SMART GLASSES DESIGN

EXPLORING USER PERCEPTION OF WEARABLE COMPUTING

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Abstract

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As technology is growing rapidly and integrating itself to all aspects of people's life, designers and developers try to provide a more pleasant experience of technology to people. One of the technology trends which aims to make life easier is wearable computing. Wearables aim to assist people to be in control of their life by augmenting the real life with extra information constantly and ubiquitously.

One of the growing trends of wearable computing is Head Mounted Displays (HMD), as the head is a great gateway to receive audio, visual and haptic information. Also due to the Google Glass project, wearables in form of glasses gained much more attention during last years.

However, because of the early stages of the technology adaptation, there is still much to explore on social acceptancy, key use cases and design directions of glasses as a type of wearable computing.

This thesis has two stages. In the first stage, the aim is to explore the different use cases of a wearable eye tracker concept in different context and study the user's perception of such a device. To accomplish this objective a user study with (n=12) participants were conducted using the experience sampling methods (ESM) and employing a mock-up of a smart-glasses as a design probe.

In the second stage the focus is to design different alternatives for a wearable eye tracker concept and evaluate the concepts by conducting focus groups (n=14) to understand the user perceptions toward different industrial design concepts of such a system.

Keywords:

Wearable computing; technology acceptance; experience sampling method; user studies.

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Contents

1 CHAPTER ONE
Introduction

In this chapter I explain the aim of this thesis, the brief background of wearable computing and the technology around this trend. Also I explain the motivation for this study and what is the focus and scope in this thesis. Finally I introduce the research question and timeline and structure of this thesis.

1.1 Aim of Thesis

Aim of this thesis is to explore use cases of a wearable device in form of smart glasses. How such a device can assist users in everyday life? What are the benefits and problems of using it for the user and people around them? In what context such a device can benefit the users? Moreover, the aim is to study the different design directions of smart glasses. What might be the benefits and problems of different design alternatives? Finally to get understanding of user's perception and expectation of different designs and to find solutions to enhance the experience of using this kind of devices.

1.2 Background

Nowadays, technology is inevitable part of people's daily life. It is possible to use technology in many ways and everywhere, from home to workplace and while doing different activities. Many people are using smartphones and various phone or web applications to assist them in their everyday life. The growth of technology can accompany new problems and new demands. For example, the process of using a smartphone; taking it out from the pocket, unlocking and navigating the interface takes about 20 seconds and it requires the user to tilt their head towards the screen. So the process can be interruptive for the users (Starner 2013, 14). Hence, it is expected from designers of new technologies to improve the experience and make it less intrusive and more helpful for the users.

One of the new trends in technology that is getting more attentions by public and coming to markets is wearable technology. Wearable technology includes a wide range of devices. It can be a wearable device with whole capability of a desktop computer to a ring with RFID chip (Dvorak 2008, Vii). Wearable devices are worn by people, they are usually always on and communicating with the user and they can provide services by providing easier and less obtrusive ways of interaction. With another new technology trends growing like the Internet of Things (IoT) wearable devices can be easier to use and assist the user in everyday life. IoT is a situation that objects and people are connected to internet and so to each other. In such a situation, everyday used objects such as parking meters, home appliances, tooth brushes and clothes are connected. In this scenario wearable devices are part

of this new trend which is growing fast (Swan et al, 2014, 1). ABI Research, estimate the market for wearable devices in the area of sports and health care to grow near 170 million devices by 2017 and annual growth of 41 percent (Chen-Tsai 2014, 267).

Another technology trend that can grow the need for wearable devices is Augmented Reality (AR). According to Van Krevelen and Poelman AR is combination of the real environment with virtuality (2010, 1). AR can be used by all senses such as sight with the use of HMD, hearing with applying hearable devices or touching such as haptic feedbacks. So, wearables are a great medium to apply AR in daily life.

One of the trends of wearable devices is head mounted displays (HMDs). HMDs have been an active area of research since the beginning of 1990's(Azuma 1993, 50-51)(Chung et al, 1989,44), and it has since come a long way from the early, bulky prototypes, which were mainly used as an interface to access virtual environments. One of the early examples is Xybernaut Mobile Assistant. Xybernaut Corporation produced one of the first commercial wearable computers with head-worn display. It was quite lightweight in comparison with other products and it had a see-through head-mounted display which enabled users to see the display and receive data in the field of view (Buergy-Seitz2013,1484).

Between years 2000-2010 HMDs developed more, mostly by start-up companies. They had enough money to develop the first prototypes but the price of the complete wearable HMDs was still too high for the market (Buergy-Seitz2013, 1484).

Today, wearable computing is an emerging technology trend, which is currently being increasingly developed as the consumer's electronics products. Especially, the trend on developing light weight HDMs is strong, and one of the most interesting form factor here are Google Glasses, which has gained enormous attention due to the Google project Glass. "Project glass is a research and development program by Google to develop an augmented reality head-mounted display (Deshpande 2013, 0). Also other products such as the Oculus Rift have brought head-mounted displays to the attention of large audiences and application developers. "Oculus Rift is a light weight headset that allows user to step into the game and look in any direction" (Desai et al 2014, 174).

1.3 Motivation

The topic in this thesis is exploring wearable computing in form of glasses. Wearable technologies are in the early stage of development and adaptation so there is a lot to explore on social acceptance and key use cases. In addition different design directions for the smart-glasses will be explored.

Working in the area of new technology trends is always interesting and challenging for designers; to explore the user experience, interaction and usability of the products or services. Moreover, it raises questions related to, e g, privacy and social acceptance.

In case of HMDs, it is even more challenging. HMDs use totally different form factors for input and output of the device; from conventional mobile technologies such as smartphones and tablets which obligate the use of new features of interacting to the device such as hand gestures or voice input. Also the invisibility of cameras might cause problems related to privacy of the people around the user. So, use of such new systems may bring out several social and cultural issues (Dvorak 2008, 311). Whereas there has already been discussion on the privacy questions related to the technology and especially Google Glass (Hassenzahl 2008,91-97), there is still a lack of user research looking at the technology and its potential future applications, especially from the user perceptions point of view.

In addition, HMDs have strong connections with the users as they are designed to be always on and interacting with the user, so their use might bring many social issues and as they are becoming mainstream these issues can have great effect on their adaptation in everyday lives (Dvorak 2008, viii).

In addition, combining the technology to a system that is easy to use is always challenging. As the device is worn on the face the design should be acceptable by the public and it should be easy to wear and comfortable. Also the design should meet different consumers' needs with different styles and interests to hit the market.

1.4 Focus and Scope of the thesis

This thesis includes two main part, first user study about HMDs employing glasses type form factor to charting out early perceptions of the users. Lo-fi mockup of HMDs is used to conduct the user research and the aim of the research is to study privacy and social acceptability of the product and study the interaction modalities in different context in everyday use in real life. This study provides knowledge for future designers of wearable HMDs.

The second part is to explore industrial design space of the HMDs device. The aim is to Study different design concepts deriving rationale from the result of user study and evaluate the concepts with the focus group.

1.5 Research Questions

This thesis is focused on charting the user perceptions on (imaginary) glasses type HMDs in a variety of everyday life use contexts. In particular, we sought answers to the following research questions:

R1. What are the most commonly emerged concerns and benefits the user perceive for using glasses type HMD?

