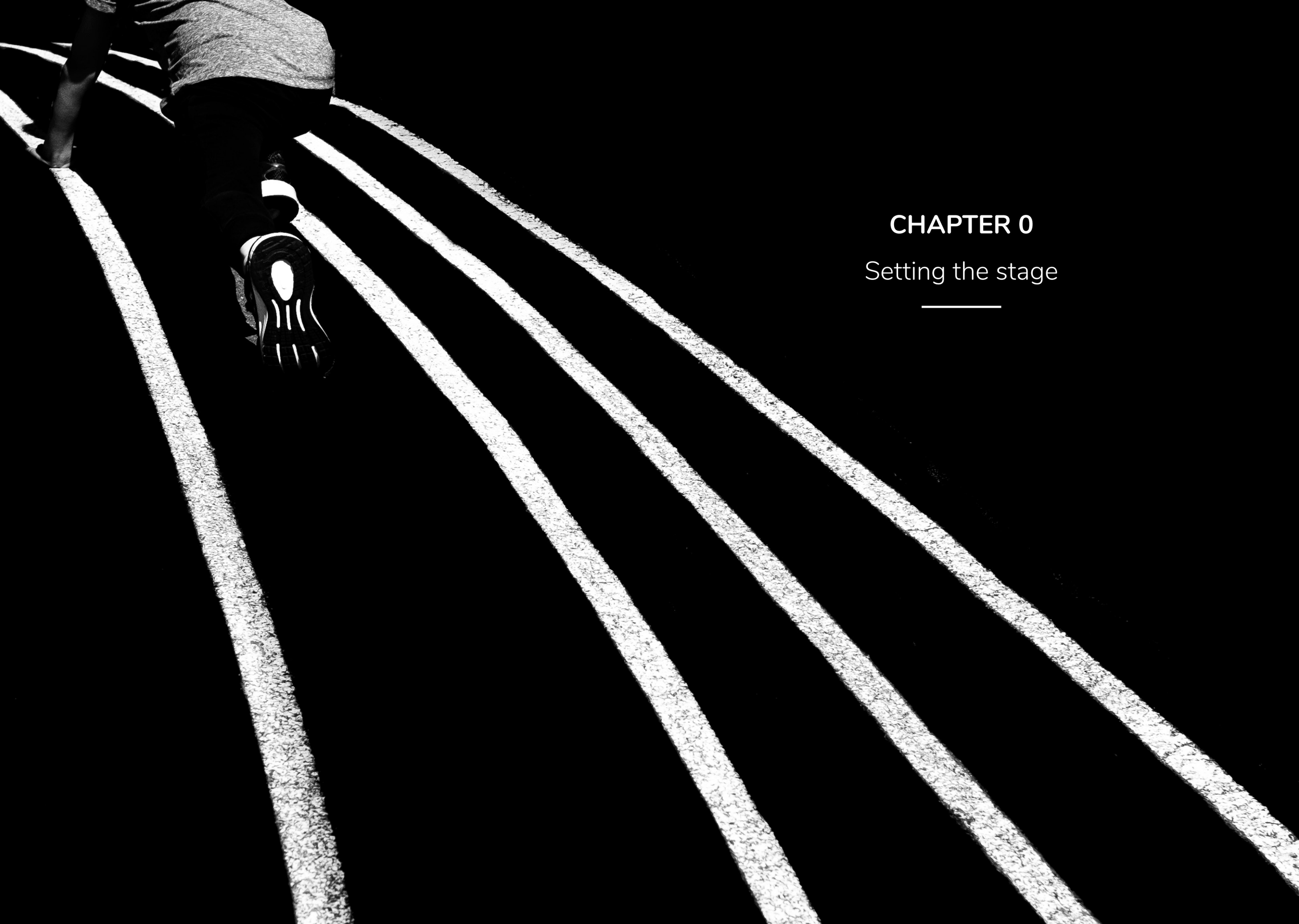
Ruben Stauttener for helping me on the electronic side of things, thank you for your time, enthusiasm and for thinking along with the concept.

"My advice to other disabled people would be, concentrate on things your disability doesn't prevent you doing well, and don't regret the things it interferes with. Don't be disabled in spirit, as well as physically"

~ Stephen Hawking



CHAPTER 0

Setting the stage

0.1

Introduction

Topic

The topic of the thesis was inspired by the notion that design for the human senses naturally leads to a meaningful design, a design with impact. The thesis focuses on designing for sensory deficits, specifically for people who suffer from Usher syndrome. The Usher syndrome is a hereditary disorder in which a person's visual and hearing abilities degenerate over time. The double sensory deficit of both sight and hearing is a form of deaf-blindness.

Anecdote

The subject of the thesis was sparked in a conversation with Mrs. Bressers, board member of the Usher Syndrome Foundation and Person with Usher herself. In an anecdote, Bressers spoke about a time she went to a restaurant with her family where the only available table in the restaurant was stowed away in a dark and noisy corner. As a result, both her sight and hearing were affected dramatically, making her unable to able to follow conversations and see anything. A dinner alone in the dark..

Vision

From a designer's point of view this anecdote should have never happened. How could such a vital part of social life become such a horrible thing to experience? Should a restaurant or any public place not be accessible to and enable to be used by everyone? Could there be designed a product that enables people that have Usher to go to any social activity, anywhere, anytime? Together with the Usher Syndrome Foundation and TU Delft the project was initiated.

Usher Syndrome Foundation

The Usher Syndrome Foundation is an organisation for and by people with Usher. The main targets of the Foundation is to raise funds for medical research on the topic of Usher, to make future prevention, recovery or treatment possible. Next to fundraising, the Foundation is working on brand awareness, general awareness of the disorder and advocacy amongst the public, for people with Usher and their families (Stichting Ushersyndroom, 2017). Moreover, the Foundation is a knowledge platform for people to get familiar with the disorder and on an international level it is aiming to establish a European network.

Consumer need

In initial conversations with different People with Usher it has become clear that there is an overall need for better and more tailored lighting and better controlled acoustics in social contexts like restaurants, bars and friend's homes. This would enable them to participate in such daily contexts which is important for them to feel autonomous, independent and live their lives just like any other.

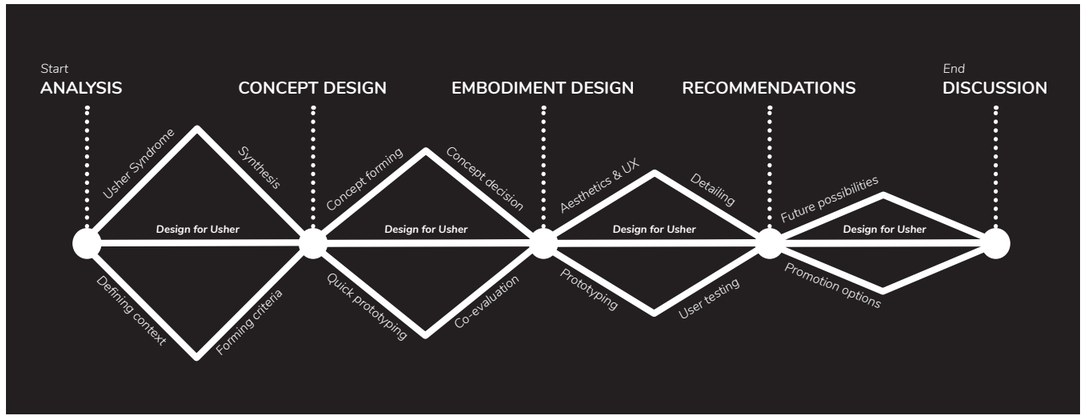


Figure 1
Thesis and process structure

Assignment and objectives

Resulting from the topic, anecdote, vision and target group needs, the following assignment was formulated:

"To design a non-stigmatizing, portable and affordable product for people with Usher syndrome, that offers enhanced control over lighting and/or acoustics, with the goal of improving their sense of involvement in social contexts."

The formulation serves as a starting point and vision throughout the design process.

This assignment intents to result in a product that could help people with Usher in their daily lives. Possible future sales of this product could in turn fund medical research. Moreover, the aim is to add value in both the brand awareness of the Usher Syndrome Foundation and awareness of the disorder, by the collaboration with TU Delft, as well as publicity though the final product and word of mouth during and after the project.

Structure

The thesis is built-up like a basic design cycle ((Roozenburg and Eekels, 1995). As a result of an analysis phase, ideas are sparked and transformed into concepts. These are evaluated with end-users and developed further into a more detailed prototype, which is evaluated and validated, again with end-users. The design is then perfected and implementation and future improvements of the design are then proposed. Above, figure 1 shows the diamond model-structure (Buijs and Valkenburg, 2000), where every vertex corresponds with a chapter in this thesis. By focusing on Usher throughout the entire process, a solution specifically for Usher is found, symbolised by the white line running through the middle of the figure.

Reading guide

Every chapter starts with a spread stating the title of the chapter on the left side, and a contextual picture and chapter introduction on the right. On following spreads different paragraphs elaborate on the chapter topic, where text is supplemented by photos and illustrations. The information shown in the report is distilled to present a clear and coherent story, leading to the final design. Complementary information is found in the Appendices, and is meant to back up the story told in the main text.

Enjoy reading and thank you for your time.

Job van Dongen

0.2

Defining design context

Introduction

Important for the decision of a context to design for is that this is done together with Ushers patients, as they know like no other how it is to experience a social context with their double sensory deficits. This paragraph gives a definition of what is meant by ‘social context’ in this project and describes a questionnaire that has been distributed. The conclusions of this questionnaire result in a decision for a context to design for.

Definition

A social context in this project is defined as a place, space, environment or scenario where multiple people come and socially interact together. This is a context outside the comfort zone of the person with Usher’s homes, since the home context is curated and specified as the user wishes it to be. This project is about social scenarios where this is specifically not the case, where the persons with Usher are at the mercy of whatever an outside context offers them in terms of acoustics and lighting (hearing and seeing).

Philosophy

A more specific design context can help defining the context factors, interactions, functions and design criteria of the project better. A questionnaire has been set up to find this context and is aimed at finding the hardest context for people with Usher to operate in. The philosophy behind this is that a product for the hardest context could theoretically also be used in contexts that are less of a challenge. As a result, a product is made that is most versatile.

Questionnaire

As there are many social contexts, there has been made a selection of contexts to work with. In cooperation with Bressers (personal conversation, November 24, 2017), nine contexts have been defined that include a range of relevant social interactions to People with Usher (Figure 3 to the right).
In an online questionnaire, 20 people with Usher and/or their relatives have been contacted. Here, the goal is to find overlaps between contexts and occurring problems to detect which context is the most relevant and why.

Structure

The questionnaire starts with an introduction about the thesis and explains the structure of the questionnaire. The participant is then asked to introduce themselves by filling in data like gender, age and level of hearing/sight. In an open question, there is asked for their experience within social contexts. Then, participants are asked to rank the 9 contexts on level of difficulty (Likert scale 1-5). Then, there is asked for an explanation for each ranking. The participants are then asked to sum up any products they use in the 9 contexts and how those are experienced. The questionnaire ends with a possibility to share any experiences they have had social contexts. Participants are thanked for their participation and asked for their willingness to participate in possible future research.
The questionnaire form can be found in Appendix I.

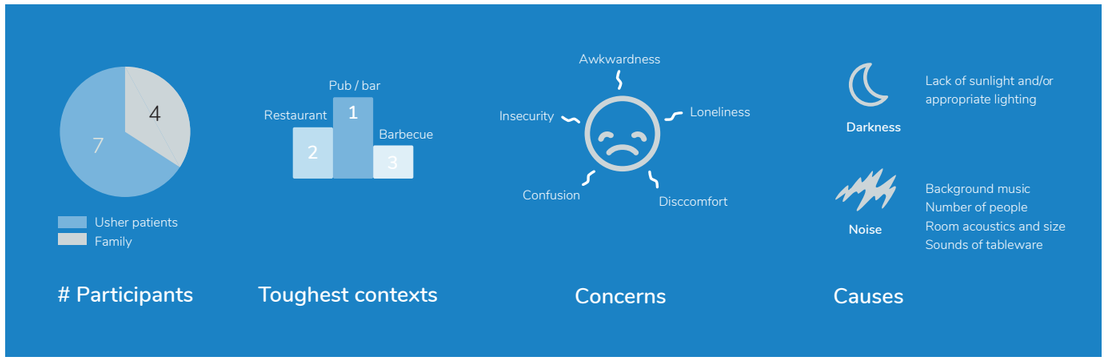


Figure 2
Questionnaire results, summarized.

Results

The results of the questionnaire are displayed in figure 2. As shown in these results, the bar/pub-context is the most relevant one; it scores an unanimous 5 on difficulty to operate in and includes the concerns and context factors that were recalled most. Most important factors are darkness caused by a lack of appropriate lighting and loudness caused by a mix of many people and surrounding sounds. People with Usher use a number of aids, but none of them are specifically useful in the 9 contexts.

Conclusion

According to people with Usher and their relatives, the bar/pub context is the most difficult to operate in. Hence, this is the chosen design context. Main reasons are the background noise and low-lit spaces. Amongst the aids that someone with Usher uses, there are none that solve these problems sufficiently.

Figure 3
9 social contexts

0.3

Chosen context experiences

Introduction

It goes without saying that the experience that most people have within pubs is different for those who have Usher Syndrome. To imagine how someone with Usher operates in, or how it would be like being in the shoes of someone with Usher in a pub, a number of analyses have been performed. This paragraph describes observations of people with Usher in a pub as well as the self-experience of 'mimicking Usher'.

Pub observations

A charity event was organised by the Usher Syndrome foundation, located in a pub in Nijmegen. This posed the perfect opportunity to experience people with Usher and their friends and family in the design context. Here, observations and conversations were made, gathering insights about people's behavior, ways of coping and problems faced. From these observations a number of things have become clear, displayed in figure 4 to the right.

Mimicking Usher Syndrome

To experience a pub like an Person with Usher, the hearing and seeing deficits of someone with Usher have been mimicked. For this experiment, music earplugs are used that are usually worn by concert visitors, dampening and muffling surrounding sound (image 1, next spread). Next to earplugs, an Usher-glasses template (from the Usher Syndrome Foundation website) is cut out and fit into a pair of glasses, turning normal vision into tunnel vision (image 3, next spread).

The experiment has taken place in the I.d-cafe at the Industrial Design faculty of TU Delft. To the right, an overview of the experiences of this experiment is given. Images showing an impression of this experiment are displayed on the next spread.

Figure 4
Pub observations

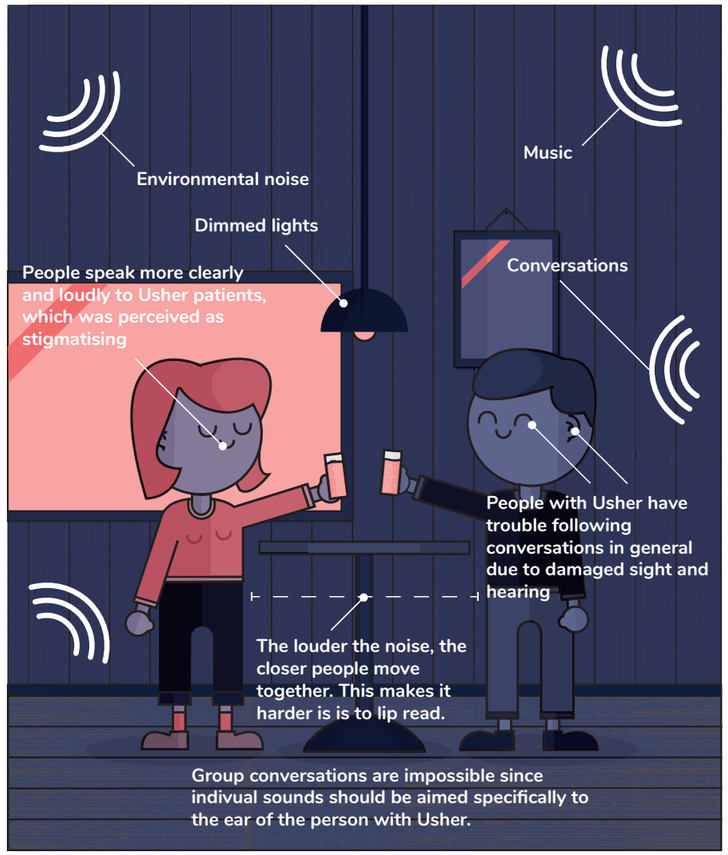


Figure 5
Mimicking Usher experiences

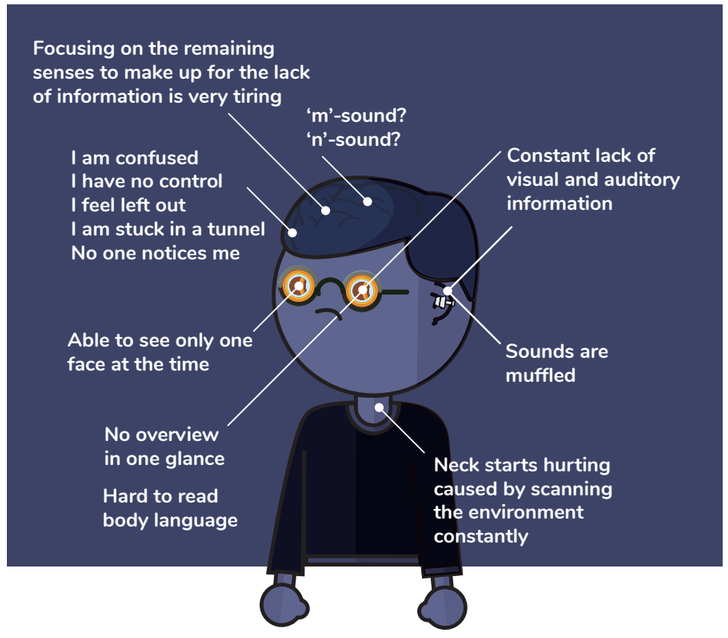


Figure 6
Quotes mentioned during the co-evaluation sessions

“Bij een groep doe je mee voor piet snot.”

“When it concerns group conversations, you’re just participating for show.”

“Help!’ Rustig blijven, glimlach, geduld..”

“Help! Stay calm, smile, be patient..”

“‘Een eilandje in een rumoerige massa.”

“An island in a noisy crowd.”

“Ik ga bijna niet meer naar de kroeg maar vind het eigenijk heel gezellig.”

“I hardly go to a pub anymore, but actually I really like going there.”

“‘Liever alleen thuis dan alleen tussen de mensen.”

“I Rather stay home alone than being alone in a crowd.”

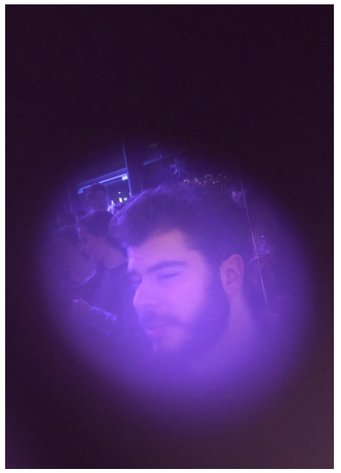


Image 1 (left page ,image to the left)
Usher glasses and earplugs

Image 1 (left page, image to the right)
Usher glasses and earplugs worn in the mimicking session

Image 3
Set of 4 photos shot through the *Usher glasses*

Pub experiences by people with Usher

Paragraph 2.4. describes co-evaluation sessions done with people with Usher, where lo-fi prototypes are tested and evaluated. From these sessions, pub insights have arisen, elaborated below.

Mixed feelings

According to the participants, the context of a pub is experienced as both positive and negative at the same time; it is a relaxing and cozy environment, while at the same time it is chaotic and is associated with insecurity.

Positioning

People with Usher have ways of dealing with the context by finding the most light and quiet spot, preferably with their backs to the noise and spotlights. Most conversations take place with people they are familiar with and mostly happen 1-to-1 with people directly positioned next to them.
Tere is an evident difference in difficulty of having a 1-to-1 conversation versus having group conversations. The first is experienced as intense but doable, the latter is experienced as very hard to impossible.

Context feel

Next to the fact that people with Usher want to see and hear other persons, it is important for them to get an idea of their surroundings like food and drinks on the table or where people are positioned in the room. This prevents for example knocking over glasses or losing track of a friend. Moreover, knowing the surroundings improves a feeling of independence and safety, features that are strongly suggested / preferred.

Hearing vs. sight

There is an apparent difference between people that still have ‘strong’ hearing or ‘strong’ sight. This depends on the stage and development of the disorder, which is linked with age but is different for each and everyone. Someone might see relatively well but has severe hearing problems, while someone of the same age sees less but hears quite alright still. In an ideal scenario a product would be designed that offers both aid in hearing as well as in seeing. Naturally, for people with strong hearing it is less apparent to have a solution that offers improved sound, whereas people with strong sight has less of a need for a solution that includes light.

Opportunities

From a light perspective, to this day there is no product that fills the gap need of having a light that is both portable, adjustable and is able to light-up the table as well as people’s faces.
From a sound perspective, there is no product that fills the gap need of having an affordable microphone system that is convenient to use (handing out and operating) with more than one person, and facilitates flexible group conversations
Audio and hearing aid/CI-manufacturers are working on improving sound experience for hearing-impaired people. This, in contrast with adjustable ‘on-the-go’-lights, which are not found on the market.
There is, however, a common skepticism amongst the participants about aiding products, because of unpleasant experiences in the past.

Quotes

Quotes resulting from the co-evaluation sessions (Paragraph 2.4) indicate people with Usher's experiences in a pub context. These are displayed on the top of this spread. The goal with this project is to relieve these concerns and change these negative experiences into positive ones.

Conclusion

Identifying with people that have Usher helps a great deal in understanding issues found in the crowded, noisy and low-lit social context of the pub. It is hard for people with Usher to have one-to-one conversations, let alone follow other 1-to-1 conversations or having group conversations. A feeling of being excluded is experienced, as a result of the tunnel vision. The process of trying to grasp what is going on in the context is very tiring, because of the extra effort of focusing on speech and necessity to move the head in order to get an overview of the surroundings. These findings are used as input and inspiration for ideation later on in the design process (chapters 2 & 3).

0.4

Problem definition

Introduction

This paragraph describes the problem statement faced in this thesis. The main problem and its factors are explained, in relation to Usher and accompanying hearing and sight deficits.

Problem at hand and scope

Although the Usher syndrome in itself is the main problem, a more specific problem definition is formed to design with a focus, a scope. It is not the aim to 'solve' the disorder in its totality; it is offering help to cope with the disorder.

The problem with hearing and sight with People with Usher is often the addition of several context factors that negatively influence the senses. They are already damaged to begin with, let alone adding elements like background noise, low-light settings, lack of body language, people speaking softly, etc. An overview of the effects of the addition of several layers of context factors is shown in figure 8 to the right.

Within the scope of the project, one or more of these factors will be addressed, to relieve the problem at hand.

Context

For people with Usher, the most comfortable context is a home context: here, all context factors have been optimized to facilitate the disorders. Social contexts (contexts where people come together to enjoy company, leisure activities and socialize) outside their homes are different however; the person with Usher is exposed to context factors that are out of their control. Such factors are mapped out in figure 7 to the right.

Design brief

By enabling people with Usher to still participate in social contexts, the hypothesis is that it will increase their quality of life and motivate them to be part of the society and have a good time, as opposed to wanting to stay at home, cancel social invitations and feeling left out. Moreover, Any solution that is found should be 1) non-stigmatising 2) portable and 3) affordable, to 1) protect integrity 2) expand the range of use conveniently and 3) enable anyone to buy the product and to not add to the notion that assistive technology should be expensive necessarily. Hence, the problem definition as recalled in paragraph 0.1 was formed:

"To design a non-stigmatizing, portable and affordable product for people with Usher syndrome, that offers enhanced control over lighting and/or acoustics, with the goal of improving their sense of involvement in social contexts."

It is envisioned that by tackling this problem definition, it is made easier for People with Usher to leave the comforts of a controlled home-environment and make being in social contexts a positive experience. And as a result, have a stimulating effect of wanting to go out again in the future.

Conclusion

The main target of the thesis is not to 'solve' the Usher syndrome; it is finding solutions to help coping with it. Specifically, in a social context where factors could make social interactions difficult. Factors include low lights and noisy background sounds. The focused problem statement aims at finding a solution to overcome such factors.

		Context factor 1	Context factor 2	Context factor 3	Context factor 4	Context factor 5	
Hearing	**Current state** damaged	Speech resolution and band-width	Background noise (including reverberation)	Unclear body language	Unclear lip reading (bad sight)	Conversation distance	**End state** damaged and troubled
Sight	**Current state** damaged	Low light	Bright light	Random movements	Unexpected events	Unclear body language	**End state** damaged and troubled

Figure 7
State of hearing and sight and the accumulation of factors that could worsen the senses. (personal communication with Bressers, October 26, 2017), (Boothroyd, 2006)

Figure 8
Contact factors home vs. outside home described by a Bressers (personal conversation, Oct 20, 2017)

CHAPTER 1

Analysis

1.1

Usher syndrome

Introduction

This paragraph generally describes the Usher Syndrome and how the senses of sight and hearing are experienced by people with Usher and how different factors play a part in its perception.
A central source for information about the disorder and its effects is Mrs. Bressers (Person with Usher, board member of the Usher Foundation and graduation project mentor), because of her experience and expertise in the field of the Usher Syndrome.

General overview

The Usher syndrome (named after ophthalmologist Charles Usher) is a hereditary disorder in which a person's visual and hearing abilities degenerate over time. The double sensory deficit of both sight and hearing is a form of congenital deaf-blindness. Other types of deaf-blindnesses can develop during a person's life (accidents, diseases, old age) but are not classified as Usher since these are not caused by the typical 11 'USH-genes' , responsible for the expressions of Usher.

As time progresses, an Person with Usher's sight will turn from full vision to a small straw-like cylindrical vision (image 4 to the right), to ultimately being completely blind. This is currently incurable and untreatable.
The sense of hearing decreases over time, up to the point where there is no hearing left. Damaged hearing is treated with hearing aids (**HA**) and eventually with cochlear implants (**CI**) when the level of damage cannot be accounted for by the hearing aids. From this point on, HA and CI will be used as abbrevitons for hearing aid and cochlear implant, respectively.
Unlike the affected sight and hearing, an Person with Usher's intelligence is not affected. Partly because of this reason, they face psychological challenges such as depression, insecurity, anxiety or even suicide (Wahlqvist, M). The degenerating nature of the disorder even causes Ushers to generally avoid each other; when two People with Usher of different ages meet there is a confrontation of 'seeing how the disorder was years ago or how it could develop in the future', and this is often experienced as too intense to cope with (I. Bressers, personal communication, October 26, 2017).

Worldwide, 400.000 people have been diagnosed with Usher syndrome, of which 800 to 1000 people live in the Netherlands (Stichting Ushersyndroom, 2017). These numbers are relatively small compared to for example 50 million people with Dementia in 2017 (Alzheimer's Disorder International, 2018) and 14.1 million cancer cases in 2012 (World Cancer Research Fund International, 2018).

As told before, the Usher syndrome is caused by alterations of a number of genes. Ongoing research is still discovering new genes. Different mutations in these genes cause different types of Usher (Hartong, Berson, Dryja, 2006). The three types are displayed in figure 9 to the right. With

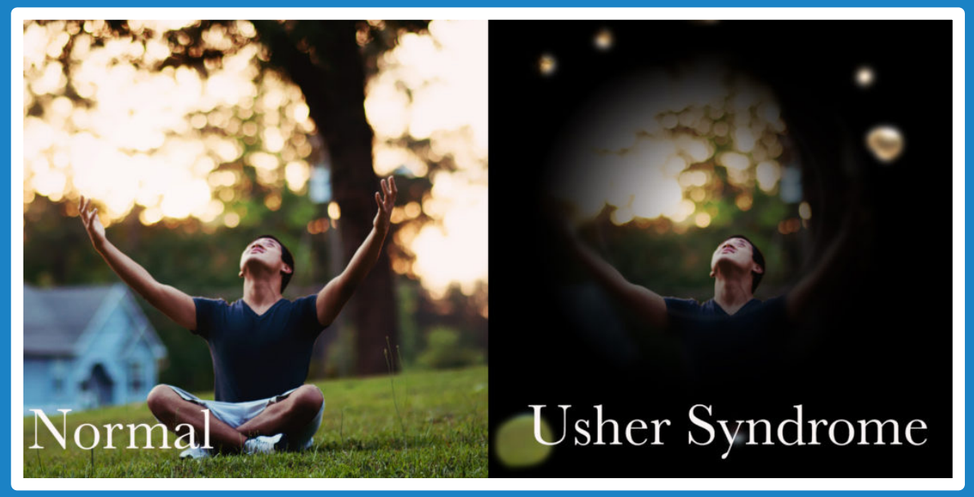


Image 4
A photo of Eddie Madera illustrating what Usher Syndrome looks like (Deaf-blind Citizens in Action, 2016)

USH1
Born deaf, first signs of night blindness and tunnel vision at the age of 10, degenerating vision, balancing problems.

USH2
Born with moderately bad/bad hearing, night blindness and tunnel vision after 10 years, degenerating vision, some people's hearing degenerates over time but is argued that this is the result of the degeneration of the vision (Reisser et al.).

USH3
Rapidly increasing loss, night blind and tunnel vision before or after 10 years, degenerating vision, sometimes balancing problems.

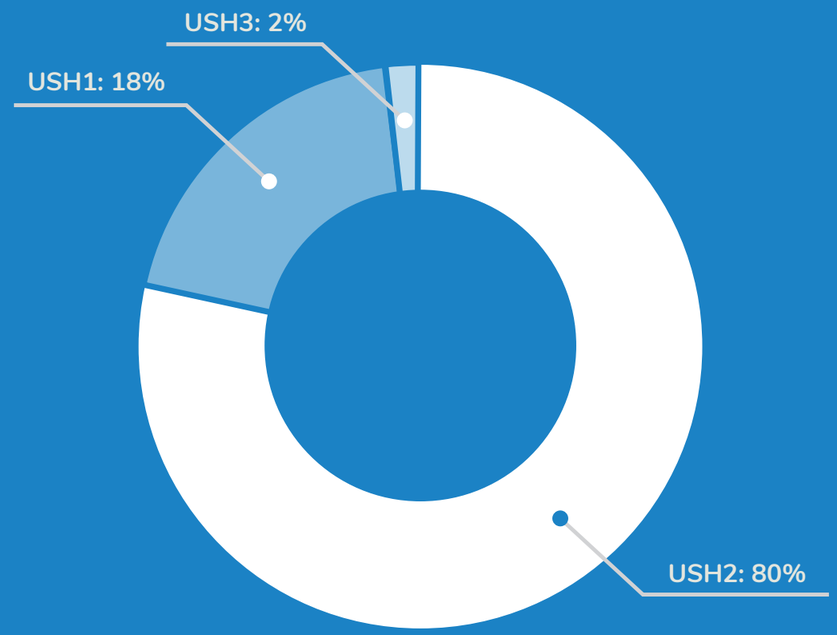


Figure 9
Worldwide statistics, after Stichting Ushersyndroom, 2017

regard to the thesis, there is no clear focus on designing for a specific type of Usher or a specific stage a person with Usher is in. This is due to the unique altering nature of the disorder for every person. Herein is the age, type of Usher and the way, speed and order of the showing symptoms varying in such a manner that it is not useful - or even impossible - to design for just for one type of Usher.

Sense of hearing of an Person with Usher

For any Person with Usher, the sense of hearing will decrease with 5 to 10 decibels every 5 to 10 years from the age of 10 (Stichting Ushersyndroom, 2017). To account for this, HAs and CIs are used as remedies (Figures 12 and 13 on page 29).

Both hearing aids and CIs are subject to 'coping with' incoming sounds. The more clear and noise-free the incoming signals, the more clear the representation of the audio-information will be displayed to the inner ear, hearing nerve and brain. This clarity expressed in a signal-noise-ratio (SNR), indicating how 'clear' the target message is recognizable amongst surrounding sound. The higher the SNR, the easier it is to understand the message and vice versa. A high SNR would be for example a conversation in a quiet room, a low SNR would be a conversation in the middle of a talking crowd.

It is difficult to compare the SNR ratios amongst People with Usher and to people with normal hearing because of the specific altering nature of the disorder and the way/ how efficient the HAs/CIs help in enhancing the sound individually. Because of these factors it is hard to have one SNR-benchmark to adjust a sound situation to: sound has is processed differently from Person with Usher to Person with Usher.

The audiogram on the next spread shows a comparison between an Usher type 2 patient and a person with normal hearing, clarifying the difference in audio-perception.

Audiogram

When a person's hearing ability is measured, a hearing threshold is expressed in a graph called an audiogram. This threshold indicates the number of decibel (loudness) that is needed for a person to perceive a sound at a certain frequency. Thus, in this graph, the loudness (dB) is expressed as a function of the frequency (Hz). The top set of lines in Figure 10 indicates normal hearing (X for left ear, O for right ear) (Alshuaib et al.). The bottom two lines indicate the hearing of a Type 2 Person with Usher (ASHA, 2017). The figure shows that as frequencies go up, an Usher type 2 patient is in need for more loudness in order for them to perceive sound the same as someone with normal hearing.

Background noise

For a person with Usher, background noise complicates the speech intelligibility; they rely on their CIs and/or HAs to make sense of the sound that is perceived. When there is just one target signal (on-to-one conversation) it is less complicated for such devices to translate the sound to audio nerve pulses or louder sound. When there is noise however, is more complicated since more sounds are offered from all kinds of directions, sources, volumes and frequency ranges. Referring back to the SNR, It is easy to understand that it is relatively easy to have a private conversation but background noise can complicate the equation.

Henry and Heinz from Purdue University (Idiana, USA) argue that CIs and hearing aids should not solely focus on the 'decoding' of how sound is perceived by the ear, but to rather focus on the background noise that is present, since - as

Normal Audiogram (top) vs. Type 2 Usher Audiogram (bottom)

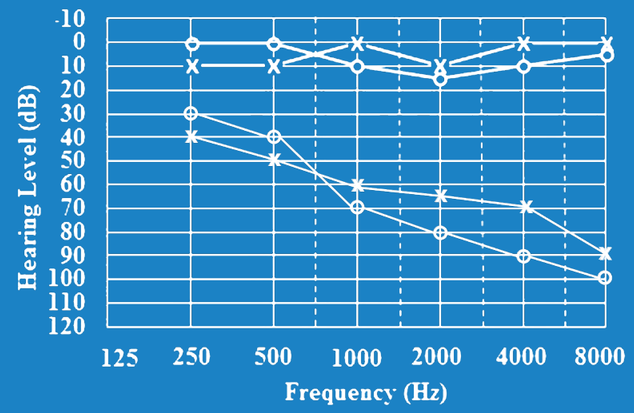


Figure 10
Normal audiogram (top) vs. Type 2 Usher audiogram (bottom) (X for left ear, O for right ear). Derived from ASHA, 2017.

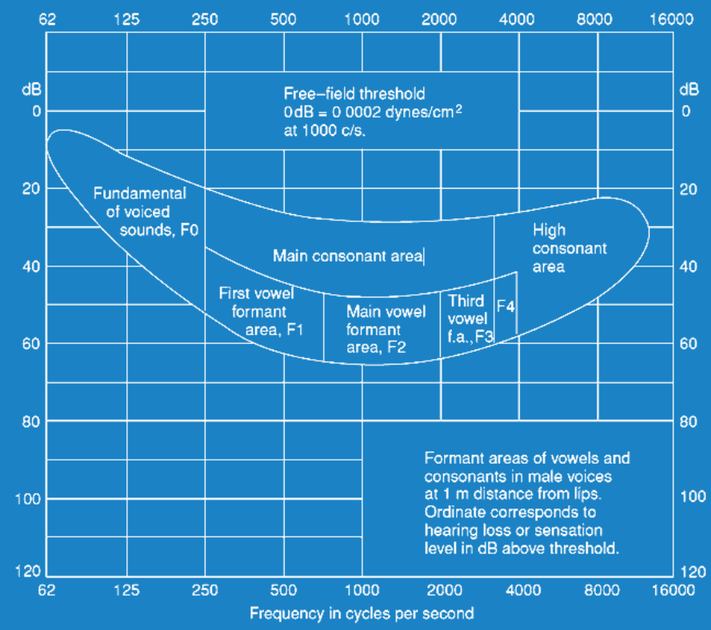


Figure 11
Speech banana of male voices. (Klangpornkun., Onsuwan., Tantibundhit., Pitathawatchai., 2013))

they recall it - the auditory nerve fibers are distracted by the background noise (Henry, Heinz). Also, Hygge et al (1990) show the same results of hearing-impaired people having a hard time performing with background noise, due to reduced temporal resolution (the resolution in which audio-information is processed by the brain). By canceling out background noise one 'allows' the auditory nerves to focus and to hear in the - for People with Usher - already limited hearing spectrum.