R2. What are the social aspects related to the device (imaginary) use, and what kind of reactions their use provokes?

R3. What are the expectations with the interaction modalities and functionality of the device?

1.6 Timeline and Structure of the Thesis

Chapter one is an introduction that includes aim of the thesis, background review of wearable technology, motivation of the thesis, why this area is interesting to work in and what is the focus and scope of the thesis. Chapter two is a review of the earlier works in the area of wearable computing and HMDs. There I explain the position of this thesis against the earlier works. Chapter three is about the

research methods and design methods that are used in this thesis. In chapter four I explain the user-study in details and in chapter five the result of user study is explained. Chapter six includes the design process and evaluation of the different concepts. In chapter seven I discuss about results and findings of the thesis and answer the research questions and finally chapter eight is the conclusion of the thesis.

This thesis interpolate materials from two papers (Vahabpour et al. 2014) and (Häkkilä, et al. 2015) which author of this thesis were author and coauthor of those publications. See Appendix 4 for a copy of the copyright agreement.

Figure 1 shows the expected timeline of the thesis.

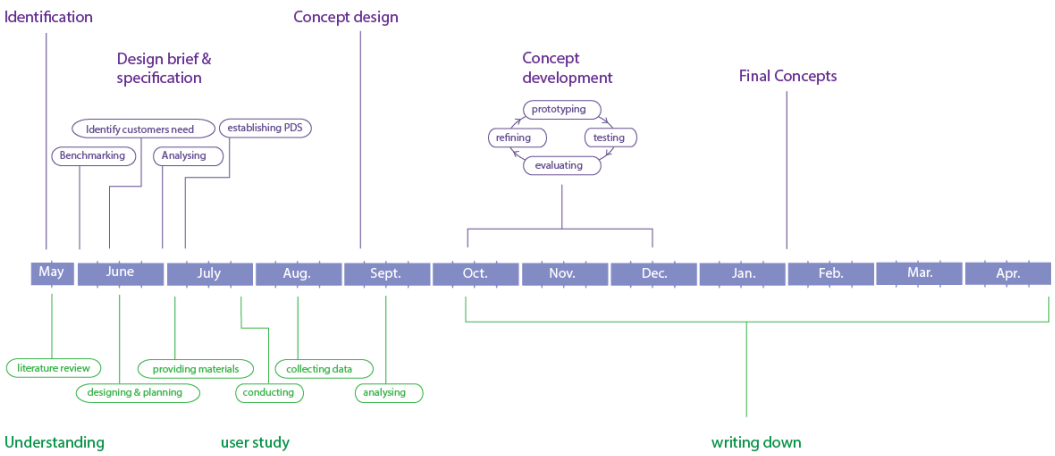


Figure 1. Timeline of the thesis

2 CHAPTER TWO
Related works

In this chapter I explain what has been done in area of wearable computing especially in form of HMDs and I briefly introduce two wearable products (Google glass and Oculus rift) to get better understanding of such systems and finally, I explain the position of this research against earlier work.

2.1 Overview of the earlier research

In the Area of the HMDs most of the early researches are related to the technology of the device. How the system works and what is the latest out of shelf technology to apply to the system and what might be the potential usage of the system (Chung et al. 1989) and most of the early research done with bulky technology setups.

In addition some research try to explore mix reality and how it can affect the user and interaction between virtual and physical environment and how user can benefit from such system (Starner et al. 1997). Also, some researches are about to study the related technology in different stage of virtual continuum and definition of different terms of virtuality between real environments to virtual environment such as augmented reality (Milgram 1994). Furthermore, in some research they try to describe the characteristics of such a system and possible applications of it (Azuma 1997).

Related to the applied research focusing around a real world use cases, research has been done to discover the potential benefits of HMDs in different area such as healthcare, manufacturing, entertainment and military by using AR system (Azuma 1997). Chung et al. have discussed the benefits of using HMDs in interactive molecular studies and virtual building exploration (Chung et al.1989). Thomas et al. have presented early work in area of architectural design, namely using HMDs as an augmented reality tool allows a building design to be viewed in its physical surrounding (Thomas et al. 1999).

Moreover, the user studies with HMDs have been dominantly made in laboratory settings with a focus in interaction research. In addition, wearing HMDs have been investigated as an interaction method for the angle of physiological aspects, for example as part of a treatment for fear of flying (Wiederhold et al. 2002), or by comparing it with other technologies such as projection display systems (Sharples et al. 2008).

Recently, due to the improved access to the hardware as well as software development tools, more research has started to demonstrate in different exploratory use cases for HMDs. For instance, McNaney et al. explored the use cases where glasses type HMDs could be applied for helping people with Parkinson disease (McNaney et al. 2014) e. Furthermore, Kunze et al. studied the HMDs

usage for older adults, how they can benefit from the technology and the difficulties they may encounter (Kunze et al. 2014).

In addition, some research has been done around potential application based on HMDs system for example, Swan et al. presented how brain training application can benefits from technology such as wearable computing and IoT and how such systems can provide background for multi modal memory games (Swan et al. 2014).

Moreover, Bronovsky et al. discussed how wearable computing can have effect on concurrent enterprise in different area such as maintenance, production, healthcare and emergency response (Bronovsky et al. 2006).

Furthermore, some research has been done to find out new potential applications for wearable computers in form of HMDs. Funk et al. try to extent the possibility of the object finding and navigating the user to the target by the devices such as Google glass (Funk et al. 2014).

Also some studies done about the acceptability of the wearable computers. Use of mainstream wearable system will raise several social and cultural issues such as social conventions, personal feelings and expectation (Dvorak 2008, 311). These might effect on how the new technology get accepted by the user. Buenaflor & Kim identified and evaluate the human factors that have effects on acceptance of the new technologies (Buenaflor & Kim 2013). Denning et al. studied the privacy point of view of individuals when they are encounter with the user of AR devices (Denning et al. 2014). Also, Abawajy discussed the human computer interaction on ubiquitous computing and how body-based interaction arise cultural, privacy and security issues (Abawajy 2009).

2.2 Review of the current products

For better understanding of the main features and characteristic of the HMD based smart device, I go through the main features of two products that currently are under development. Design and main characteristic of Google glass and Oculus rift will be explained to get better understanding of the HMDs.

2.2.1 Google glass

Project glass was a research and development project at Google x Lab that works on futuristic technologies. Google glass (Figure 2) is an augmented reality based HMDs. It basically provides hands free heads up display to reach the data from the smartphone.

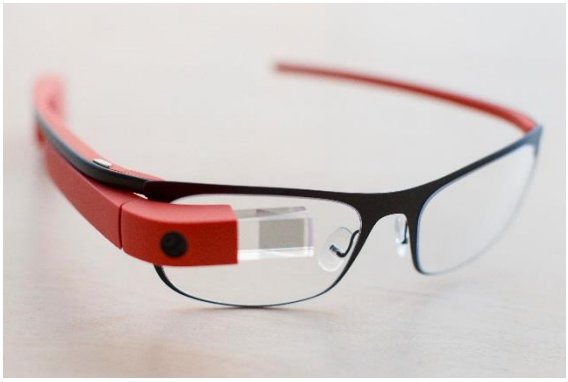


Figure 2. Google Glass

Google glass includes a small video display which works in pop up form and displays the information in front of the user's eye. Basically the display works with a projector and a prism that directs the light from projector to the user's retina. The image is slightly transparent so user can comfortably locate it in front of the eyes without blocking the view.