Clear speech and lip reading

Clear speech is about techniques to focus on when speaking with a person with an hearing impairment. This can be done by speaking more slowly, take breaks in between words, speak louder, make words sound longer, a focus on the sound quality of the vowels in the words and have more intense stop consonants (to clearly stop the sound of a consonant) (Picheny et al.). Knowledge about how to converse with a person with an hearing impairment can increase the intelligibility and quality of the conversation. Moreover, clear articulation of words can stimulate lip reading, a technique widely used by People with Usher to link what they see with what they hear. This includes movements of the lips, expressions of the face, gestures, body language and context indicators (Stichting Hoormij, n.d., Medicinfo. , n.d.). When lip reading is unclear or non-visible by a lack in the sense of sight, the hearing is affected correspondingly.

'Normal hearing' can adjust automatically various factors and is thus better equipped in coping with dynamic sound situations. Healthy sight is able to read body language and read lips, which make up for possible lacking audio information.

Sense of sight of an Person with Usher

The degeneration of sight of a person with Usher is mainly caused by a phenomenon called Retinitis Pigmentosa (RP). This is an umbrella term for a number of hereditary disorders of the retina. The nature of this disorder is for the light sensitive cells (rods and cones) in the retina to degenerate, slowly shrinking the field of sight to an increasingly smaller tunnel. As a result, people have trouble seeing during twilight hours and in the dark and become more blind as time passes. Research is ongoing for treatment of RP (Hartong et al., 2006). Having RP is no reason for the need of wearing glasses specifically, since it is not the ability to focus (which is done by the eye cornea and lens) that degenerates; it is the receptors of light that degenerate, which has no remedy as of yet. Some factors affecting the sight of someone with RP however, are contrast, brightness, the abundance of light in the environment and the location of the light source relative to the person.

As shown in image 4 and "Usher-mimicking session"-pictures in paragraph 0.3., the field of sight of someone with Usher looks much like a tunnel. The tunnel differs from patient to patient, because of the unique developing nature of the disorder. The sharpness of this tunnel however, is dependent on the specific light situation in a context. Light strength can be too low, too high, just right or somewhere in between. As an Usher's sight is already compromised, it is vital to have the right light conditions to make the best of this compromise. The optimal situation would be to be in daylight, preferably diffused or indirect daylight. At night however, the light strength is often low (faint street lights, atmospheric candles, dimmed spots), causing a blurry tunnel.

Sum

It is often thought that the effects of seeing and hearing deficits seems to be a linear accumulation of the two. For example, the notion that vision and hearing loss of both 30% would lead to a loss of 60% in total. However, their relation to each other is more complex. A study of Reisser, Kimberling, and Otterstedde (2002) shows that when type 2 People with Usher lose visual cues for communication, they perceive their hearing to be worse.

As Bressers (personal communication, October 26, 2017) recalls it correspondingly, the loss of sight affects the hearing (e.g. it is harder to read lips) and the loss of hearing affects the sight (e.g. it is harder to anticipate a moving object). Bressers calls this the 1+1=3 effect, where helping one or both senses can lead to a greater total as a whole, and vice versa.

Conclusion

Usher syndrome patients suffer from a double degenerating deficit: becoming deaf-blind over time. Thus-far the degeneration of both is non-curable, however is mediated with cochlear implants, hearing aids or external factors as proper lighting or reduced background noise. Next to physical effects, Usher also has a mental effect on its patients, including anxiety and insecurity. By helping at least one of both senses, the effect on sight and/or hearing can be increased dramatically.

1.2

Hearing tools

Introduction

Since cochlear implants and hearing aids are such vital interfaces between the world and People with Usher, this sub-chapter is dedicated to these means. Elaboration is given on the use, functions and ways of connecting. No paragraph is dedicated to primary seeing tools, since there is no sight-equivalent to HAs or CIs apart from bionic eyes. Such advanced technologies are outside the scope of this project.

Cochlear implants

In a CI, the conventional hearing channel, eardrum and bones in the middle ear and the hair cells are bypassed to perceive sound, mainly for middle and high frequencies (ASHA, 2017). A CI is a hearing device existing of roughly 4 parts (Figure 12 to the right): A behind-the-ear (BTE) piece (1), an outside coil (2), a surgically inserted coil (3) and wire with electrodes (4). Microphones in the BTE-piece (5) capture acoustic sound from the environment and transforms and converts this into electric pulses. These pulses are sent from the outside coil to the inside coil. This coil is attached to a wire with electrodes. This wire runs to the inner ear and electrodes are connected directly to the cochlea (6). Here, the hearing nerve is stimulated, enabling the brains to process ('hear') sound.

In some CIs, the normal way of hearing is used still, however just to amplify low frequencies. This, since these frequencies degenerate latest in the degenerating process of the Usher syndrome; the longer someone is able to make use of the normal hearing abilities, the better. In such CIs, there is a wire, amplifier and speaker included, as shown with the hearing aid in figure 13 (7).

The resolution of which sound is being offered to the hearing nerve by a CI is lower than that of a natural ear. Due to technological restrictions and available space on the cochlea, a maximum of 24 electrodes can be connected to the nerve (Namasivayam, 2004). For now, this is displaying the highest possible resolution, but it is not comparable to the resolution generated by the thousands of hearing cells present in a healthy ear.

Since a CI does not use the hair cells that degenerate over time but replaces their functions, it is a more 'durable' way of treating the sense of hearing as opposed to using hearing aids. However, surgery could have complications (Loundon et al.), could be very expensive (depending on the country of surgery and health insurance plans) and demands hearing training afterwards. Moreover, since the technology is relatively new (first cochlear recipient in 1978) (Cochlear Ltd), the technology has not fully matured yet and is subject to software and hardware developments. Specialists call this the 'electro-neural bottleneck"; the relationship between acoustic signals from the environment and the use of technology applied to auditory central nervous system (Namasivayam, 2004).

Hearing aids

In processing sound, hearing aids function differently from CIs. Here, sound from the environment is picked up by a microphone in the aid (BTE or in the ear) (5), is amplified (instead of transformed) and played through a speaker close to the eardrum (7). The amplified sound enables a person to hear sound better. This this is called linear amplification: sound which is amplified linearly over (parts of the frequency range.

Hearing perceived by a hearing aid cannot be compared to the hearing of a healthy ear due to the damaged hearing cells

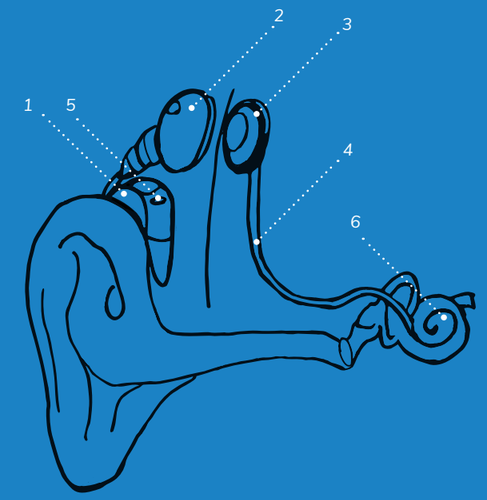


Figure 12
Ear with Cochlear implant

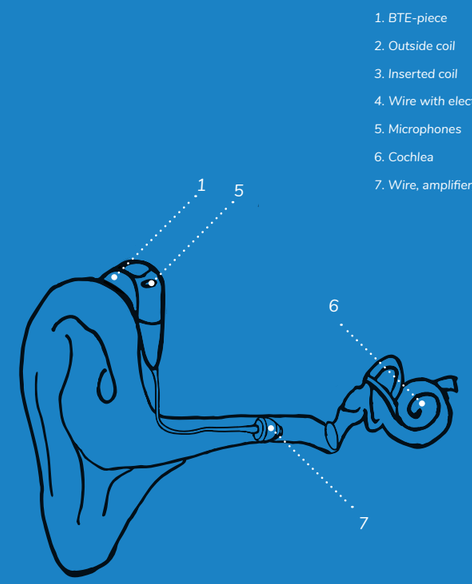


Figure 13
Ear with hearing aid

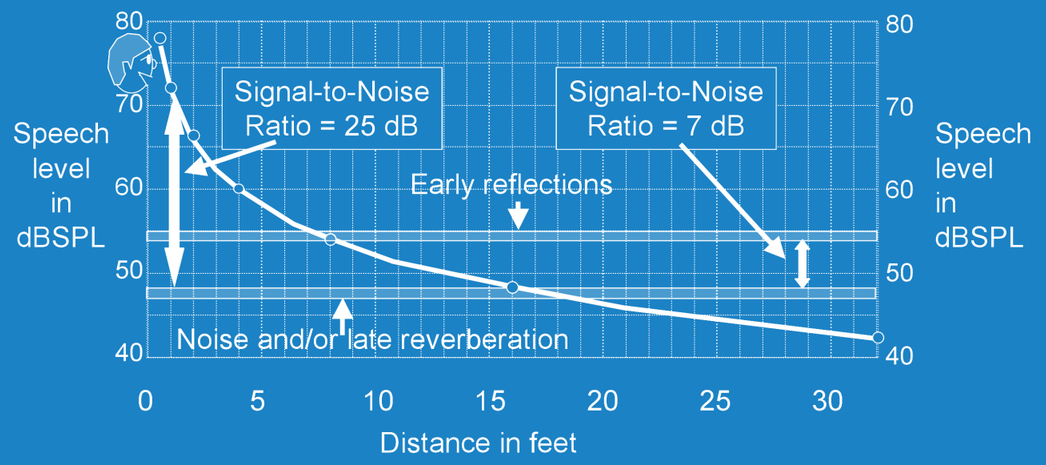


Figure 14
SNR ratio increases as distance from source to recipient decreases
After Boothroyd, 2006

that remain present, no matter the presence of the aid. The aid optimizes what is left of the sense of hearing.

Control and connections

CIs and HAs are both controlled by dedicated buttons on the outside of the BTE-piece, where it can be switched on/off or be switched between different audio modes (for example a mode for conversations, a mode for hearing loops in public spaces, etc.). Some CI- and hearing aid devices allow for software control through a smartphone app, for a more convenient user experience. The trend is to integrate these connection means in new CIs/HAs (Hearing Solutions of North GA., 2017, Hear.com, 2018).

To the right, an overview is given of how audio sources are connected to CIs and HAs. The nature of the sound source determines what means are used. For example, in a situation without background noise and close distance between source and Person with Usher no additional aids are needed on top of hearing aids or CIs. However, when there is noise or distances increase (for example in a restaurant or during a classical concert respectively), different means can help in coping. Herein different interfaces (body-worn devices and smartphones) and types of signals are used, each with their pros and cons. Appendix F explains these means, interfaces and signals in more detail.

Software / hardware

Both CIs and hearing aids have software and hardware that process incoming sounds, translating the sounds to the brain as natural as possible. This remains highly personal, as every person experiences their impairments and aids uniquely. Together with an audiologist it is attempted to find the right 'settings'.

One way of processing surrounding sound in CIs is called sound compressing. Here, the software adjusts the volume and distinguishes vowels and consonants from each other (Souza, 2002), enabling for speech to be ultimately translated as most intelligible. However, when there is background noise, compression does not offer significant difference as compared to linear amplification used in HAs. The use of directional microphones would give the best result in such a situation. (Souza, 2002). These microphones focus on the sound source and are non-sensitive for sounds coming from other directions, hence giving a clean sound output.

In addition, it is recommended to bring a microphone close to the mouth of the speaker, for improved hearing (Boothroyd, A., 2006): Figure 14 on the previous spread shows the increase of SNR when distance becomes smaller. On top of that, Galster and Rodemerk (2015) argue that "Remote microphone technologies offer significant benefits in difficult listening conditions when compared to hearing aids alone.", indicating the usefulness of using an aided microphone system to enhance the hearing on top of CIs or HAs.
Because of the sound processing done by the HAs/CIs, it is proposed not to add additional sound processing products like noise canceling or speech filtering algorithms: processing the sound twice would negatively influence the resolution of the target sound.

Difference in brands

Hearing aids have a broad variety of brands, whereas cochlear implants are only offered by three different manufacturers worldwide. This is mainly because of the technical complexity of CIs. The relationship of an Person with Usher with a CI brand is a lifelong one, since it is surgically implanted in the head and because of the large investment made in the aid. With hearing aids the relation is less permanent and brands compete in the way they capture, process and amplify sound. A downside to this competition is that every brand offers their own software and hardware to connect with their devices, decreasing the amount of possible connections across the aids and connecting devices. Prices range from a few hundred to a few thousand euro per pair of hearing aids, making the choice for any brand a conscious one.

Conclusion

CIs and AIs are the primarily used aids to assist an Usher' patient's hearing. CIs offer benefits for when the sense of hearing cannot be assisted by HAs anymore. (External) (wireless) hardware and software help in enhancing sound, to represent it to an Person with Usher's hearing as natural as possible. Herein, different types of connections are possible, from bluetooth to electromagnetic waves. Brands compete over the CI/HA-market, making the devices expensive and exclusive.

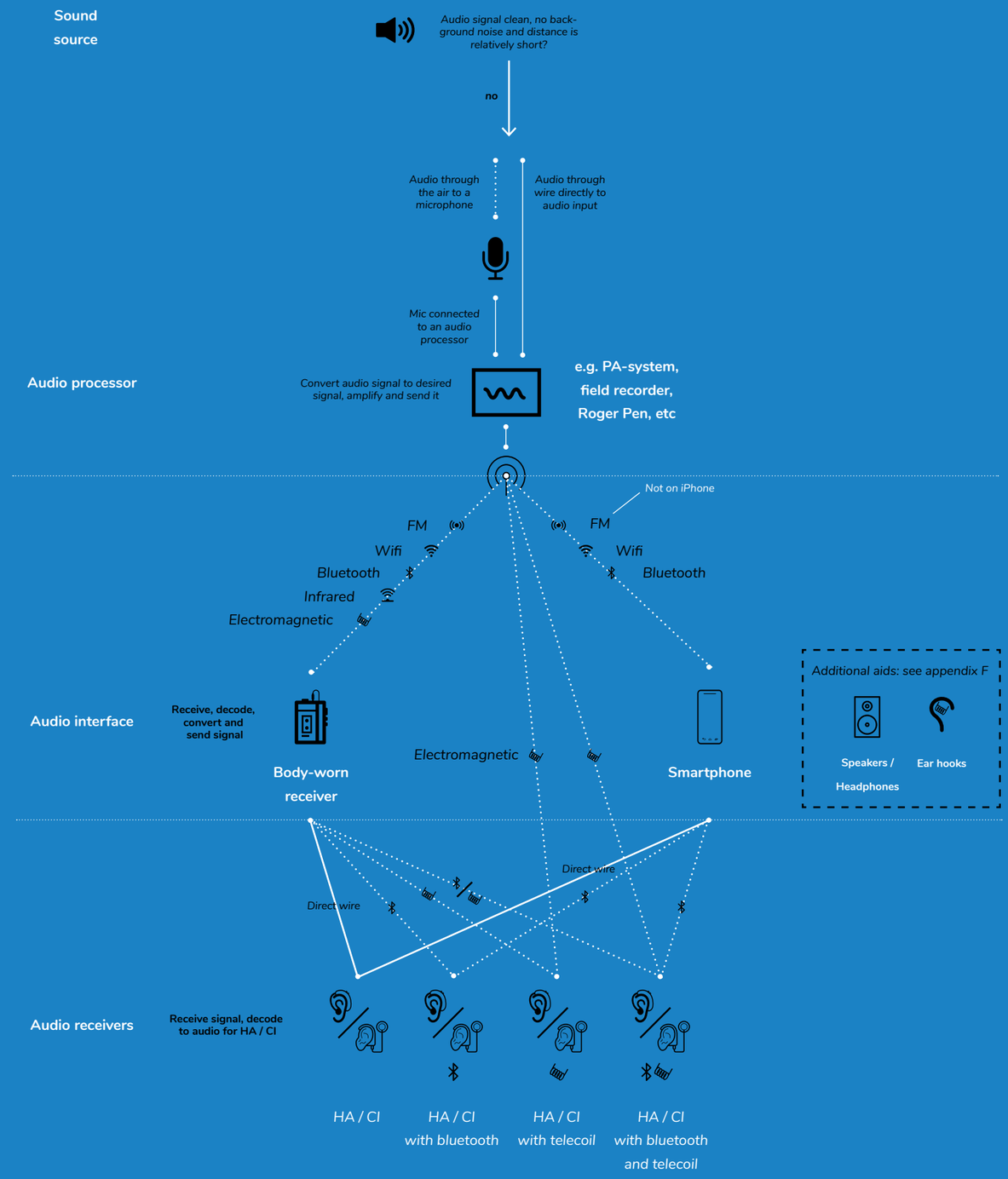


Figure 15
Ways of connecting HA / CI (Van de Weijer, 2018) (O Bengtsson, P., & B Brunved, P., n.d.)

1.3

Current conversation aiding solutions

Introduction

As can be seen in paragraph 2.5 (Concept decision), a concept is chosen that consists of a wireless microphone system. This paragraph describes the variety of such systems on the product market including their benefits and drawbacks. Knowledge about the competition shows opportunities to improve on, related to the specific target group and context of this project. An analysis of other assistive technologies is shown in Appendix G3.

Type of microphone systems

A number of (wireless) microphone systems can be seen on the market. Generally speaking, the following categories can be recognized, and are displayed on the right page. To go wireless is the trend here, as the size of the electronics are small, the speed is fast, energy low and there is no cluttering of any cables whatsoever.

Comparison regarding the project

Even though current microphone systems are functional, they show their drawbacks when compared to the needs for this project. Generally, the following can be stated:

- Current microphone systems are designed for a specific high-end use, making them expensive.
- Microphone systems are manufactured exclusive for one brand only, restricting size of the user base.
- Dedication is needed to either discreetly clip on a mic, install a PA system or integrate a hearing loop in a building.
- Small microphones fail to facilitate both one-to-one conversations and group conversations in noisy contexts.
- Mini microphone systems do not allow for volume control per mic.
- Current mics often look bulky or stigmatising, making them stand out.

By aiming at overcoming these factors, a design is envisioned (Chapter 3) that will be both better suited to the end-user and distinguishes itself from the competition.

Conclusion

Many microphone systems are existent on the market, both for regular consumers and People with Usher. Specifically for the project, drawbacks of products used by Usher can inspire improvements for a new product.

Clip-on / lavalier / lapel-microphones

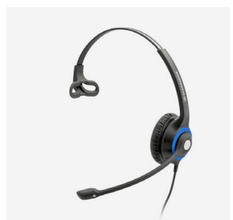
These small microphones are low-energy, portable, and often used in interview settings. Here, both interviewer and interviewee are wearing a lavalier mic and transmitter, which offers convenience since it can be used hands-free and is nearly invisible.

PA-systems

These systems are used at for example concerts and conferences. Here, spokesmen/women speak/ sing into a stage microphone which is hooked-up to either a transmitter or by wire to an audio control board. Here, sound is equalized and in the case of musicians sent back to either an in-ear bud or monitor to give feedback about the sound.

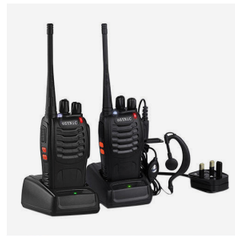
Headsets

Headsets are often used by gamers, call-centers, but also for example by motorists or in helicopters. With a headset, a microphone is directly connected with headphones, enabling hands-free conversations and at the same time being able to hear other audio-input like music or ambient gaming sounds. Moreover, by closing off the ear, the output sound is better recognizable from noise for the outside world. Often there is a server, satellite or control center between a conversation.



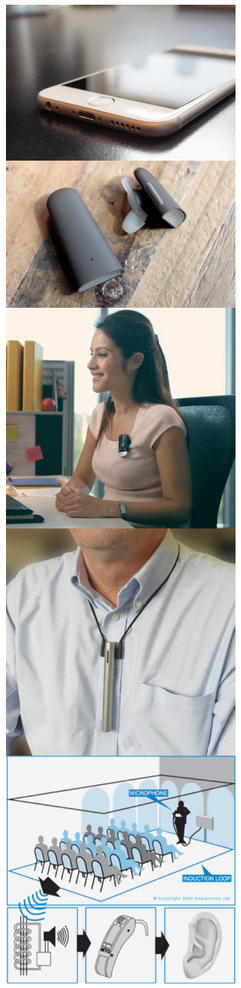
Walky talkies

Walky talkies are often used in the army, on festivals or as kid's toys. This familiar system makes use of local frequencies which two or more people can use to transmit audio on. This frequency allows for multiple listeners, but only for one transmitter at the time and is most used in short-range settings.



Systems used by People with Usher

Examples of microphone systems that are being used by People with Usher distinguish themselves automatically because sound always needs to be communicated to their HA and/or CI. This means there is always a medium in between the microphone and the patient's ear (paragraph 1.2, figure 15). Microphones are uses as table mics, clip on mics or dedicated room installations. Every solution uses a type of exclusive and/or software/ hardware, limiting the amount of users and buyers of such systems.



CHAPTER 2

Concept design

2.1

Design for Usher: Functions and requirements

Introduction

In this paragraph, findings from the analysis are translated into design functions and requirements: what functions should the product contain (and with which requirements) to be a successful product for people with Usher in its context of use? By taking these functions and requirements into account when designing the product, it is assumed to answer the project assignment.

Table elaboration

In the table to the right, the functions and requirements for this project's design are shown. On its left side, main functions are listed. The main functions encircled with blue are the most important, as these make or break the product. The second column shows the sub-functions that build up the main functions. The third column describes the envisioned performance of each sub-function to make sure it ultimately assesses the main functions. In the last column the ways of validating the requirements are listed.
Note that for this project the requirements are somewhat special, as a result of the nature of the disorders of the target group. Each person experiences the disorder differently from another: this means that the performance of - for example - the volume cannot be put to a set value. One product should perform differently to different users.

Conclusion

Functions and requirements for the rest of the project are now collected in one environment: the table of functions requirements. It allows for a structured ideation and assessments of what the product should contain - function-wise - to answer the thesis assignment. Four main functions are selected that weigh heaviest in assessing the project assignment.

Project assignment

"To design a non-stigmatizing, portable and affordable product ***for people with Usher syndrome****, that offers enhanced control over lighting and/or acoustics, with the goal of* ***improving their sense of involvement*** *in social contexts."*

Main function	Sub function	Requirement	Validation method
1. Offer advanced control over lighting	**1a**. Enable control over light power	70lm - 700lm (low to bright), depending on need of People with Usher syndrome	Measure brightness (lm), Measure response of user
	1b. Enable control over what area is being illuminated	Between the surface area of a human face and a pub table, depending on need of People with Usher syndrome	Measure light intensity (lux) per unit of area, Measure response of user
	1c. Offer control in color temperature	From 1000K to 6500K (cold to warm), depending on need of People with Usher syndrome. (wish: high color rendering index)	Measure color temperature (K), Measure response of user
2. Offer advanced control over acoustics	**2a**. Enable volume control of the target message	From fully muted to amplification of which is useful to people with Usher syndrome	Measure volume, Measure response of user
	2b. Enable reduction of background noise	Reduction to a SNR that is useful to people with Usher Syndrome	Measure volume, Measure response of user
	2c. Enable connection with hearing aid(s) and/or cochlear implant(s)	Wireless, no delay and in a range of 0-10 meters	Measure connection strength
	2d. Enable reduction of distance between sound source and person with Usher	As much as possible, to a limit of face-to-face distance	Measure distance
3. Be non stigmatising	**3a**. Enable independent use	It should be able to be operated by one person	Count amount of people needed to use the product and assess if this number can be reduced
	3b. Enable non-obtrusive use	Should score average of 4 out of 5 on the question of people would mind using the product in the context of use (5 = do not mind at all)	Test with end-users and score on a 5-point Likert scale
4. Be convenient in use	**4a**. Enable reduction of amount of steps needed to operate the product	The product should have as little of operating steps as possible	Count amount of steps needed to operate and assess if this number can be reduced
	4b. Does not disturb other people	Level of annoyance should be as low as possible	Measure emotional responses of other people
	4c. Be intuitive to operate	Level of complexity of use should be as low as possible	Measure difficulties in use by the user
	4d. Have readable interfaces	Score average of 4 out of 5 on readability on a Likert scale	Test with end-users and score on a 5-point Likert scale
5. Be portable	**5a.** Have compact dimensions	Handbag-size	Measure if the product fits in an average handbag
	5b. Be light-weight	50-500 grams (Manageable to be carried with one hand)	Measure weight
6. Be affordable	**6a**. Have a reduced amount of parts	The amount of parts should be as low as possible	Count amount of parts needed to use the product and assess if this number can be reduced
	6b. Have a material which has a high quality/price-ratio	Quality/price-ratio should be as high as possible	Compare different materials and assess if the quality/price-ratio is the most valuable.
	6c. Have a cost-effective way of manufacturing	The manufacturing method should be as cost-effective as possible	Compare different methods and assess if the quality/price-ratio is the most valuable.
7. Be aesthetically pleasing	**7a**. Have beautiful looks	Should score average of 4 out of 5 on a Likert scale of aesthetic pleasure	Test with end-users and score on a 5-point Likert scale
8. Be feasible in the short term	**8a**. Make use of available technology	Necessary parts should be available and useful off-the-shelf	Assess if proposes technology is available and can be applied

Figure 16
Table of functions and requirements

2.2

Ideation

Introduction

This paragraph describes the steps taken throughout the ideation process. It is presented in a chronological order as each step builds on the next. Every step either diverges or converges: Diverging means that there is a lot of information and possibilities are open. Converging means narrowing down the information, to focus. Although the project results in a sound-based solution (Chapters 2 & 3), ideas for a lighting product are still presented here, to show its potential and why a sound solution was chosen as the better option.

1) Initial ideas & creative session (divergence)

As a result of the analysis of chapter zero and one, ideas have been sparked and put onto paper. The ideas are categorized in light and sound products, as the aim is to "offer enhanced control over lighting and/or acoustics". This is shown in image 5. Moreover, a creative session is held to come up with even more ideas (image 6).

2) Function and requirement-forming (convergence)

To better address the assignment of the thesis, functions and requirements have been specified (paragraph 2.1). This allows for categorisation and combinations of ideas to answer the purpose of the project. It defines the scope and limits of feasible and useful ideas.
The reason that this is step two instead of the first step, is that it is important to, at first, be able to freely ideate without feeling restricted.

3) How-tos (divergence)

In order to answer the functions and requirements, 'How-tos' (H2s) have been formulated. In a brainstorm, ideas/ principles on how to generally solve these H2s have been created. This is shown in image 7. A more detailed overview of the resulting H2s and ideas is displayed in a flow diagram in appendix J1. Herein, the ideas have been categorized on the different human senses, to increase readability.

4) Focused ideas (convergence)

Form is given to the best ideas (which answer the functions and requirements best or are novel and creative), shown in image 8. These ideas are then worked out in more detail, to assess their potential better. This is shown in image 9. Appendix J2 shows these ideas in more detail.

5) Top three (convergence)

From these product ideas, the three best ones have been selected based on their function, feasibility and originality with regards to the list of functions ans requirements. The ranking table of this selection is seen in Appendix J3. The three are then transformed into crude prototypes, elaborated in the next paragraph.

6) Co-evaluation session and further steps (convergence)

A co-evaluation session, described in paragraph 2.4, is made and performed with 9 People with Usher, to quickly get feedback on the direction of the ideas and their usefulness to the target group in the design context of the pub Conclusions from these sessions result in a 'winning' concept direction, consisting of parts of the three prototypes. This is described in paragraph 2.5.

7) Conclusion

From a starting point of an abundance of information, ideas have been generated and ultimately narrowed down to three crude concepts. These can then be used to evaluate with the target group to assess their strength and feasibility and opportunities.

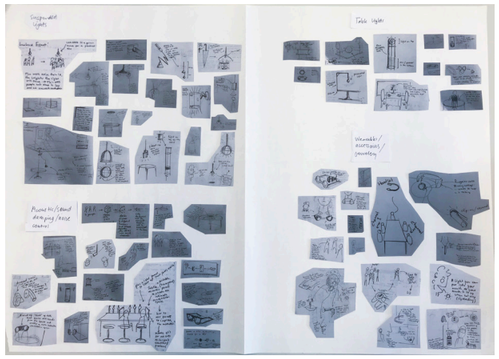


Image 5
1) Initial ideas, categorized (divergence)

Image 6
1)creative session (divergence)

Image 7
3) How-tos (divergence)

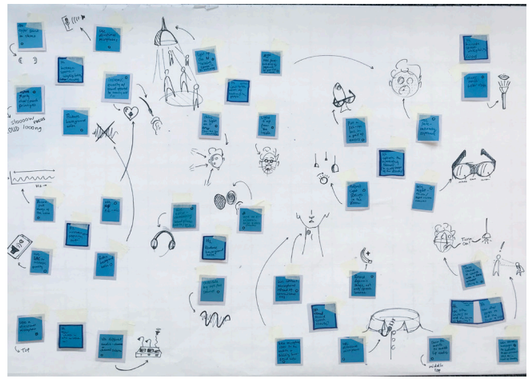


Image 8
4) Focused ideas (1/2) (convergence)

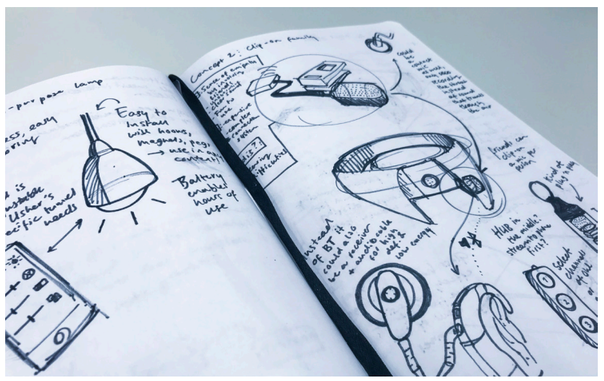


Image 9
4) Focused ideas (2/2)(convergence)

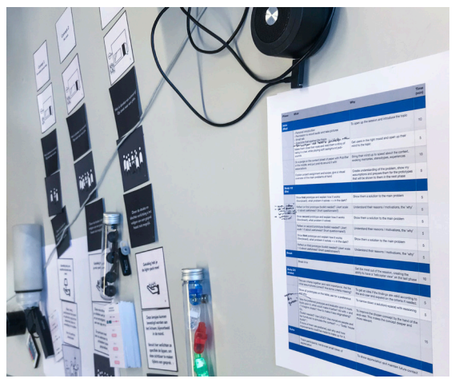


Image 10
5) Top three concepts are evaluated in co-creation sessions (convergence)

2.3

Lo-fi Prototyping

Introduction

As shortly addressed in the previous paragraph, three crude prototypes have been made as a result of the ideation phase. This paragraph describes each prototype, its values and what it is made of. The purpose of doing rapid prototyping is to quickly get feedback from the end-user. This first validation indicates if the ideas and assumptions make sense and what direction to take next.

Why these three

Appendix J (J1-J3) shows the 8 best ideas, the ideation flow chart (process of ideating and deciding) and its ranking when compared with the table of functions and requirements respectively.
The latter shows that ideas 1 and 2 (Multi-purpose lamp and Mic pack) are the most feasible. Idea 5 (Light pack) is not necessarily the best but it has potential to spark ideas in a creative session because of it's out-of-the-box character and is therefor included in the selection of the three.

Concept 1: Portable light

The concept of the Portable light (Image 11) is to have a light that is portable and connected through a smartphone app. Within this app, the user is able to tweak the light in its brightness, color and saturation. The idea here is that the person with Usher can adjust the light according to their needs, in any context where the light is too dim. The prototype consists of a remote controllable LED strip, a sand blasted plastic bottle with handle and mockup of the app on foam board.

Concept 2: Mic pack

The concept of the Mic pack (Image 12) is to have a portable package of mini-microphones, that are easy to bring and are divisible amongst family and friends. These microphones then connect with a smartphone app, where volume of each microphone can be adjusted. The app connects to the HA/CI consequently, to display each voice of the friends/family to the ear of the person with Usher. The prototype consists of a plastic cannister filled with four spray-painted tablecloth weights and a mockup of the app on foam board.

Concept 3: Light pack

The concept of the Light pack (Image 13) is to have portable lights which light up the mouths/faces of friends/family, so People with Usher are enabled to lip read better and at the same time indicate the location of their friends inside the context of use. The idea is for friends/family to pin-up the light anywhere on the body (shirt, hand, in the mouth) and from there light up the face/mouth. The prototype consists of a plastic cannister with four small LED lights and magnets that allows them to be attached anywhere.

Conclusion

Three lo-fi prototypes have been created as a result of the ideation phase. Each concept entails aspects to assist People with Usher in either hearing, sight or both. With these three prototypes, feedback from the end-user can be gained.

Image 11
Prototype 1: Portable light

Image 12
Prototype 2: Mic pack

Image 13
Prototype 3: Light pack

2.4

Co-evaluation sessions

Introduction

Sessions together with end-users enable designers to get richer insights in their experiences, reasons and motivations (Sanders, Stappers, 2012). It helps in understanding both the user and context to design for. The goal is to gain user feedback on three concepts that have resulted from the analysis phase. To assess this user-feedback, co-evaluation sessions have been held, described in this paragraph.

Methods

Participants

Participants in this research are the end-users of the to-be-designed product: People with Usher (both hearing and seeing deficits). Their age varies from 34-52. The selection of participants does not concern gender; both men and women have participated. Participants make use of hearing aids, CIs and/or writing interpreters. In total, 9 people with Usher have participated the test.

Stimuli

As the end-user in the case of this project is not any ordinary person but one with sensory deficits, the session is built-up tailored to them. Stimuli that are included in this tailoring can be summed up as follows:
- The sight of someone with Usher is focused in the center, so any (graphic) element shown in the session should be positioned in the center.
- High color contrast and large text size help in seeing more clearly.
- It is hard for people with Usher to focus for a long period of time (length depends on age and progress of degeneration) as they tire more quickly than 'normal' session participants. This makes it vital to keep the session focused, short and clear.
- Clear speech principles (paragraph 1.1) are applied to convey any spoken information in the most clear way possible.
- The location of the session is chosen to be at participant's homes, given that they have difficulties traveling long distances and by the assumption that the light and acoustic conditions at their homes are optimized to the them.

The session is created with guidelines from the book Convivial Toolbox For Designers (Sanders, Stappers, 2012). Elements from the book have been taken and are then tailored to fit this particular session.

It was decided not to do a *co-**creation*** session with people with Usher (where ideas are explored, drawn, constructed in more depth), but instead to do a *co-**evaluation*** session, because of the intense and (time-) demanding nature of co-creation sessions (where for example ideation and the creation of concepts from scratch is desired). Evaluating on pre-made mockups during a co-evaluation session was considered to be easier and quicker to perform and give better outcomes as a result.

During the session, the crude mockups of the previous paragraph are presented. The goal of these mockups is to enable the participant to imagine functionalities of and interactions of a such a new concept and if something like these mockups would be desired in the first place. Moreover, it can spark ideas and improvements.

Procedure

The session itself is structured in three main parts, where the participant is prepared, involved and engaged in the evaluation of the concepts, respectively.

Introduce, associate

Here, a short introduction to the graduation assignment is given, as well as an opportunity for the session-participant to introduce themselves. The context of the bar is explained and associations with it are triggered by a context-story and a context-purge.

Evaluate

Here, the three mockups are shown to the participant. They are asked to reflect / evaluate on them and write down / draw / say their opinions and ideas about and around it. The three options of writing, drawing and saying are given so they feel comfortable to express themselves in any way desired.

Evolve, reflect, imagine

In this third stage the three concepts are re-evaluated together. Here, the most favourite(s) concepts are picked and discussed consequently. How could this concept be improved, what could be included in the way it functions and looks? Are the assumptions that were used to create these concepts correct? Is there information missing that could help in making the concepts more meaningful? Do these concepts offer solutions that are aimed in the right direction?