It also has a video camera that can take photos and videos. In addition, it can sense the environment and recognize people and objects. It also has a speaker and a microphone to make and receive calls and to take the voice commands. A bottom is provided in one side to make physical touch input.

The Google glass can communicate to the smartphones via Wi-Fi and Bluetooth, it also has a CPU and sensors like GPS and a battery. Most of the processing take play in cloud environment and all the parts are embedded in a small glasses frame (Deshpande et al. 2013).

2.2.2 Oculus rift

Oculus Rift (Figure 3) is a HMD, based on virtual reality. It allows the users to step inside the simulated 3D environment. Also, the head tracking system allows the users to seamlessly look into any direction and control the view (Desai et al. 2014). The device

Figure 3. Oculus rift development kit 2

creates stereoscopic 3D view by providing two parallel image for each eye as the natural way the eyes perceive the environment and it provides approximately 100 degree point of view. Oculus rift development kit 2 is currently available for developers (Oculus website). The design is similar to ski goggles with two displays inside and it currently works with cables. In addition it is uncomfortable to use if the users wear glasses (Desai et al. 2014).

2.3 Gaps and the position of our research

Despite the fact the technology around the wearable area is booming there is still a lack of research about the end user perceptions and wider set of possible use cases especially in the form of HMDs. Many researches are particular in a special area such as healthcare and there is lack of research to study the benefits and problems of using HMDs in daily life.

This calls for user research, where the area is investigated through a field study, where participants are probed to chart and assess the different possibilities with the technology.

In addition, research about the industrial design space related to HMDs are still very scares: especially around the expectation of the end user towards styles and form factors.

3 CHAPTER THREE
Research methods

In this chapter I go through the research methods that are going be used in user study. Also, design methods for designing and evaluating the concepts will be explained.

3.1 User study

The aim of this thesis is to understand what people do and what they feel when they are using HMDs and what is their expectation of such technology in their daily life. How they will use such device in different context and what are the benefits they get and what might be the problems. In order to reach this goals one should be able to evaluate such a technology. The type of HMDs that is going to be studied in this thesis is in class of ubiquitous computing which is expected to be used by the user all the time, in changing environment and while doing different tasks.

Designing for this kind of technology can be challenging because of the variability of the users, context of use and changing environment and evaluating of such technology cannot be approached in laboratory setting (Consolvo & Walker 2003, 24) as people should adopt and use ubiquitous computing in different situations and different environments . So, one should use a method of evaluation that makes it possible to study it in various situations.

The appropriate evaluation techniques to study such ubiquitous applications would take place in situ environment (Hurlburt & Heavey, 2006), with several participants and over a period of time (Consolvo &Walker 2003, 25). In order to accomplish these objective a method called "Experience sampling method" (ESM) will be used with the help of a design probe which in this case is a Lo-fi protitype of a HMD.

3.2 Experience Sampling method (ESM)-Study of everyday life

Experience sampling method also known as "time sampling", "beeper study" and "ecological momentary assessment" is a technique from the field of psychology (Consolvo & Walker 2003, 24-25). In this method researchers ask individuals to provide systematic self-reports randomly in a period of time (Csikszentmihalyi & Larson 2014, 21). In this way it is possible to gather data from people about their experience of daily life which can answers questions such as "How do people spend their time? What do they usually feel like when engaged in various activities? How do men and women, adolescents and adults, disturbed and normal samples differ

in their daily psychological states?" (Csikszentmihalyi & Larson 2014, 21). Therefor, areas such as mood, time use and social reaction can be understood with this method. (Consolvo & Walker 2003, 24)

In this method participants receive random alerts in a period of time for example one week, during the waking hours and after receiving the alert he or she should complete a self–report questionnaire which asks about their experience. Participants should fill the questionnaire as soon as they get the alert if it is possible for them no matter what they are doing.

The questions usually consist of participant's objective situation such as "what the participant were doing?", "where was he or she?" and "with whom was he or she?" and subjective state at the moment of receiving the alert which is included "items dealing with the content of their thoughts; their cognitive, emotional, and motivational states; and their perceptions of their current social situation" (Csikszentmihalyi & Larson 2014, 23)

One of the benefits of using ESM method is that it is not retrospective (Hurlburt & Heavey 2006, 78).The participants do not need to recall anything; instead the questionnaire asks about their current situation so this method has less chance of cognitive biases (Consolvo & Walker 2003), as it does not need the participants to think back over and remember the thoughts or feelings from the past.

In this method researchers usually describe the research process for the participant and do an interview in the beginning and at the end they go through the questionnaire and do the last interview. This self-report evaluation and minimal presence of researchers can help to reduce biases compared to the situation where participants being observed. Another prospect of this method is that it is possible to collect both structured data to analyze it quantitatively and unstructured data for qualitative analyzes (Consolvo & Walker 2003, 25).

3.2.1 Design probe

Understanding the potential users is one of the key successes to design for future experiences (Mattelmäki 2006, 20). To reach this goal designers should engage the user in the design process to understand their needs, feelings and values by

considering their views into design. Using design probes is one of the methods that helps designers to reach these goals.

Since the use of probes in 1999 by Gaver et al. probes have been used in wide areas and scopes from design to HCI and in heterogeneous ways both in design and form (Wallace et al. 2013, 3441).

Design probes can be physical artifacts (Wallace et al. 2013, 3442) or can appear as interactive device or systems, which are used as a tool to understand the user needs and feelings and explore the design opportunities.

In probe study, users act as active participants and their perspective can enrich the design. Probes study the user's daily life including "social, aesthetic and cultural environment" (Mattelmäki 2006, 40).

This approach helps to explore new opportunities by facilitating the participant's reflection to an experience and provoking the users by involving them to a set of activities (Wallace et al. 2013, 3442). Design probes offers a possibility to conduct user research in the wild especially for futuristic concepts with complex notions and experiences.

In this thesis a prototype is used as a design probe to help the user experience the smart glasses in the different situations. Traditionally prototypes have been known as highly finished physical models, while nowadays contemporary designers use any kind of representation of the products to help the others to understand it and this gives the opportunity to designers to explore their product easier and faster (Milton & rogers, 101) and same time explore features of the product without any preconception.

Depending on the project prototypes can be anything from paper-based storyboards, electronic pictures and video simulations to actual working product. With prototyping, users can interact with the product, feel the experience of using it and explore the potential use-cases (Sharp et al. 2004, 531). Therefore, in this thesis a low-fidelity prototype of smart glasses used to help the participants of the study to role-play in different situations and imagine the potential uses of smart glasses during the study by providing visual and tangible cues to the participant and the people around them.

3.2.2 Similar studies

In this thesis an early perceptions user study of smart glasses has been conducted in the field by using Experience Sampling Methods (ESM), enhanced with a design probe and a user diary.

A similar study has been conducted earlier by Wilson et al. in the context of portable pico-projector. In pico-projector study in order to chart user's perceptions and preferences on the technology, Wilson et al. conducted a two-phase user research. In the first phase they utilized ESM with 15 participants that probed to the use of Pico projectors and project different content based on what they were doing in real life context. The feedback on these occasions was collected. In the second phase diary study has been done to investigate the usage of a phone projector in daily life (Wilson et al. 2012).