Data Analysis

During the session, audio recordings and notes have been made. These recordings, notes and session results (drawings, written feedback) are analysed after each session. As a result, an overview is created of the participants, as well as the benefits and drawbacks of both the design context and the three concepts. New criteria rising from the sessions have been added to the program of functions and requirements

Results

A short overview of results of the sessions are described below. Session quotes are shown in paragraph 0.2. For the full results, refer to appendix A.

Concept 1 (Portable light) is praised for its ability to create an overview of both people and elements in the environment. It encourages individuality and a feeling of safety. Downsides are the risk on a light source that is too bright and obtrusive. Additionally, positioning might be difficult.

Concept 2 (Light pack) is praised for the convenience of handing out the microphones, the ability to have conversations with multiple people at the same time and its ability to adjust volume of individual people. Downsides are the set-up procedure of the microphones, risk on overly usage of the app and a skepticism of a microphone that could even function properly in such a context.

Concept 3 (Light pack) is praised for its humor and out-of-the-box character. Downsides are conspicuousness, hygiene and doubts about if the lights would help at all, if not only blind the person with Usher (by looking straight into the mouth light).

Discussion / Conclusion

Reflecting on the collected results, the following conclusions can be drawn from the co-evaluation sessions:

Concept 1 is ambitious as it is a challenge to provide a portable design that offers sufficient lumen and battery life and also lights up both surroundings and people's faces whilst at the same time do not disturb the surroundings with a light that is too bright or cold.

Concept 2 is ambitious as group conversations are very dynamic, fast and hard predict (more people could enter the conversation, people may leave, etc). Moreover, it might be a challenge to find the right microphones and get wireless connections running smoothly.

Concept 3 was not regarded as a feasible idea. However, the idea of localising someone with a light was found to be useful.

Image 14
Co-evaluation session picture

Image 15
Co-evaluation session picture

2.5

Concept decision

Introduction

This paragraph describes the decision for the final concept, based on the design functions and requirements (paragraph 2.1) and feedback gained in the co-evaluation sessions from the previous paragraph. The decision is supported by factors as the concept's urgency, context fit, feasibility, the designer's preference and more. The co-evaluation sessions were not aimed at selecting a final concept, the goal was rather to assess assumptions that were made, get general feedback on the mockups that were proposed and so spark new ideas. However, the feedback and possibilities for the chosen concept showed this much potential, that it has been decided to further develop this idea.

Best sense to assist for a conversation

As seen in appendix G3, a number of assistive technologies have been analysed. However, while some technologies use other senses to communicate a message (e.g. reading through braille), none is as sufficient in speed and involvement like the sense of hearing. Hence, it makes sense to focus to design for this sense. Improved lighting can help in lip reading but adding a light to a dark and crowded context is assumed be too obtrusive. Moreover, quoting someone from the evaluation sessions indicates the value of helping the sense of hearing:

"It is nice to be able to see what is going on, but that's 'useless' when you can't follow any conversation. Seeing helps in lip reading but if you cannot hear a thing in the first place, than light alone cannot solve the problem"

Functions

2a. *Enable volume control of the target message (++)*

By having a microphone for each conversation partner in combination with an volume-mixing app, the volume of each and every voice can be controlled individually.

2b. *Enable reduction of background noise (++)*

Being directly tuned into the voices of the people a person is with, background noise is not picked up along with it (which would be the case when one central mic would be used)

2c. *Enable connection with hearing aid(s) and/or cochlear implant(s) (++)*

Bluetooth connection is the new standard for HAs/CIs, which means they can be connected directly to any sound/hub, wirelessly. By sending the microphone sounds to this hub, sound can reach the HA(s)/CI(s)

2d. *Reduce distance between sound source and person with Usher (++)*

Capturing the sounds of each and every person individually is like bringing the mouths of every person to the ear of the person with Usher, and so virtually reduce the distance to 0.

3a. *Enable independent use (+)*

The microphones are controlled by the person with Usher, and therefor do not need others for its use. This function has one '+' instead of two since other people are needed to clip the microphones onto, which decreases the independence a little.

3b. *Enable non-obtrusive use (+)*

The microphones are envisioned to be small and therefor non-outstanding in its context of use. However as discussed at 3a., other people are needed to be part of the use, and this might be conceived as obtrusive.

8a. *Make use of available technology (++)*

It is envisioned to use existing microphones and wireless streaming services like bluetooth or wifi. By cleverly putting together the right components, an innovative and feasible product is created.

Urgency

The urgency of tackling a problem as stated in this project is high since it is sometimes nearly impossible to follow a conversation in a pub having healthy hearing, let alone having hearing and seeing deficits. On top of this, current products that aim to solve this (paragraph 1.3) fail to deliver speech separated from background noise, making their usefulness obsolete and leaving no products for people with Usher to use in such scenarios.

Context fit and extra targeted use-cases (beyond Usher)

Such a microphone system offers functionalities beyond the context it is used for. Imagine birthday parties, trips by car, running in teams. Moreover, not only people with Usher could benefit from the product. Imagine the friends and family members that are helped as it also improves their conversation quality. Also, think of hard-hearing elderly or hearing impaired students that have to work in groups at school. Both the addition of contexts and user groups add to the "Design for Usher ***and beyond***"-part.

Innovativeness / originality

The combination of speech/background noise-separation, volume control, convenience of use (size, wireless connectivity) and affordability (by using existing components instead of newly engineering them) make this concept an innovative one.

Market opportunities

The qualities named above (Innovativeness/originality) makes the product separate itself from competitors that offer similar but different qualities. By addressing the innovativeness of the product marketing opportunities can be exploited.

The larger the variety of users, the less stigmatizing a product is and the easier to market amongst conventional channels (and avoiding being condemned to sales in the deaf-blind market only).

Feasibility

Technologies used in the concept are not being invented: their functionalities have already been engineered and proven to be working (like directional microphones, bluetooth receivers and app software). It is the unique combination and embodiment together that make it a novel product.

Personal preferences

Job van Dongen has a preferance for the Mic pack concept, because of its discussed potential but also because of the interaction possibilities (UX) the product brings. The use of the product before, while and after can be designed in such a way to offer the most convenient and fun experience as possible, while having a meaningful (social) impact. Paying attention to such details is experienced as an enjoyable part of designing.

Negative user feedback: what to do with it?

From the user feedback a number of doubts about this concept have arisen. However, these arguments are no elements that cannot be solved necessarily. For instance, the assumption that the set-up procedure can be inconvenient or that the app will be overly used is a matter of interaction design: the amount of steps in the setup-procedure could for example be reduced and the interface of a smartphone could be replaced with a dedicated piece of hardware that can be controlled without the need to look at it. The argument whether a microphone would work or not is totally dependent on the choice of microphone, way of filtering and processing the sound. These are design challenges that can be tackled.

Client wishes

Mrs. Bressers from the Usher Syndrome Foundation has indicated (personal conversation, March 19, 2018) that, for the foundation, it is preferred to include aspects of a light next to sound to make it an Usher-specific product. Light would not be main functionality, but could supplement functions or interactions.

From an economical point of view, Mr. Smits from the Usher Syndrome Foundation (treasurer) has indicated (personal conversation, April 19, 2018) the urgency for a low-cost solution, to compete with other microphone manufacturers. Moreover, he has indicated that convenience of use is of importance, to relief people with Usher from performing superfluous tasks when using the product.

Name

'Micall' is chosen as a placeholder name for 'chosen concept', 'the product', 'concept 2' or 'Mic pack', to ease communication and inspire further product development. This name will be used from the next chapter on. Micall comprises the following symbolism:

- Giving it a human name (sounds like Michael) gives it personality and makes it easy and short to pronounce
- It describes what is does: it puts a **mic** on **all** the friends/ family
- It indicates 'my call', to (finally) give people with Usher their say in the matter.

Conclusion

Micall is the chosen concept based on a number of arguments. Of which most importantly, it promises to enhance control over acoustics and it improves an Person with Usher's sense of involvement in social contexts by being more engaged in conversations. By realising this concept, the initially proposed problem statement is addressed, the goal of the thesis.

CHAPTER 3

Concept elaboration

3.1

Embodiment design process

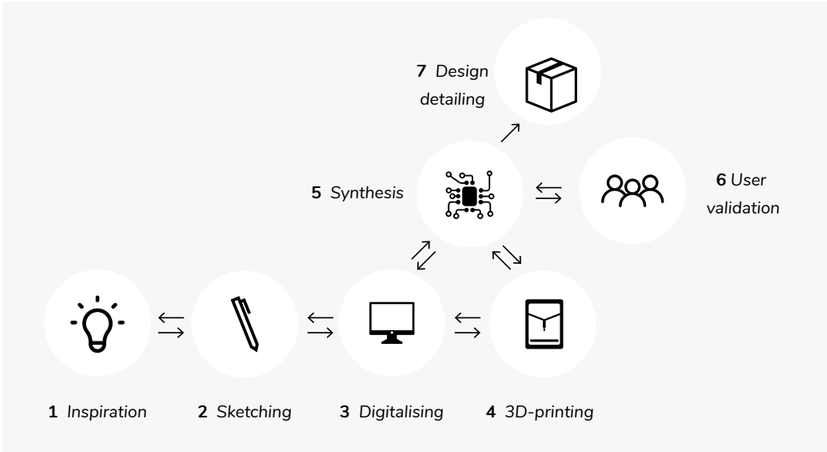


Figure 17
Embodiment design process

Introduction

This paragraph describes the embodiment design process of Micall. The process is divided in seven stages, ranging from collages to a final design proposal. Every stage is not static however; feedback loops improve the design in an iterative process (figure 17 above). Since the embodiment process is quite elaborate, only important decisions are stated here. Appendix K elaborates on the process in more detail.

Stage 1: Inspiration

The current market segment inspires types of technology, sizes and way of assembling, build quality and so forth. Moreover, in inspires the shape, use of materials, colors, texture and ways to interact with a product.
Micall was inspired by small clip-able products, subtle fillets, bright colors, the use of a plastic-fabric combination (Figure 18 to the right).

Stage 2: Sketching

Inspired by the collages from stage 1, ideas are put on paper (Figure 19 to the right). Technology-wise it was important to make sure technology would actually fit inside the housing of the product, and that it can be manufactured by injection molding (to increase affordability). Aesthetically speaking one of the goals here is to deviate from standard shapes for both microphones and corresponding charging cases. Different shapes of cases and mics have been tried out, and ultimately this deviation is achieved by adding symbolism to the design: the shape of a speech bubble. Since the product is all about communication, this is a convenient touch to make the product stand out from the rest and add meaning to the embodiment. The charging port of the case is positioned in the pointy end of the speech bubble to represent the 'feeding' of the conversation when it is being charged.
The interactions with Micall are designed to be the most convenient and fun with every step of its use, from charging the product to bringing it, opening the case, connecting it in the app, using the app, wearing the mics, putting the mics back into the case, etc.

Stage 3: Digitalising

Sketches are transformed into 3D models using SolidWorks. Digitalising gives more realism to drawings, as different parts are now restricted to dimensions. These dimensions are based on off-the-shelf components that are envisioned to be in the product. The app is digitalized and made interactive by the use of Sketch and Proto.io software. (Figure 20 to the right)

Figure 18
Inspiration collages

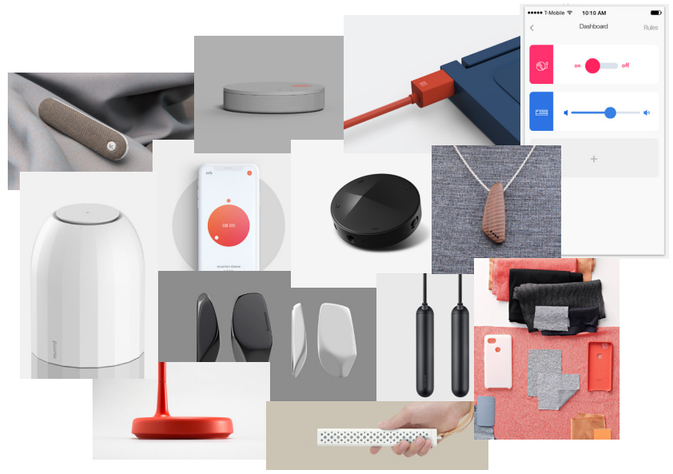
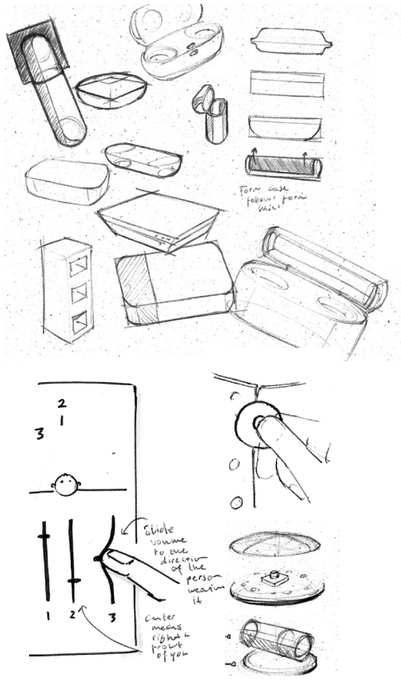


Figure 19
Design sketches



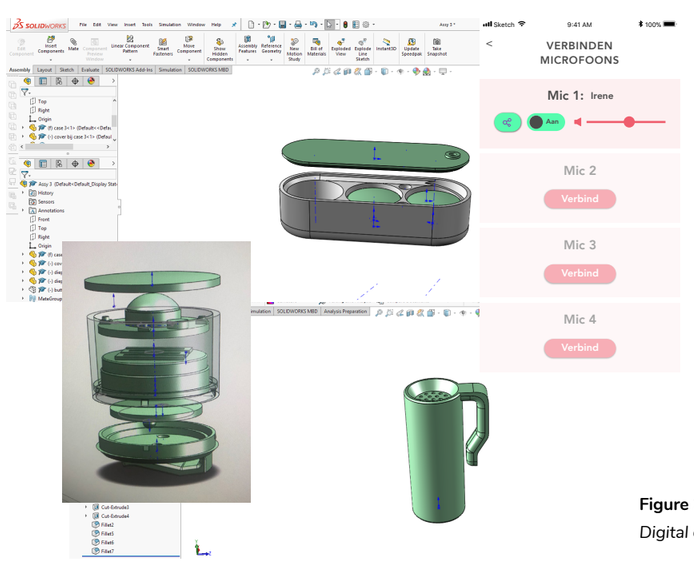


Figure 20
Digital designs

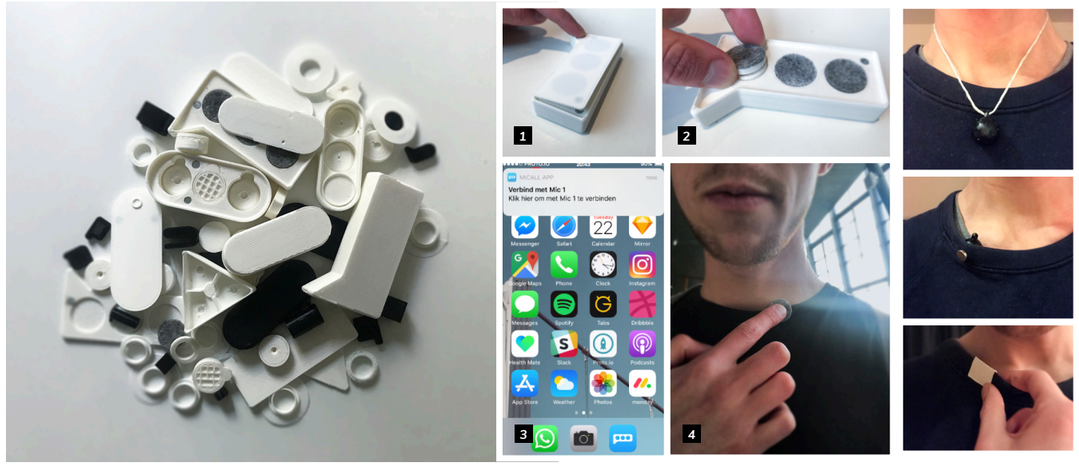


Figure 21
3D printing and interaction tryouts

Stage 4: 3D printing

Using a PLA 3D-printer, different ideas for Micall have been printed. Having physical models enables to assess the look and feel better, as well as the envisioned interaction with the product. Magnets are used to test the 'magsnap' of the case and cover, as well as the magsnap of the mics and case.

Stage 5: Synthesis

Together with an electrical engineer, components are specified for the envisioned functionality of Micall. Having defined components mean that aesthetic details can be added to the design, and by using an SLA 3D-printer these details can be realized. Moreover, a translation is made between the concept of envisioned technology (bluetooth connections, functioning app, etc) and a functioning model, for validation tests in the next stage.

Stage 6: Validation

This stage is described in its entirety in paragraph 3.2. Five people with Usher and eight family/friends have participated and validated the aesthetic and functional model of Micall. The results of this validation show if the functions and requirements set in paragraph 2.1 are met. The results are taken to the next stage, where improvements to Micall are made.

Stage 7: Final design proposal

Paragraph 3.4. (Design proposal) is all about this stage. Here, improvements found in the validation rounds are applied to the Micall design. The design proposal serves as a starting point for a future phase, where it can be developed to a next level.

Conclusion

From scratch,different design and iteration steps have been taken, resulting in a final design proposal for Micall. Validation with end-users will prove the worth of both the aesthetic model as well as the functional prototype.

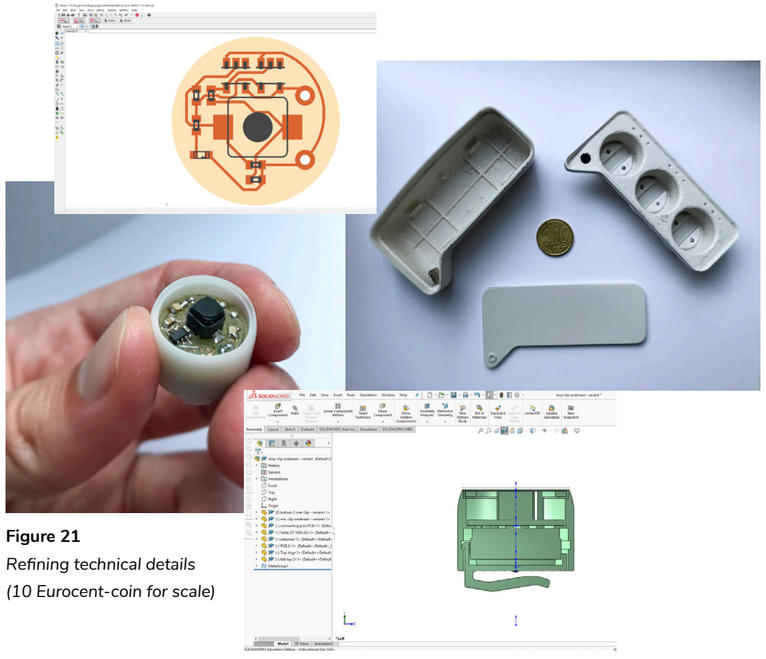


Figure 21
Refining technical details
(10 Eurocent-coin for scale)

Figure 23
User validation

3.2.A.