Regarding to lo-fi prototyping method to explore new technologies Posti et al. used Lo-fi prototyping method to explore design possibilities of user interfaces of stereoscopic 3D mobile devices for location based services (Posti et al. 2014).

3.3 Concept design and evaluation

One characteristic that makes designers specific is turning ideas to reality. In order to do that, designers need methods to develop ideas and turn them to products or systems (Koskinen et al. 2011, 140). One of the aims in this thesis is to design concepts for the glasses-type wearable computing and evaluate the concepts in order to get design rationales for future design projects. To achieve this goal, different concepts for the glasses will be generated by the product design methods and different design alternatives with distinct form factors will be explored and evaluated by a focus group study.

3.3.1 Product design methods (Design drawing, vALUe, PMI)

One of the simple and versatile tools in early stages of design is drawing by hand. In this way a designer can explore shape of the product, function and aesthetics. With this skills designers can communicate about the ideas and concepts clearly

and generate and evaluate it for further development. In design drawing different methods can be used from simple sketching to 3D CAD drawing and depends on the stage of the project, different methods can be used. Usually in the early stages of the project hand sketching can be more versatile as it is simple and quick and when the design directions are clear CAD rendering and prototyping is more beneficial (Van Boeijen et al. 2014, 159).

In this thesis hand sketching will be used in the early phases to generate different ideas freely without thinking about the limitations. Further, Value method will be applied to evaluate the basic concepts and get a better insight of each ideas. According to Van Boeijen et al. "vAlUe stands for: Advantage, limitation, Unique Elements." In the early stage of design process when we have a large set of different ideas and concepts Value is a quick and systematic solution to evaluate the early concepts (Van Boeijen et al. 2014, 149). Basically we can compare advantages, limitations and unique elements of the ideas. This method helps to modify what advantage or disadvantage each idea has and helps to understand and validate the ideas. In the next step PMI method will be used to compare the ideas and choose or combine the best ones for further development. With PMI method we list the plus, minuses and interesting aspects of each ideas, so it helps to evaluate ideas in a systematic way and make decisions for concept development. After deciding the concepts for further development, CAD rendering will be used to visualize the concepts and simulate the real product for further evaluation and getting the perception of users (Van Boeijen et al. 2014, 145,149).

3.3.2 Focus group

Focus groups are group interviews to reveal what and how people think about a topic (Kuniavsky 2003, 201) and it helps to collect data through group interaction (Hague 2004, 48). With focus groups it is possible to get insight about what people perceive and how they experience a situation (Kruger 2014, 87).The dynamic situation and interaction between participants and moderators differentiate focus group from interviews (Lazor 2010, 193).

Ideally focus group is an environment that people feel comfortable to reveal their thought and ideas and it helps researchers to understand their values, desires and

assumption about a topic, a product or an experience (Kuniavsky 2003, 202). The outcome of focus group is qualitative data (Hague, 2004, 49).

It is crucial to have a right audience in the focus group. The participants should be comfortable to talk to each other and open up and discuss about their thoughts; they should feel comfortable to talk about the topic of conversation (Kuniavsky 2003, 209). Focus groups usually made up of 5 to 10 people so the group is small enough that everyone can share their thoughts and big enough to get diverse ideas. Moreover, to get a proper result it is advised to conduct about 3 to 4 focus groups for a subject (Hagua 2004, 48, 54).

In Focus groups moderators follow a discussion guide so they will have a consistent framework and schedule for all the focus groups. Questions usually contain 3 to 5 main topics to investigate and the questions should not be directional so it would not create bias to participants (Kuniavsky, 2003, 227,228). Moderators should be skillful so he or she can direct the discussion in a way that everyone has enough time to talk and are willing to participate in the discussion (Hagua, 2004, 59).

In this thesis focus groups are conducted to analyze people's perceptions about the future product. With the aid of simulation, participants could visualize how the product would look like so they could express their ideas about the different designs.

4 CHAPTER FOUR
Study set-up

In this chapter the user study set-up and procedure will be explained. As mentioned in previous chapters the aim of this thesis is to find out which situations would have the potential for users to benefit from using the smart glasses, and in particular from eye-tracker based interaction and what is the potential use cases for this kind of technology. Especially the aim is to explore how people might use and feel while using the device and what is their perceptions and what might be the reaction by bystanders and society to a new technology like the smart glasses.

4.1 Prototype

Three identical prototypes of the glasses have been created; the device consisted of the frame of a normal glasses with a small camera lens and a module that was similar in size of an eye-tracker attached to the frame (figure 4). The prototype was not functional but allowed participants to role-play imaginary situations and envision potential uses of smart glasses during the study by providing visual and tangible cues to participants and bystanders. Using a prototype helps participant to use their imagination to create new ways of using the product without any limitation that actual product might have. So users are able to be more creative and free to use their imaginations and envision new applications for the product in different actual situations.

Figure 4. Prototype in use by a test participant (image taken from participant's self-recorded diary

4.2 Study procedure

The overall process of the user research included the following steps:

- Introduction session

  - Filling in the consent form
  - Completing the background information
  - Explaining the concept of smart glasses with showing pictures and a video about possible functionalities of such devices.
  - Explaining the study procedure.

- Diary studies

  - First phase: in this phase the test participant carried the prototype device with them and completed the paper diary questioners. This phase lasted for 2 days

- Second phase: in this phase the smart glasses prototype was not used, and forms were filled electronically. This phase lasted for 3 days.

o End interview

- Reviewing the diary entries and photos taken by the test participant in the semi structured interview

- The participant completed a survey assessing their overall experience of using the smart glasses.

In total, 288 text messages were sent to the 12 participants. The time at which the text messages were sent was different every day, in order to capture the participant doing different activities and in different locations. In the following, the test procedure is explained in more detail.

In the introductory session the aim of the study was described to the test users, and they were asked about their familiarity levels with head mounted displays and augmented reality in general. Before starting the study, all the users were given a short introduction on how the smart glasses concept was imagined to work, and what were the (imaginary) possibilities to using the device. Functionalities such as taking photographs, viewing augmented information, and control possibilities via voice, gesture and eye-tracking were explained to the participants. A video about current Google glass in the market was shown to participants in order to understand some of the applications of the smart glasses more clearly and it was also mentioned to participants that they can freely use their imagination and imagining any future stick application without thinking about any restrictions.

In total each participant completed 5 days of diary studies during which they were sent 24 text messages, prompting them to act. For the first 2 days, the participants were asked to carry the device and diary questionnaires with them. In this phase,

every user received 6 text messages per day, which requested them to undertake a test process with the prototype and complete a paper questionnaire. Each time after receiving a prompting text message(Figure 5), the participant was asked to put on the smart glasses as soon as it was safe to do so. They were instructed to try to use it regardless of what activities they were doing, and to imagine all the possible uses of the device in that context. The participants were also asked to take photos of themselves and the surroundings if it was possible.