Concept validation:

Prototype play

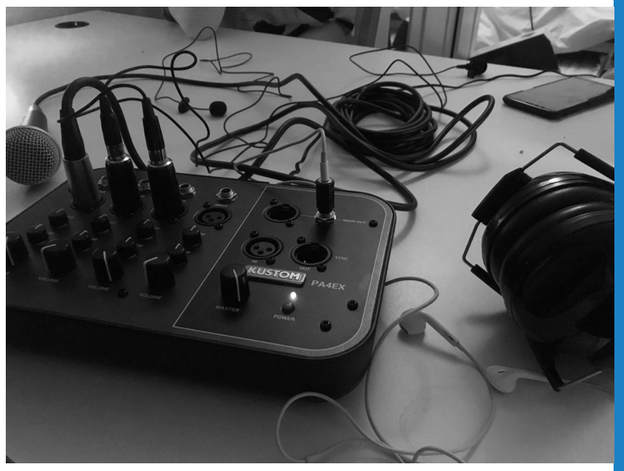


Image 16
Two lavalier microphones and in-ear ear-buds connected to a compact 4-channel mixer. Volume control enables dynamic control over the output signal.

Image 17 & 18
Prototype play-pictures

Introduction

Just like medical research, new designs are first tested with healthy people, to test and benchmark its effects. The same is intended with testing the Micall prototype. Playing with the prototype allows for (risk-)free exploration of how its functions are experienced. Another aim of 'playing' is to observe how the interaction with the product is and could be improved, without restrictions of an official test structure. Different approaches for a test-setup have been explored, further elaborated in appendix N. The one that functions best is described in this paragraph. Paragraph 3.3 will approach the test in a more structured way, when end-users are involved.

Prototype play

Participants

In total, 5 'normal' people (aged 23-25) have participated the protoype play tests.

Setup

The setup consists of a table with a compact 4-channel mixer. Plugged into the inputs of the mixer is one cardioid stage mic, one cardioid lavalier mic and one omni-directional lavalier mic. These mics are attached / held by three participants. Into the output of the mixer, in-ear ear-buds are connected and put into the ears of the fourth participant. Over the earbuds, earmuffs are placed to mimick hearing difficulties.

Procedure

Two test persons each attach a lavalier microphone to their shirt, one holds the stage mic by hand. A fourth person acts as someone who is hearing-impaired, by excluding their hearing from the environment by use of the earmuffs.
A conversation is started amongst the mic-subjects. With the mixer, the hearing-impaired actor can tweak the volume of both lavalier microphones and the stage mic, as well as the master volume of the output on the mixer. The output signal of the mixer is then sent to the ears of the hearing-impaired person.

Results

Outcomes from the 'Prototype play'-sessions are visualized in figure 24 to the right. The most important aspects that have arisen are that the concept proves to be working and is experienced as fun and convenient. However, this is done with subjects who have healthy hearing abilities. Even though impaired hearing was mimicked by the ear muffs, a prototype test with People with Usher will be necessary to get a full proof of principle.

Conclusion

Prototype play tests show a promising start for the functionality of the Micall test setup: Microphones work, speech is intelligible and people have fun using both the microphones and mixer. However, test with end-users are needed to show a more realistic proof of concept.

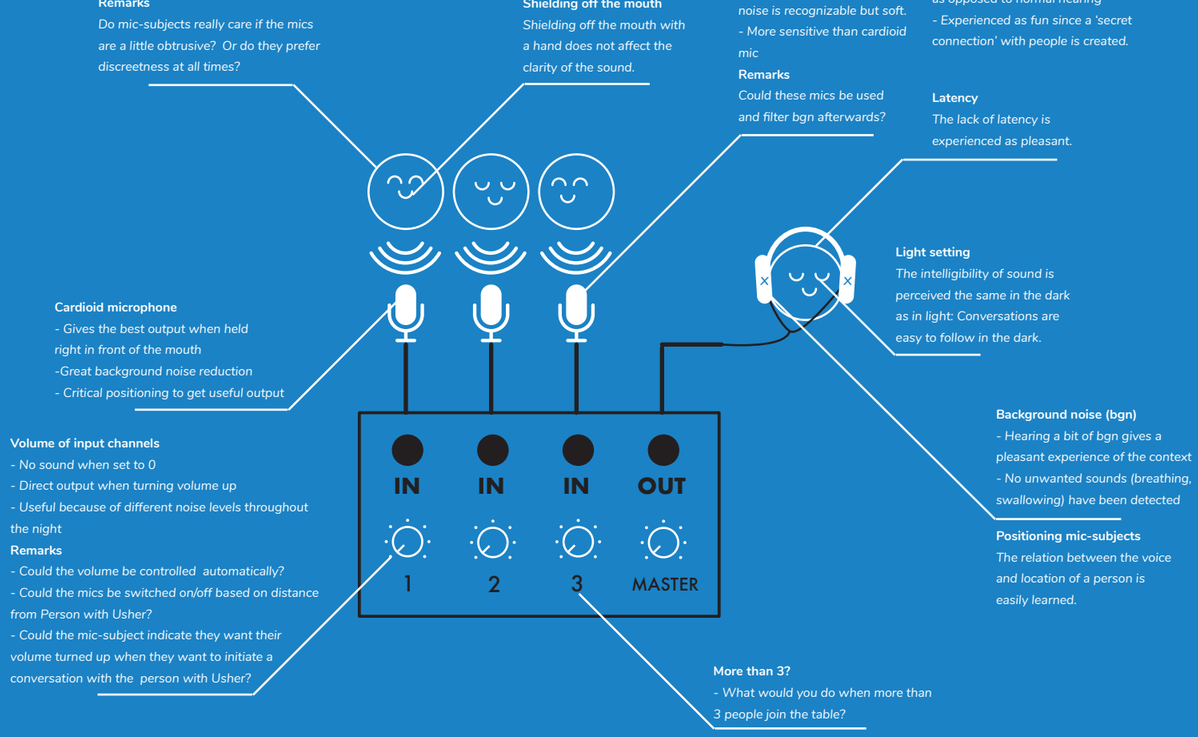


Figure 24
Prototype play insights

3.2.B.

Concept validation:

End-user tests

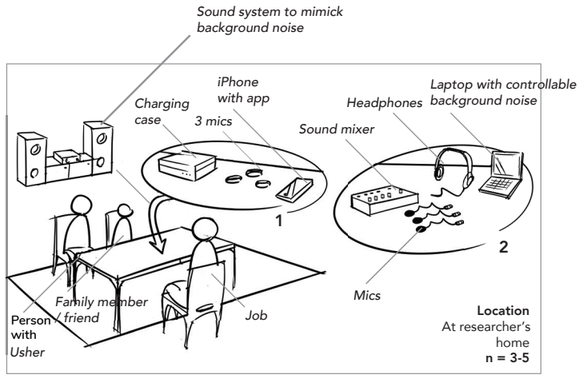


Figure 24
Use test setup

Figure 25
Translation from aesthetic prototype to functional prototype

Images 19 & 20
Validation test photos

Introduction

Tests performed in the previous paragraph were focused on getting familiar with the test-setup and its functions. This paragraph describes a more structured approach to test the product: use testing with end-users. The goal is to confirm the current design of Micall and to generate insights for future improvements.

Methods

Participants

Participants in this use test are People with Usher and their family / friends, as they both represent the end-users of Micall.

People with Usher

In total, 5 patients have performed the test.
The age varies from 44-62. All of them have Usher type 2. Sight loss varies from 50% - 95%, Hearing loss varies from 60dB - 100dB. All people with Usher were female. This is by chance, not by selection. Participants make use of HAs and/ or CIs.

Family / friends

In total, 8 family/friends have performed the test.
The age varies from 16-59. Participants have healthy seeing and hearing abilities. The selection of participants does not concern gender; both men and women have participated.

Stimuli

The test-room is be simulated like a pub: cozy lighting and background noise, chairs and a table with drinks and snacks. All participants are exposed to aesthetic mockups of Micall, which consists of a charging case, 3 mics and an iPhone with a iPhone app-mockup and Apple Watch-app mockup. Later in the session, the participants are exposed to functional mockup of Micall, which consist of a music mixer, 3 functional mics and headphones. Images are shown to the participants which show the connection between the aesthetic and functional mockup (figure 25).

Procedure

Before the beginning of the test, informed consents are signed. Users are asked to take place at the 'bar table', where they are introduced to the test and to the aesthetic mockup of Micall. The mockup is explained and users are asked to tryout several actions: opening, clipping-on, closing, etc. After this introduction and familiarisation, the functional mockup of Micall is brought to the table (sound mixer, functional mics, headphones), where its functions are explained in relation to the aesthetic mockup. Roles are divided: People with Usher will be wearing headphones, friends/family will be wearing functional microphones. A conversation is initiated, where the Person with Usher can tryout the sound mixer to alter incoming sounds from the mics of the friends/family. Context factors are then added to simulate pub-noise and pub-lights. Family/friends are asked to mask their mouths while talking to make lip reading impossible. After, the Person with Usher is asked to close his/ her eyes to preclude the ability to read any body language. After around 20 minutes the conversation is stopped. A questionnaire is filled in and an open conversation is initiated after.

Data Analysis

During the test, audio is recorded. The primary focus is to listen and engage with the participants, to get deep insights in their actions and motivations. Audio recordings are used afterwards to gather useful quotes and input that was unheard during the test. Answers to the questionnaires are analysed and put together in one figure (Figure 27). All insights are used to improve the design of Micall.

Results

Results from the user tests are promising, proving the need for a product such as Micall for both people with Usher, but also to their family and extended target groups (elderly, hearing impaired children in special schools) and in different use-cases (at the camping, in the car). The aesthetic as well as the functional prototypes are validated positively on every important aspect: It improves speech intelligibility, it enables group conversations as well as one-to-one conversations and body language like lip reading is not always necessary anymore, regardless of other people talking, low-light settings and pub noise in the background. Also the design was perceived as aesthetically pleasing.

Moreover, people had fun using the prototypes and were happily surprised by its functionalities, up to the point where there was offered help in future development of this product. In short, a proof of concept has been achieved.
Regarding the app, real interest was shown in the localize and test-functions in the app. Tips were given to make icons and text larger and to use more primary colors (also on the Mics)

The next spread shows an overview of the test and its results, displayed in a sound-mixer style. Black dials represent feedback from people with Usher, white dials that of friends/ family. On the left side of the spread quotes are displayed that show the enthusiasm of the participants. Apparent here is the large difference with the quotes named in paragraph 0.3.

Conclusion

Validation tests with end users have been held and proven to be successful; comments and reactions from the target group (both people with Usher as their family) indicate that a proof of concept has been achieved.

Figure 26
Quotes mentioned during the Validation tests

“En wat ik dus merk omdát je het meekrijgt, zit je er wel relaxter bij inderdaad. Echt cool dit zeg..”

"What I notice is the fact that since I'm able to follow conversations, I feel more relaxed. This is really cool."

“Dit is echt heel opmerkelijk hoor dat zij met de ogen dicht het gesprek kan volgen.”

“It's really remarkable you know, that she is able to follow the conversation with her eyes closed.”

“Je ziet duidelijk dat dit concept verder gaat dan de Roger Pen of Smart Link, je helpt in gesprekken waar meerdere mensen meedoen.”

"You can clearly see that this concept surpasses the Roger Pen or Smart Link, it helps in conversations where multiple people are involved"

“Heel goed om de effecten bij hun te zien, dat het zoveel toegevoegde waarde kan hebben.”

"It's really good to see the effects on them, to see so much added value."

“Hiermee krijg je weer een stukje terug en dat is gewoon echt de meerwaarde.”

“With this you get something back what was lost. That's really the added value”

<"Ik kan jullie nu perfect verstaan." >"Beter dan normaal gesproken?" <"Ja, het zit nu direct gewoon recht in m’n oren, en anders zit de afstand ertussen."

>"I can understand you perfectly now." <"Better than usually?" >"Yes, I can hear it now directly in my ears, whereas otherwise there would be a distance in between"

Figure 27
Validation test results

People with Usher: 5 (Black)
Friends / family: 8 (White)

USER INPUT

OUTPUT FOR THE PROJECT

Quotes, insights, ideas, next steps

3.3.A.

Design proposal: Use and interaction

Introduction

All the project results have led to a final design proposal. This paragraph describes the use and interaction of the design; how would Micall be used in the envisioned context: going out to a bar. This is divided in a before, while and after-stage.

Before

At home, the Micall charger-case can be charged with a regular phone charger and a USB-C cable (Figure 27-1). A low charge is indicated by a red LED positioned just above the USB-C port. As it is charging, the red LED changes to blue. Once it is charged, it switches to green. Inside the case, each Mic has three indicator lights, showing their charging status. This ranges from red to orange to green. Both the charging status of the Mics and the charger-case can be viewed in the app as well. Since Micall is small, it can easily fit in the pocket of a jeans or fit in a purse/handbag; this makes it is easy to carry along.

While

After having arrived at the bar, take Micall out of the pocket/bag (The charger-case is light gray so it is easily spotted in the dark inside of a bag). A press on the pointy end of the lid of the case opens it up (Figure 27-2). The lid can be stored on the bottom of the charger-case by a magnetic connection. The mics can then be taken out of the case (easy to pinch with two fingers, Figure 27-3). Taking them from the case sends a notification to the iPhone of the Person with Usher, with a request to connect with that Mic. The connection can also be done in the app before taking it out, whatever order of actions is preferred (Figure 27-4).
The connected Mic(s) are then given to the friends/family members, they can clip-on the Mic(s) using the clip on the bottom of the Mic(s). When worn, the Mic(s) blend in with the clothing because of the the fabric material on top (Figure 27-5). The color of and number on the Mic(s) correspond with the color and number of the Mic(s)in the app, so the person with Usher can distinguish different persons who wear Mics from each other.

On the Person with Usher's side, the only interaction is with the app. Here, three things can be controlled: The volume of each Mic, muting/unmuting them and assigning a name to the Mic (Figure 27-6). The control of the volume allows for better and more specific control of the conversations.

The carrier of the Mic is able to put their Mic on stand-by mode by pressing on the top of the Mic. This gives them autonomy, whenever is desired. To indicate this stand-by state, a red light will light up softly. Moreover, when the carrier leaves a perimeter of 10 meters, the Mic will automatically switch to stand-by mode.

After

At the end of the night all the Mics can be stored again in the charger case, where they will start charging immediately (Figure 27-3) They 'snap' back in place because of a magnetic connection between the charger case and the bottom of the Mics. Putting a Mic back in the charger-case disconnects it automatically, and puts any name that was assigned in the app back to normal, making it ready for the next use. When a Mic has not been given back, the name stays in the app and is thus easy to trace back. After use the charger case (including Mics) can be closed again and stored for future use.

Figure 26
Micall elements

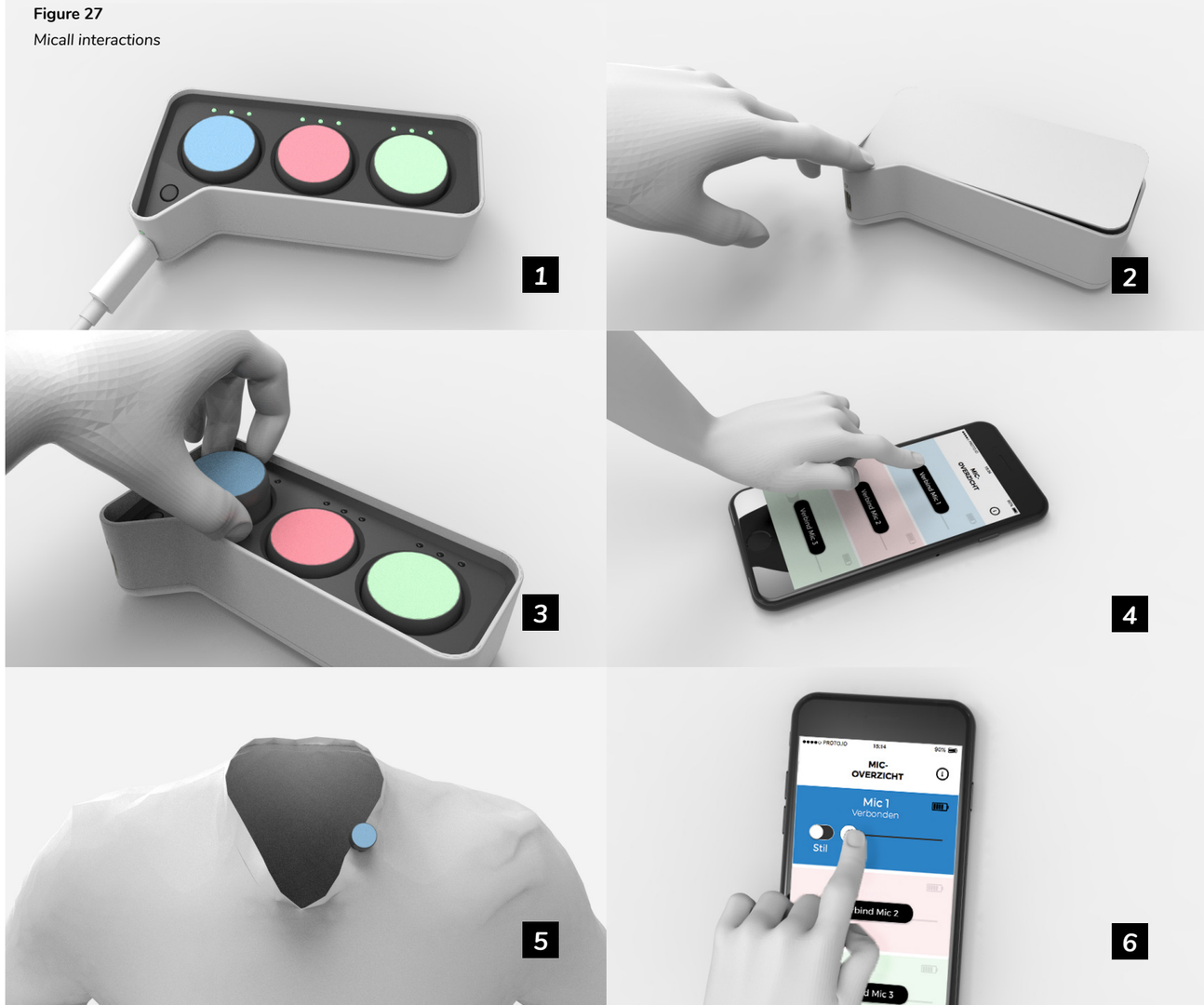


Figure 27
Micall interactions

3.3.B.