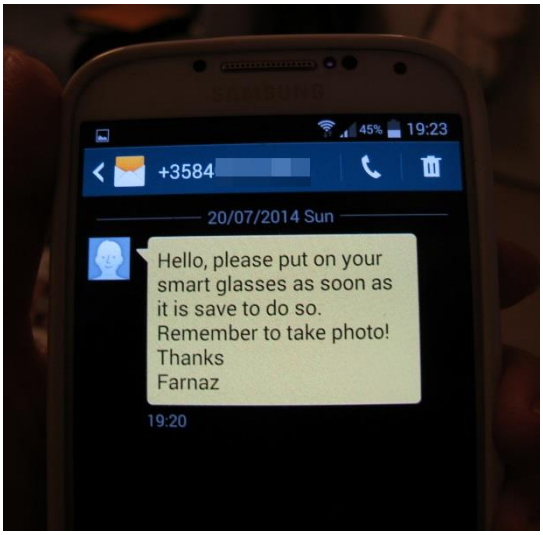


Figure 5. Example of the prompting text message

Following this, participants completed the paper questionnaire in the study diary. The questionnaire consisted of questions related to the location, current activitiy and the reaction of people nearby to the smart glasses. Questions also included alternative interaction methods, voice, touch, gesture and gaze control, from which they should select those that suited their current context. Additionally, two Likert scale questions were used to capture the subjective usefulness and comfort of the smart glasses.

For the final 3 days of the study the user did not use the physical smart glasses prototype. In this phase every user received 4 text messages per day, prompting them to record their location, activity and imagined uses for the smart glasses, as in the first phase of the study.

At the end of the study, the participants returned the prototype and the study diary, and participated in a final interview. The interview included different questions about the experience; they were asked if they felt embarrassed using the smart glasses, their comfort level, their feelings, other people's reactions, and if they would like to use this kind of product in future. They were also questioned about their ideas for potential uses of the device, and the biggest benefits and the worst moments of using the device. Finally, they were asked to add any additional ideas or comments about the smart glasses and their experience of participating in the

study. The test participants were rewarded with a 20€ shopping voucher for participating in the study.

4.3 Number of user study participants and their background

Altogether 12 participants aged between 16 and 36 (M=26.3, SD=4.6) took part in the study. The test group was gender balanced, consisting of 6 males and 6 females. Table 1 provides summary description of each participant.

User	Gender (M/F) / Age / Work / Hobbies etc.
1	M 31. Works for a large company. Watching TV. Lives with his family.
2	F 24. University student. Surfing Internet and reading. Lives with boyfriend.
3	M 26. University student. Doing sports and surfing Internet. Lives alone.
4	F 25. Working. Playing games on tablet. Lives alone (with dogs).
5	F 16. High school student. Taking lot of photos and watching movies. Lives with parents.
6	M 29. University student. Playing video games. Lives with a flat mate in a student apartment
7	F 27. Works as tourist guide. Doing sports and cooking. Lives alone.
8	M 23. Works as a librarian. Plays drums in a band. Lives with two friends.
9	M 25. University student. Surfing internet and reading books. Lives with flat mate in a student apartment
10	M 26. University student. Listening to podcasts and music. Living with flat mate.
11	F 36. Works in the tourism industry. Jogging. Lives with her husband
12	F 28. University student. Photography and cooking. Lives with her husband

Table 1. Summary descriptions of study participants.

5 CHAPTER FIVE
Data and results

To analyze the data both qualitative and quantitative methods have been used. In this chapter I explain how the data is categorized related to comfort and usefulness of the device in different situations and later all the findings that emerged from the user research will be introduced in detail.

5.1 Collected Data

After concluding the study and analyzing the results, the participants had completed 234 diary entries, of the possible 288. Figure 6 shows the number of diary entries and photographs taken by each user during the total duration of the study. Only 3 of the participants (#3, #4 & #12) gave responses in response to all 24 of the trigger points. Figure 7 shows the number of entries gained for each ESM trigger. An example of one of a completed diary page entries is shown in Figure 8.

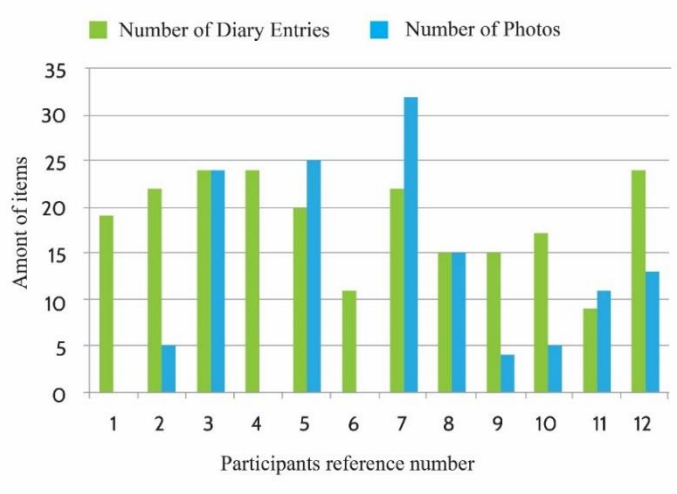


Figure 6. Total number of diary entries and photographs recorded by each test participants during the study