Design proposal: Technical details

Introduction

This paragraph describes the technical details of Micall. Here, three technical aspects are highlighted that are important for Micall's functionality. The full list of components (BOM) is found in appendix M.

Bluetooth

As a means of both connecting the Mics with the charger-case and charger-case with the iPhone, bluetooth is chosen. Advantages of bluetooth are its speed, versatility (most devices enable bluetooth services nowadays), its convenience in connecting devices, low energy use (versus for example relatively high-energy wifi), its ability to measure distance and the way it works with profiles. In the case of Micall, it is convenient to be able to measure distance because having a conversation is always related to distance: people do not have conversations 10 meters apart. Hence, it makes sense to put a Mic on stand-by mode when this distance is reached and bluetooth can be used for this. Two bluetooth profiles are used: A2DP and AVRCP. With A2DP, one is able to and transmit high quality audio. AVRCP is usually implemented together with A2DP, and allows to control a bluetooth device remotely. One can for example adjust volume, pause or skip songs, etc. (Sparkfun Electronis, n.d.) By applying these profiles in the right place in the system (Figure 28 to the right), the right connections are made.

PCBs

Most components used in Micall (except for the housing) are off-the shelf products. However, this does not mean that making them work as a whole is just plug and play. A specific PCB and software is needed to tie the components together. In collaboration with an electric engineer, first proposals are made for PCB designs, for both in the Mics as in the charger-case (Figure 29 to the right). This is a first wireless version, using FM-transmission instead of bluetooth as this was an easier step between the wired version of the validation tests and the envisioned bluetooth product. The functionalities of the PCBs can be shortly described as follows (R. Stauttener, personal communication, June 2, 2017):

Mic

The omni-directional mic picks up sounds from the environment and are then amplified in the pre-amplifier to a signal that can be used. Here, possible sound filtering can take place, if desired. After the amplification the audio goes to the FM-transmitter, which modulates this to a adjustable frequency. This adjustment is controlled by the microcontroller. The microcontroller is always in 'power down'-mode, and thus does not waste any electricity. By pressing a button, the microcontroller is 'awakened' and the right parameters are set. The PCB is powered by a LiPo-cell at a voltage of 3.7V. This cell is charged by the charger via the connectorpads on its bottom.

Charger-case

The charger-case is powered by a LiPo-cell. This cell is charged via the USB-C connector which has its own charging-IC. The LiPo-cell gives power to the Mics in the charger-case. Every Mic has its own charging-IC, which charges through contact charging when the bottom of the mics touch the pogo pins in the charger-case. It takes about 25 minutes for a full Mic charge. By pressing the button the indication LEDS will show if the Mics are charging or are already charged.

Batteries

In Micall, two types of rechargeable batteries are used: One in the Mics and one in the charger-case. As the batteries are the largest components, these determine the minimum dimensions. And in this case, the smaller the better (portability). However, there is a trade-off where the smaller the battery means a shorter capacity. By comparing the Mics of Micall with similar products on the market, a necessary capacity of at least 120mAh for the use of 4-5 hours is needed. This means that, if one wants to charge 3 mics at least two times (to be on the safe side, preventing a sudden-dead battery), the capacity of the charger-case battery should be at least 720mAh. For the Mics, a rechargeable 3.7-4.2V 120mAh LiPo coin cell is chosen, for the case two 3.7-4.2V 370 mAh LiPo-cell are chosen. Having two batteries in the charger-case allows for more geometric freedom in its aesthetics. Designing a battery that would fit the exact dimensions of the product and performance needed would be ideal, but to save costs off-the-shelf batteries (that are already certified and safe to use) are selected (Tran, 2016)).

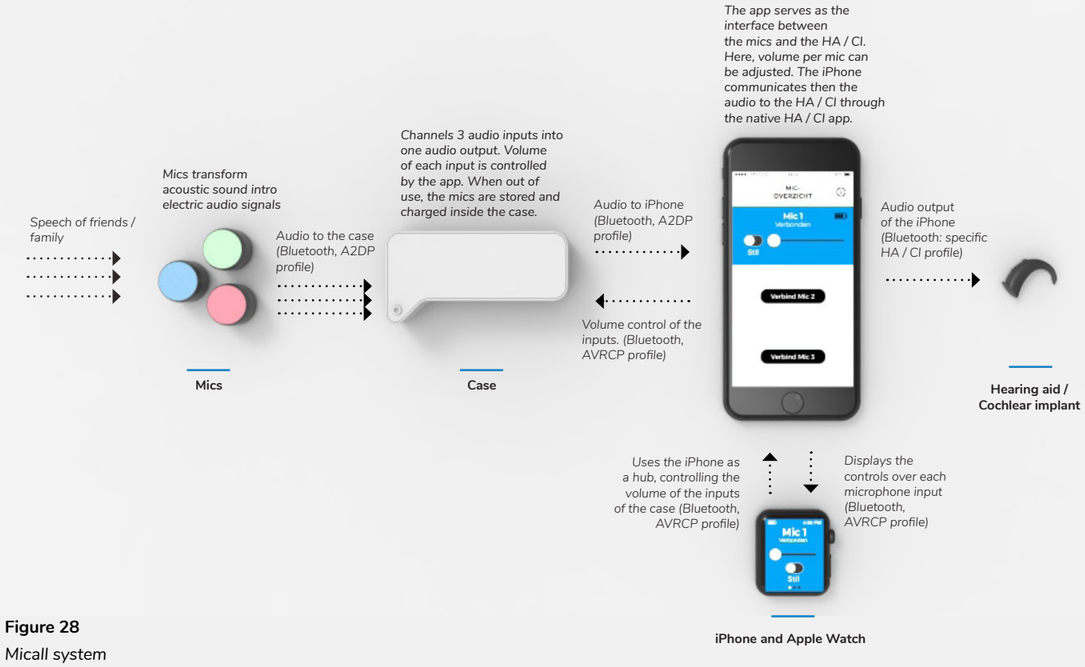
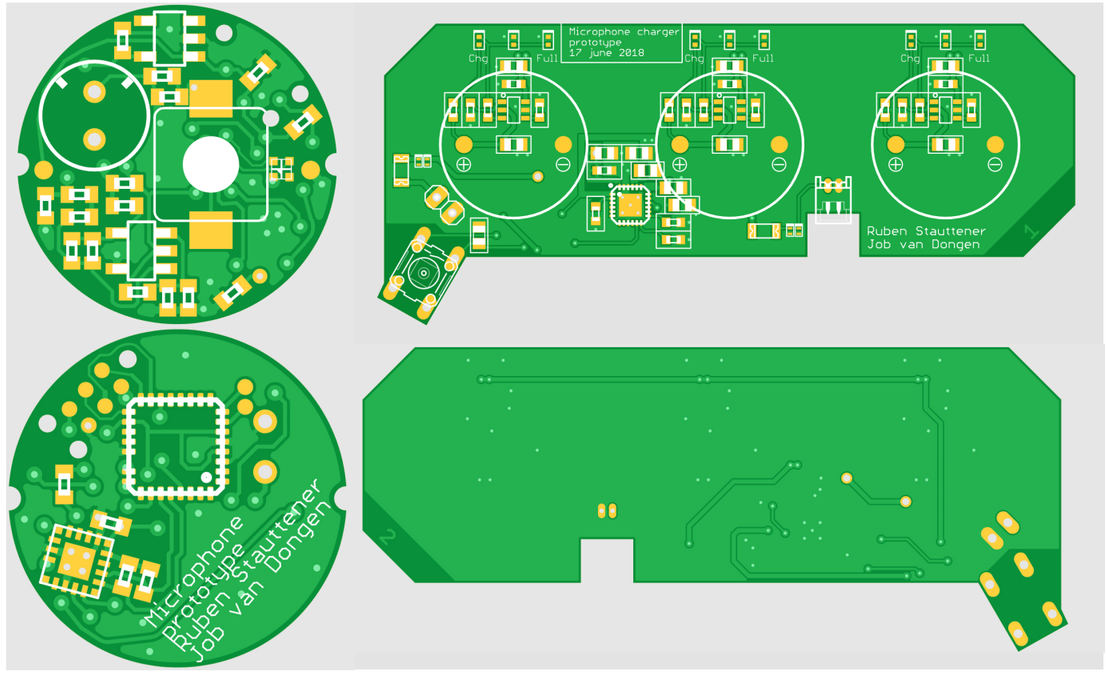


Figure 28
Micall system

Figure 29
First PCB designs for both the Mics and the charger-case that offer wireless connectivity.
Top and bottom images show the top and bottom of the PCBs, respectively.



3.3.C.

Design proposal: Mobile application

Introduction

An important aspect of the Micall product is the corresponding app. This paragraph elaborates on its functionality and interaction with it.

Interface

The app allows the user to have an interface of the sound coming in from the one side and the output to the other. Having the iPhone as an interface is ideal for a number of reasons: the interface is interactive, is programmable, versatile and is usable in a dark context since it emits light. The interface of the Micall app has gone through iterations and ultimately narrowed down to a few core elements: The use of highly contrasting (basic) colors, large text and less functionalities (only volume, mute/unmute and name input). Functions like location lights and test-volume buttons were not perceived as useful in the validation tests and thus have been removed. All boil down in a final proposal of an iPhone and Apple Watch app (Figures 30 & 31 on the right page). The latter is included because of the opportunity of a more discreet use, since it is small and worn on the wrist. It offers the same functionalities as the iPhone app, with a difference that names cannot be assigned on the Watch-app, by the lack of a keyboard (due to its size). This can be done on the iPhone instead, whereafter it will syncronize on the Watch. By swiping trough the Watch screens, different Mics can be operated.

Recognizability

The colors and numbers of each Mic in the app correspond with the number and color of the physical Mic, to increase recognizability. Moreover, one is able to insert a name instead of a number by tapping on the number in the app. Since there is always a link of color, Mics can never be mixed up. When a Mic is put back in the charger-case, the connection with the app is automatically broken and the name is set back to the default number, ready for its next use. This is also illustrated in the top figure on the right. A bigger version of the same figure is displayed in Appendix O.

App cues

A number of cues help to make the app more clear and understandable. When picking up a Mic out of the charger-case, a notification is automatically shown, proposing a connection with that Mic. Once the connection is made and the user would for example go back to the iPhone home-screen, a red bar in the top indicates that a Mic is being used, serving as a reminder. Another reminder is the name that people can assign to a Mic. In the case where someone takes it home by accident, it is still visible who was in use of that mic. As discussed before, when putting back a Mic in the charger-case, its connection with the App is broken. To underline this even more, a notification pops up clarifying that the connection is indeed broken.

Volume control

As has been shown in the validation sessions, the volume control is a critical part of the Micall product. It makes it unique from its competitors as they do not offer such sound-mix abilities amongst different people in a conversation. The volume control is achieved in the app by the use of a slider, the same used in music apps, using its archetype to make the interface more understandable. The mute-switch uses a similar archetype strategy, since such a toggle is widely used for switching functions on or off.

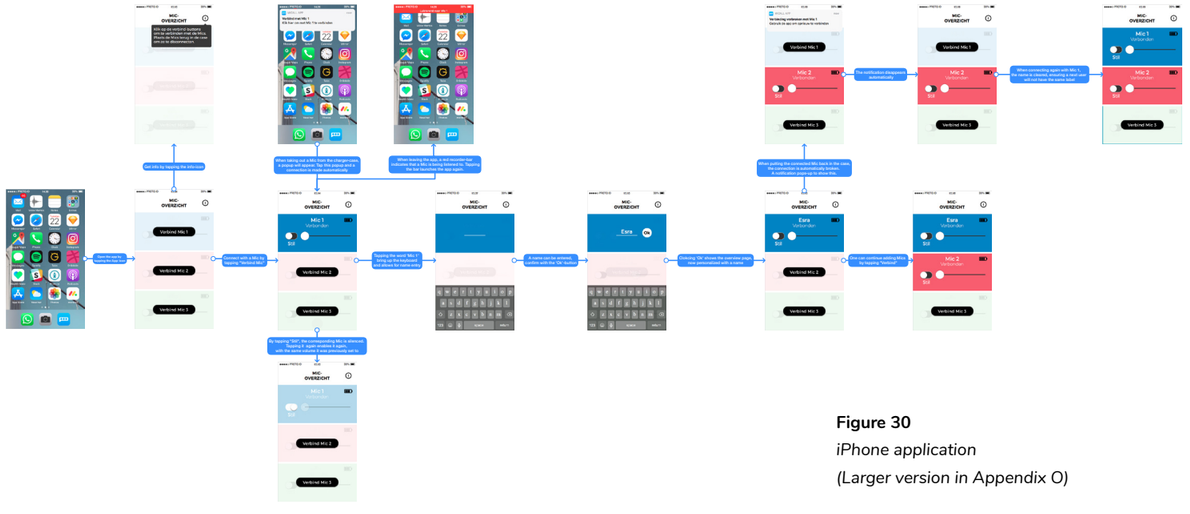


Figure 30
iPhone application
(Larger version in Appendix O)

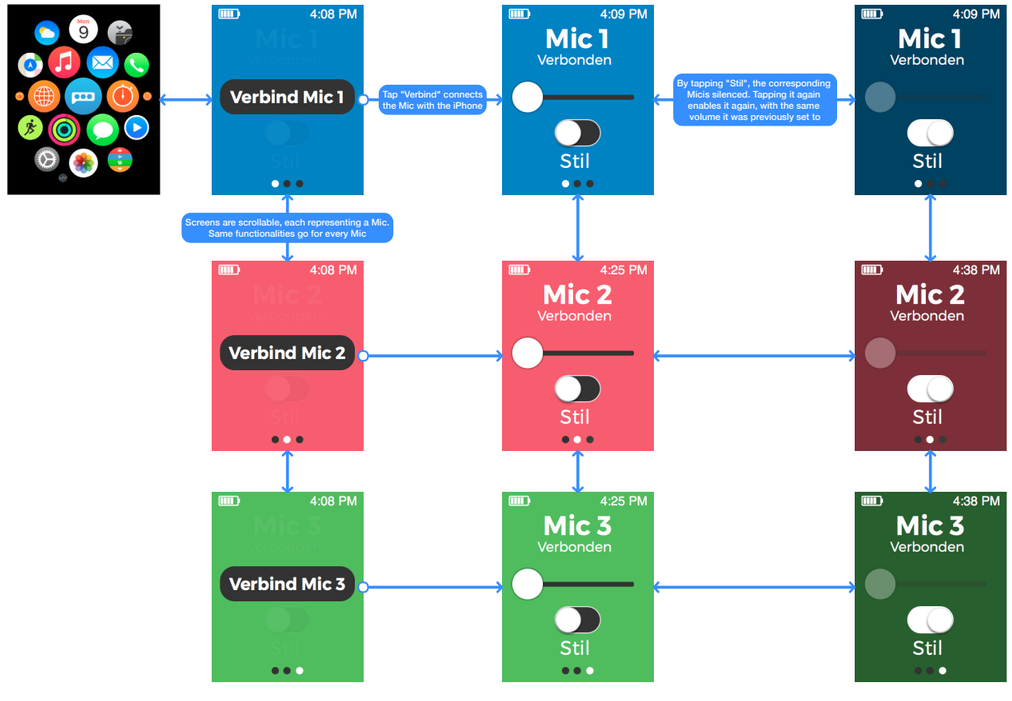
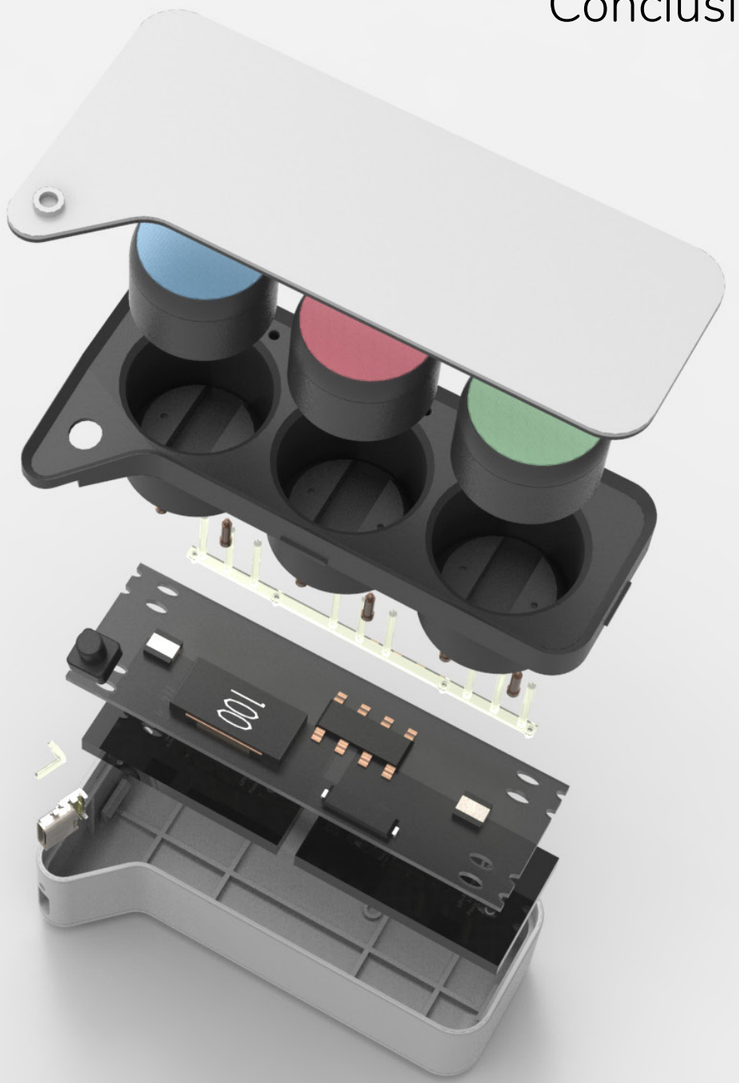


Figure 31
Apple Watch application

CHAPTER 4

Conclusion, reflection and recommendations



4.1

Future improvements / recommendations

Introduction

This paragraph describes the improvements that can be made to Micall in a future scenario. Ideas for these improvements result from the validation tests described in paragraph 3.3., as well from a personal vision about how the product could be improved.