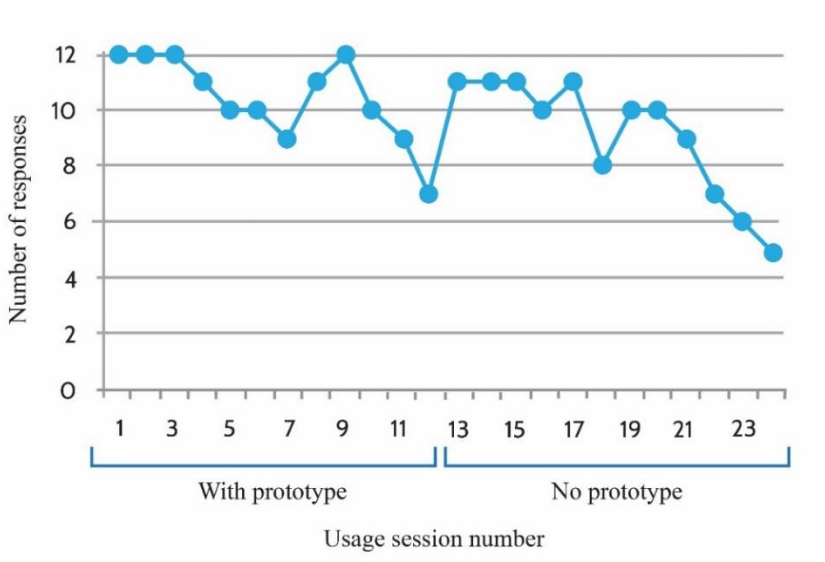
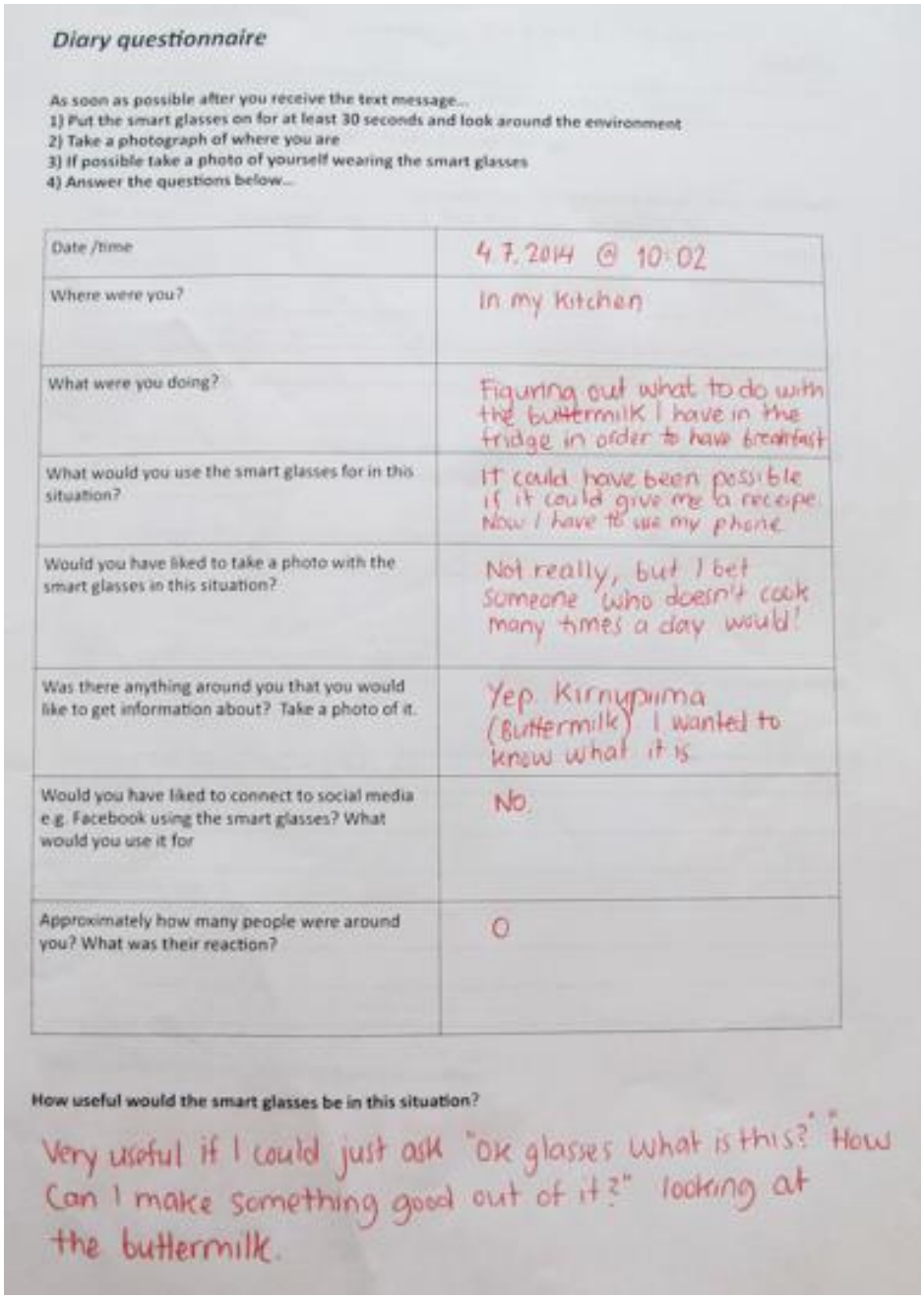


Figure 7. The number of responses recorded at each of the trigger text message points.



Diary questionnaire

As soon as possible after you receive the text message...
1) Put the smart glasses on for at least 30 seconds and look around the environment
2) Take a photograph of where you are
3) If possible take a photo of yourself wearing the smart glasses
4) Answer the questions below...

Date /time	4.7.2014 @ 10:02
Where were you?	In my kitchen
What were you doing?	Figuring out what to do with the buttermilk I have in the fridge in order to have breakfast
What would you use the smart glasses for in this situation?	It could have been possible if it could give me a receipe. Now I have to use my phone.
Would you have liked to take a photo with the smart glasses in this situation?	Not really, but I bet someone who doesn't cook many times a day would!
Was there anything around you that you would like to get information about? Take a photo of it.	Yep. Kirnupiima (Buttermilk) I wanted to know what it is
Would you have liked to connect to social media e.g. Facebook using the smart glasses? What would you use it for	No.
Approximately how many people were around you? What was their reaction?	0

How useful would the smart glasses be in this situation?

Very useful if I could just ask "Ok glasses what is this?" "How Can I make something good out of it?" looking at the buttermilk.

Figure 8. An example of one of the diary entries recorded by the study participants. Each text message prompt resulted in the participant recording a one page diary entry such as this.

The data from the participant's diaries was first transferred to Microsoft Excel. Based on the location contexts in which the participants recorded diary entries and 14 different context categories were identified. This was further reduced by combining categories such that 10 different categories were produced. After that participants' data were parsed into the context categories.

5.2 Contexts of Use

Based on the usage locations recorded by the participants, ten context groups were identified. Here, each category represented a similar contextual setting, being as follows: Home, City (e.g. market place, car park, and train station), Visiting (friends, parents), Outdoors (walking, jogging), Work, Driving (car, bike), Beach, Restaurant (or cafeteria), Sports, Passenger (in car, bus).

This grouping has been applied to the data, in order to identify common issues related to the usage context. Of a possible total 288 diary entries, 234 entries were made and categorized. Thus, 54 locations at which the prompt messages were received were unknown due the incomplete diary entries. Figure 9 shows the number of responses per context category. The reported subjective usefulness and comfort of use in each of the contexts is presented in Figure 10.

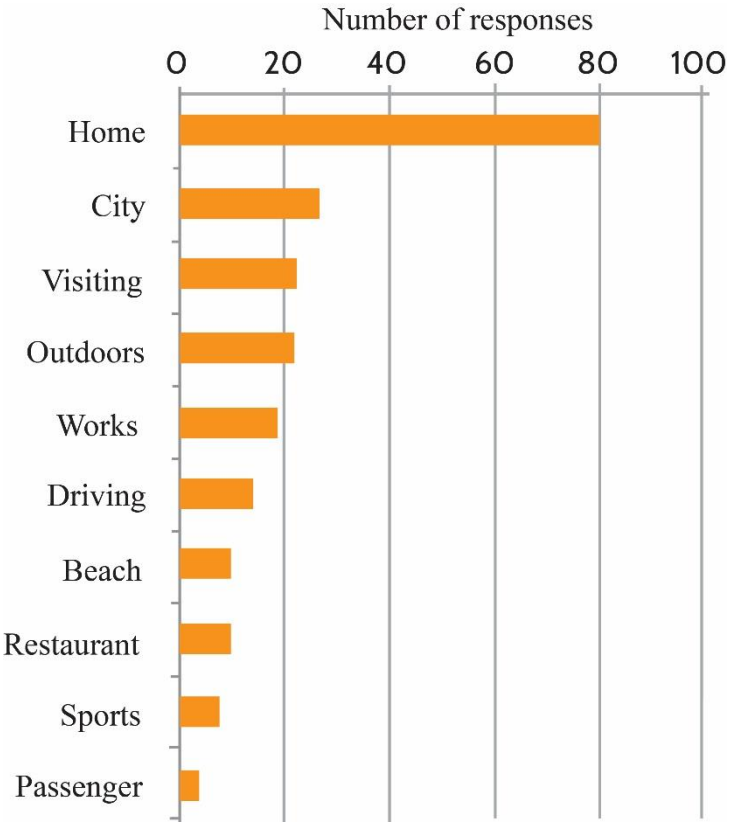


Figure 9. The number or responses per context category.