Microphone type

From the validation tests as well as the 'prototype play'-sessions, it has become clear that there is an unanimous preference for a unidirectional mic. This sound is perceived as most crisp and does not pickup ambient noise like smacking lips, chewing, moving fabric, etc. However, this mic also slightly picks up sounds from the background, like light chatter and music. Even though these sounds are often neglectable (especially when people are already hard-hearing), it would be interesting to find or engineer a specific unidirectional mic that is more selective as to what distance it can pickup sounds from. Ideally this would be in the 10-20 cm range, from the collar of the shirt to the mouth. This should be done closely with a sound engineer and be tested with people with Usher in noisy contexts, to stay true to both the user and context of use.

Number of mics

Another preference resulting from the validation tests is the number of Mics that are included within Micall. Having more Mics does not mean a person with Usher should be involved in a conversation more people at the time; it just allows them to have a conversation with more people, without having to ask them to clip-on their neighbor's mic or having to walk to the other side of the table to start a conversation. It allows for a more convenient use. Three mics were preferred as a minimum, five as a maximum. In a future version the charger-case should then be either made longer, or a totally different shape charger-case should be designed.

Extension-sets

On top of the addition of extra Mics, an idea risen from the validation sessions is to make specific Mic sets which can be used in different context. For example, one could have a basic indoor set but with the possibility to extend it to make it also useful in windy contexts (by adding foam filters e.d.), headset-mounts when using it outside on the bike, etc. By keeping the basic set low-priced most people can benefit from the main product, and people that want to extend and spend more money are then also reached.

Wind suppression

Adding to the extensions, the need for wind-suppression was expressed in the validation sessions, but also in the beginning of the project in the co-evaluation sessions.
It would be interesting to research what should be fundamentally different from this design proposal to make the use of Micall possible in windy contexts as well.

(splash)Water proof

Making the product water tight would increase the product's lifespan but also make it more expensive. For now it is not suggested to include this in the design, as it is not intensely used in a 'wet'-context. But, for example, when it would be used a lot in sports and other outdoor activities, it would be an interesting aspect to include in Micall.

Broadband

An option would be to be able to switch between certain frequency ranges within the bluetooth profile used by Micall. This way, multiple people with a Micall product could engage in the same group without signal interference and extend the amount of Mics used.

App platforms

Currently the app is developed for iOS, since the research indicated that most deaf-blind people use this platform. However, from the validation tests it has become clear that Android is also often used. To make the product as accessible to everyone, an Android version should be developed as well.

Testing bluetooth connection

An important feature that has not been tested thusfar is the wirelessness of the product: connection and streaming over bluetooth. A future functional prototype should include bluetooth functionality in order to test the delay in sound and the connection of the mics with smartphones and subsequently with the HAs/CIs. Also could be tested if it makes sense to switch the Mic to standby when the distance exceeds a certain distance. By developing a more advanced prototype in the future pilots can be run to gain even deeper insights on the usability of the product, and on a bigger scale.

Manufacturing

As earlier indicated, there has not been too much focus on the manufacturing-side of Micall. It would be interesting to research how Micall could be manufactured in a most cost effective (and environmentally friendly) way, and so ensure affordable retail prices. Moreover, materials could be explored for cost-effective manufacturing but also for beneficial acoustic properties and a pleasing look and feel.

Marketing channels

Assistive technologies are often covered by medical insurances, and manufacturers know this. As a result, prices of such technologies skyrocket. The vision with Micall is to not take this road. Instead, it should be sold as an audio product, that anyone with a smartphone and bluetooth connection (be it bluetooth headphones or HAs/CIs) can use. Using this approach, the product is not stigmatized and doomed to be overly expensive; it has become a regular consumer product and free from bureaucratic assistive technology manufacturers.

Investments

Investment models should be researched in order to come up with viable ways of developing, producing and selling the product, especially given that the Usher Syndrome Foundation is not a product developer itself. Investments could be done through crowd-funcing for example, on websites such as Kickstarter or Indigogo.

Mic clip

It was noticed that the Mics clipped to the shirts were hanging down because of their weight. As an alternative, a different location of the clip is suggested, so the mic will be directed more upwards and look less 'sad' or 'flimsy'.
For example, the clip of the Mic could be positioned on the vertical side to balance it more when it is worn and also aim the built-in mic to the mouth better.

Indicator lights

There has been given thought to the charge-state of the Mics, but not necessarily to the charge-state of the case itself. This could be done both in the app and by adding indicator lights on the charger-case itself.

Price

As stated in the project assignment and table of functions and requirements, to be affordable is a main function to tackle with this design. On the one hand this is realized by using components that are already available like LEDs, pushbuttons, microphones and bluetooth modules. However, on the other hand, as the project developed, the need arose to have dedicated soft-and hardware, which often need expensive electrical engineers. Moreover, the maintenance of having an app (helpdesk, software updates, marketing back-end) could be costly. Future developments should take these aspects into account.

LED

From the use-tests there has not been expressed a specific need for LEDs to light up to show the position of the person wearing a mic. People indicated that by labeling the mics with a number and/or color in combination with the voice they hear already communicates who is wearing the Mic. Moreover, regarding on the remaining tunnel vision, it might be even a challenge to find the position of the LEDs. However, it was perceived as useful to have an indication of whether the mic is picking up sound or not. As an alternative, the stand-by mode is suggested. Here, only a red light is shown when the button on the top is pressed, for example when going to the toilet. However, a regular switch (like on the side of an iPhone) might work as well, getting rid of LEDs altogether (and saving costs and battery life).

Stand-by message

The app should give a notification when the wearer of a Mic puts the Mic on stand-by, so the person with Usher knows that that person is out of range or engaged in a different conversation. This assures them that it is normal that this person is out of sight, without fearing of having lost that person in a crowded space.

4.2

Promotion proposals

Introduction

This paragraph describes ways the Usher Syndrome Foundation can benefit from a product developed for people with Usher (and beyond). Given that the Foundation is not concerned with product development necessarily, it is interesting to see how such a project can still be made beneficial.

Focus

Obviously the Usher Syndrome Foundation is not concerned with the developments of consumer products, since they are primarily aimed at collecting money for medical research. The goal and focus herein is to find medical cures and/or treatments to prevent or heal Usher on a genetic level. However, having a product at their disposal can offer a number of advantages, described below.

Sales

Imagine Micall to be successful amongst people with Usher, elderly, people with hearing problems, schools, etc. First in the Netherlands but later also internationally. The sales of this product can be used to 1) improve people's lives 2) fund the Foundation on the medical research-part, 3) increase Usher-awareness and 4) improve the product to a next level. The Foundation does not have to market itself as a developer of products, but could do that through a different branch and so keep the primary mission statement of the Foundation clear.

Competition

Direct competitors of Micall are microphone systems that are aimed at faciliting conversations to people with hearing deficits. Herein, popular examples are the Phonak Roger Pen, the Cochlear Mini Mic and Soundhawk's Soundhawk. What these products fail to deliver, however, is that they can only amplify sound as one total package. Micall is able to separate voices from background noise (including volume control), and thus offer a more clear and meaningful sound. Moreover, Micall is not limited to one brand of HA/CI/Bluetooth headphone, since the only requirement is having a bluetooth enabled hearing device and bluetooth enabled interface (smartphone). Because of this freedom, it is possible to market Micall as a regular sound product, avoiding the expensive and stigmatising assistive technology market. It is proposed to market Micall as a product for everyone that could use a little help in a crowded space, and not specifically aimed at people with Usher necessarily.

(Brand) awareness

Not only will the Foundation be able to sell Micall, it is now also able to promote the awareness of Usher through this collaboration with TU Delft. Spreading the project amongst the Industrial Design faculty could spark an interest among future graduation students on the topic of Usher. Since the first project has been performed, a network with the university is formed and future entries will be more easy. Moreover, a successful graduation project is often promoted on the TU Delft website and articles written about the project by the Foundation can peak interest when TU Delft is involved in it. Think of partners of both TU Delft and the Foundation that get word of this project and show interest in future developments of Micall. To the right, ideas for a Micall webpages are shown, to illustrate publicity possibilities.

Hope

The fact that a product for people with Usher is being developed at a research facility as TU Delft sparks hope for the future; it is not solely dependent on the efforts of the Foundation alone. Increased awareness could spark future research and so increase the odds on innovations.

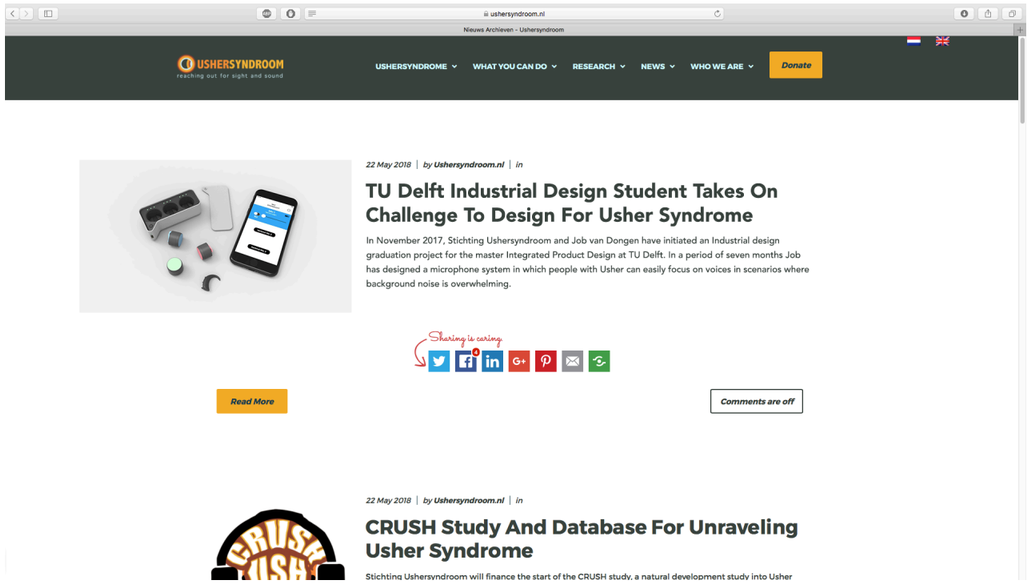


Figure 32
Usher Syndrome news page

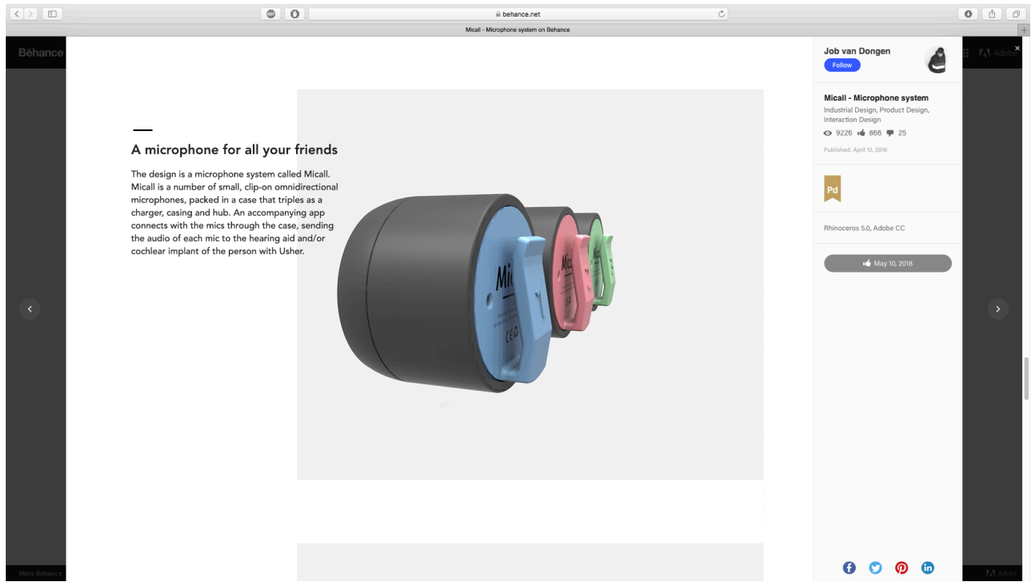


Figure 33
Behance portfolio page displaying the Micall project

4.3

Conclusion

Project Assignment

Usher Syndrome is a hereditary disorder, where people's sight and hearing degenerates over time. The project was initiated to help people with Usher Syndrome to still be socially involved, regardless of the disorder. The project assignment is stated:

"To design a non-stigmatizing, portable and affordable product for people with Usher syndrome, that offers enhanced control over lighting and/or acoustics, with the goal of improving their sense of involvement in social contexts."

Research results

As a result of the deficits caused by Usher, having conversations with other people can be challenging, especially in rooms that are low-lit and that include background noise. In understanding a conversation, speech contains the most information. By aiding the sense of hearing, speech intelligibility can be improved. By separating speech from background noise, conversations can be followed regardless of any background noise that is present. Other functionalities that add to the intelligibility is the reduction of the distance between speech source and person with Usher, as well as enabling volume control over the speech source. Lastly a connection with a connection with the hearing aid(s) and/or cochlear implant(s) should be enabled.

Assignment answered

The functions and requirements are translated into a design proposal: a microphone system called Micall. Micall contains small microphones that can be divided among friends/family, and can pickup sounds from each person individually rather than capturing an entire scene like current microphone aids do. Voices of different persons are then sent wirelessly to the hearing aid(s) and/or cochlear implant(s) of the person with Usher and can be each be volume-adjusted through an app. This allows for full control of each and every voice. Speech is now separated from background noise and is made more intelligible. Positive feedback in the validation of this concept shows that this concept answers the assignment at hand, as it offers enhanced control over acoustics and improving sense of involvement in social contexts.

4.4

Critical reflection / discussion

Introduction

This paragraph describes a critical look on the project in its totality: what could be improved in a future version of such a project, what have been complications?

Solo project

The most apparent aspect of this project is the management of a research project from the ground up, all the way to a concrete product proposal. It is good to test a big spectrum of the capabilities of a master student but to do a half year project by oneself is, in my opinion, a task that is too far from how companies work in reality (and thus not necessarily a good preperation for the job market). A better alternative, in my opinion, would be to let a student be part of a design company and carry out a project while he/she is able to communicate, collaborate, share and carry out the project together with people from different disciplines, something which comes closer to reality and which can indicate if a student would be ready for the job market after. Inside a university environment this could be a project in collaboration with other faculties, where different disciplines meet and collaborate, working together towards an end-goal, with each their own objectives.

From the heart

Given that graduating is a very demanding task, I would highly recommend to anyone to initiate a project that is close to one's heart. When the project is not going as planned or motivation is hard to find, the project will be ensured to be carried out since it is close to the designer's heart. The idea of designing for people that would benefit from the product in the case of this project helped me to stay sharp and focused, to have extrinsic as well as internal motivation.

Prototyping and testing

There was a relative long time between the design of the test-setup for validating the concept and the actual planning and performance of the validation tests. This was due to focus in other areas like reporting and consideration of other concepts. In hindsight, I should have trusted my intuition and be more pro-active by executing such a test more fast. Even though a test might fail, any result of such a test can be used: Negative results inspire improvements, positive results validate ideas.

Test subjects

Tests carried out in this thesis have primarily been done with middle-aged people with Usher (aged 40-60). This can both be seen as good and bad: On the on hand, testing with both younger and older people with Usher gives a more complete overview of how different stages of Usher influence test results. On the other hand, participants were in an advanced stage of Usher (some had 5% sight left and/or hearing loss over 100dB), which gave a good indication of how impactful the concept is: if the concept works with these people, it must be a successful one.

Test setup

Some use tests have been performed in small groups, and this experience goes two ways: On the one hand people inspire and stimulate each other to perform during a test. Moreover, I had the feeling that tacit information is surfaced more easily when people are in a group, since they discover similarities in each other's experiences, which then sparks memories about their own experiences. Once this flow is going, the outcomes are very deep and useful. On the other hand, however, it is hard to follow every input given during such a 'crowded' test (hence making audio-recordings) but also to respond to everyone's input with focus and attention. Tests with only one or two persons might spark less ideas or feedback, but the researcher is able to respond more thoughtfully to each input, which - in turn - might lead to deeper insights. As a recommendation I would suggest to consider before planning any use tests if it would benefit from a group setting or that a one-to-one setting would suit better.

Intuition vs. methodology

Doing a graduation project in a research facility of TU Delft requires the need of methodology and a structured approach. While this is ensures that a project is carried out from start to finish in a substantiated manner, it lacks a human part in my opinion. Here, intuition and gut feeling play more important roles. Such motivations are not always explicit but do feel right because the subconscious has already figured it out. I am convinced that the methodology and structure within a research institute is the best approach, but I would recommend to give more room for intuition where possible, especially within a design faculty. It is good to learn to trust methods, but it is also beneficial for both the project and one's personal growth to learn (how) to trust one's intuition.

Achievement of functions and requirements

The way the functions and requirements are fulfilled by the validated concept and proposed design determines the success rate of the project. Appendix J3 shows the ranking of both the initial ideas in the beginning of the project and that of the final design proposal. In short, it can be stated that the final design proposal answers the project assignment as it is perceived by end-users as non-stigmatising, portable, it enhances the control over acoustics and improves their sense of involvement in social contexts. The affordability is - like always - hard to estimate in this stage and state of the project. However, it is attempted to use as many off-the-shelf parts as possible, and therefor reducing costs. In the future further elaboration into the costs of manufacturing and hardware/software developments should indicate a more complete cost overview.

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