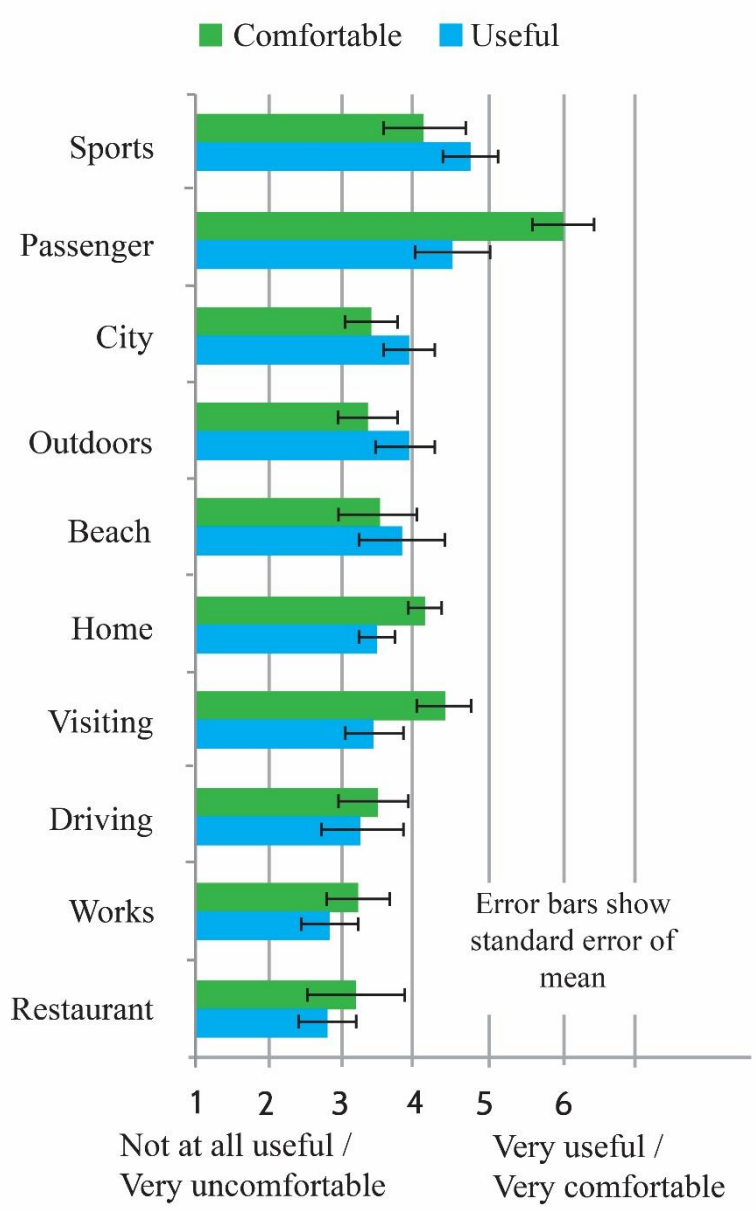


Figure 10. Subjective usefulness and comfort of use per usage context category. The contexts are presented in order of perceived usefulness with the most useful at the top.

5.3 Prominent themes

In this section most prominent themes that merged from user's diary will be explained.

5.3.1 Hands-full use situation

Figure 11. Example of ESM triggered diary entry of hands-full use situation

Throughout the participants' comments in both diaries and interviews, the glass was most commonly regarded as a useful and practical device when hands were occupied with other activities such as washing dishes or riding a bike. The glass could help the user to search the information related to activity he or she is doing or provide the opportunity to do multitasking. For example (user #7) mentioned that "*when I was curling my hair it was possible to reply messages with smart glasses*" while with the smartphone she had to stop one activity and start the others. So in this way she could save time. Another useful situation that many user mentioned was following the recipe while cooking. For example, (user #8) commented: "*the best situation was when I was cooking so I did not had to go to my room to check the recipe at my computer*" thus, with the glass, it can be much easier for the user to follow the recipe and cook. He does not need to wash his hand every time to touch the screen of the smartphone or to use the keyboard on computer, hence, he can be quicker. So, in this way many activates such as texting, replying to messages or emails, taking photos and getting information would be easier and faster without interrupting the user from her main activities that occupies her hands. Figure 11 shows an example of a hands-full use situations.

5.3.2 Home related application

One of the interesting uses of the glass that some participants mentioned was using the glass as a device to help them repair a broken home appliance. In this way the glass can show the manual to the user either by video or augmented reality to help the user easily follow the repairing or installing instruction. Reading the paper

manual or watching the video from phone or computer both requires to use hands or heads down and interrupt the working process. So with help of the glass it would be much easier for the user to do the activity in shorter time and easier way. For instance, user #7 wanted to know how she can repair the handle of the laundry machine. Also, when user #3 was installing a platform for the shower mentioned "I wouldn't have a use for the glasses. Maybe only for looking at instructions."

Also, (user #1) wanted to use the glass while renovating the bathroom as a tool for measurement and looking at the plan. He said that "It is good to use for showing the sprit level and for measuring the distances and showing the 3D model of the finished room."

Another practical usage was helping to choose furniture and decorate homes with the augmented reality. The glass can help the user to visualize the 3D models of furniture and interior design of the home. For example, looking the furniture in the website and augment the real size furniture to actual physical place can help the user to make the right choice and make the online shopping more convenient and trustable. Regarding the home decoration (user #1) mentioned that he likes to use the glass "*to check the IKEA e-magazine and use the AR-application to see the virtual furniture in physical place.*" This application is already exist for the smartphone or tablets but with the glass, the screen is bigger and it gives the user a more realistic experience.

In addition, the glass can help the user to find objects at home; this can help people who suffer, for example, from amnesia, dementia or Alzheimer's disease. In this way especially with help of eye-tracker and augmented reality, when the user is looking for objects, the voice command or virtual notes can guide her to the goal.

Also it might be possible that people make virtual notes to each other if for example they change the places of the objects in kitchen. Thus it would be easy for family members to find what they need. Regarding to object finding, user commented e.g. "*It would be handy to get instruction on how to find object at home, for example, the kettle or etc."* (User #2). This kind of object recognizing application can be helpful for people to recycle the trash easier. For example, user #7 mentioned that she likes that the glass helps her to figure out where it is possible to recycle the glass jar.

5.3.3 Driving related applications

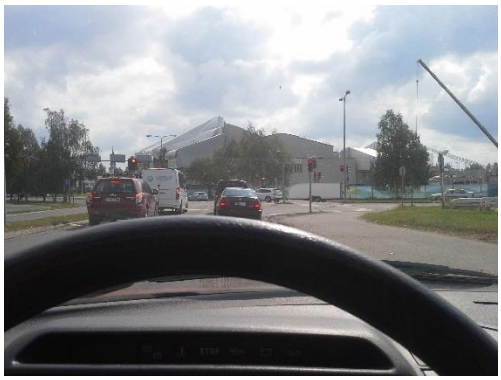


Figure 12. Example of ESM triggered diary entry photo of the situation when user was driving a car

One of the commonly commented purpose of using the glass was navigation. With the current navigators in the cars, drivers sometimes require to look to the screen which it higher the risk of accident while with the glass the driver can use the navigator with head always up. Furthermore, using the glass as a driving guide was one of the expected areas. For instance, one participant mentioned that he liked to use the application that helps him to consume less fuel while driving, he expects the glass to monitor the fuel amount and give advice for the distance and speed that leads to lowering the consumption of fuel. Another purpose that was mentioned was comparing the fuel price in different gas stations and navigating the car to the cheapest ones. In this respect a user commented "*I want to get information about the cheapest price of gasoline in the town.*"(User #11). Also, another participant wanted to use the glass as a guide to find free parking place. Figure 12 shows an example of situation that user is using the glass while driving a car.

5.3.4 Sport activities

There are already many sport related applications which help the user to manage and organize their workout routine. Activity trackers and smart watches already are used in this regard and there are many applications related to health care and fitness in the market for smart watches. However, users usually interact with smart watches or activity trackers through voice commands and screens while smart glasses can make a huge difference in this field with applying visual elements always in front of the user's eyes. For instance, using virtual trainers are getting popular nowadays, but to use a virtual trainer, one needs to have big enough screen, so the sport activity can occur inside the building while with the smart glasses it is possible to have your personal trainer with you everywhere and every time. In this

regard some of the participants made comments as follow, "I like to check the timing while I am working out at the gym and watch something while I am warming up." (User #7). "*I like to review the exercises for different muscles in the gym.*" (User #12). "*When I am playing tennis the glass could be used to track and analyze the game. Also there could be this eagle-eye integration to know which shots missed the field and which were in.*" (User # 3).

Figure 13. Examples of diary entry photos related to sport activities

Moreover, areas around the head can be great gateway for fitness tracking while with smart bands the user can falsify his movement with just moving his hands or the sensors could misunderstand the moves.

Also, some participants mentioned about using the glass when they are watching a sports match. For example the glass might help them to follow the game easier with augmented reality by following the scores and analyzing the game. User #9 mentioned that he likes to check the status of players when he is watching a football match in the stadium and user #3 said that the glasses could be used to access charts and track the game while he is watching baseball. Also, User #7 commented "*the glass can help me to understand the game, because I am watching American football for the first time, and maybe to record and repeat some part of the game.*" Figure 13 shows examples of situations where user watching or playing sports and using the glass.

5.3.5 Educational applications

During the interview with participant #6, as he was learning a new language, he thought that the glass would be useful tool to learn languages. User can employ the glass as his personal language teacher. For example, with the help of the eye-tracker, words in new language can be shown or pronounce when user stare on

specific objects so in this way glass can help user to memorize the words. Also, words can appear while the user is doing her routine works so constantly she is learning the language.

In addition, some of the participants mentioned that while they are walking outside, they like to get information about the interesting objects around them. In this regard user commented that "*I saw a flower which I like when I was a child, I want to know the name of it.*" "*I was listening to a bird above me in a tree and I like to get information about it.*"(User #7). "*When I was boating I pass through a land with lots of birds. I would like to know what kind of inhabitant it is*." (User #12). "*When I was at the beach relaxing I like the glass help me to identify birds.*"(User #3). Getting information about objects around might be used as an entertaining application but most importantly it might be useful in educational matters like science or geography courses for students to help them to get knowledge about nature and environment.

Also one participant mentioned that he likes to use the glass to do 3D design or virtual sculpting. User #6 thought it can be interesting to use the glass as a 3D design tool, so he can imagine the object in front of him and shape it and share it with people who use the same device.

5.3.6 Searching and translating by images

Another theme mentioned by participant was searching by image. It is much easier and faster with the glass to take a photo and do the search by image and get information about an object. For instance, user #6 commented "*in some bus stops, there are sometimes movie or event advertisement, I like to take photo and search information about them.*" He also mentioned that he was in a restaurant and the menu was not in English so he liked to look at the menu with the glass and see the translation. This might be possible if the glass can track the eyes when he is reading and recognize the text and translate it to the user's language. Image translating is already possible with android Google translate application but it requires to take a photo of the text, scan it, choose the text and translate it. So the glass can make the process more fast and convenient.

5.4 Social Aspects

New technology always rise questions regarding its social aspects and its effects to people's everyday life. In this section the most important issues and concerns that emerged from user's diary and interview will be explained.

5.4.1 Breaking social norms

In regard the social aspects, it was pointed out that use of the glass could have a negative effect on the face-to-face interaction with the people present, and divert the attention away from the social situation. This is illustrated in the comments related to possible interruptions caused by the glass: *"For example if I am with my friends or driving I don't like something suddenly coming in front of my eyes. It can distract me from my friends and the environment. It's invisible to the others but it will distract me." (User #5) "You always have to be ready if somebody sends you a message, with glasses you're always online." (User #2)*

Privacy concerns were also mentioned, but interestingly, mostly in the context of assumptions other people might be drawing about the expected use of the device. Several participants mentioned that they were concerned that the nearby people would think them doing something unethical or forbidden with the glass for example taking photos on the girls at beach, or recording actions of a police. Related to this issue users commented: *"When I was in supermarket, imagining searching a product, one of the staff was suspicious of me."* (User #8) and, *"I was embarrassed when I was at the store and I had to use it in front of people." (User #3).* Figure 14 shows a situation that

Figure 14. Example of ESM triggered diary entry photo where the participant were concerned about breaking social norms

user where concerned about breaking social norms while using the glass in a super market.

5.4.2 Cheating with Extra Information

Figure 15. Diary entry photo related to the comment on cheating

As it mentioned in sport application section, one of the commonly commented purpose suggested for the glasses use was getting information about the sport activity which in some case can be related to cheating. Mostly this was connected with the ability to search extra information without the others noticing it. The possibility to cheat was mostly regarded with negative connotations. In this respect users commented, e.g. *"When I was playing chess with a small girl, she got mad when she lost because she thought that I cheated." (User #3).* See Figure 15 as an example of cheating situation with the glass.

5.4.3 Legal issues

Another concern which gave rise to several comments related to legal issues, was the use of the device prohibited in some situations. For instance, it was wondered if the use of the device was allowed when driving a car: *"I would use it when my hands are occupied, or when I was driving. I don't know is it forbidden or not?" (User #4).*

In addition, the ability to take photos or videos unnoticed was discussed. For example, *"I think it would be good that you have to touch the glasses to take a picture to give an aid for people to see that you're taking a picture of them. There are also laws about taking people's pictures and they should be respected in this regard." (User #2).* Similarly, *"I was at the beach with my friends and they thought*

it would be invading privacy if I would have taken pictures of other swimmers wearing their bikinis." (User #1)

5.5 Design, Interaction and Functionalities

5.5.1 Users' opinions and concerns related to design

In the interview it was asked from users their opinions and expectation of the design of such a device. Some of the ideas are as follows:

- Design should be unique and something to be proud of using it. It should bring the feeling of a personal device.
- It should be comfortable to use and light weight.
- It should be easy to carry when it is not in use.
- It should fit the style of the user and he or she can choose between the different models and colors.
- It should not disturb the style of the user, for example hair style and make up.
- It should be recognizable from normal glasses.
- The design should not disturb the vision. For example covering part of the purview.
- It should be recognizable by others if the user is taking photo or video.

5.5.2 Modalities

When doing the ESM triggered diary entries, the participants were also asked to select which modes of interaction they preferred for the particular situations. The interaction modalities that the participants considered to be the more appropriate in each usage context are presented in Figure 16. It should be noted that participants were able to identify more than one modality at each test point.

As seen from Figure 16, driving context was with the strong preference for voice input. The least desired contexts for voice input took place when the user was a passenger, visiting someone or in the restaurant – all these being social contexts. Thus, the use of modalities has a connection with the social acceptability. In addition, the choice of preferred modalities link to the use of the device when the user's hands were occupied by another task, and when interacting by touching the device was impossible.

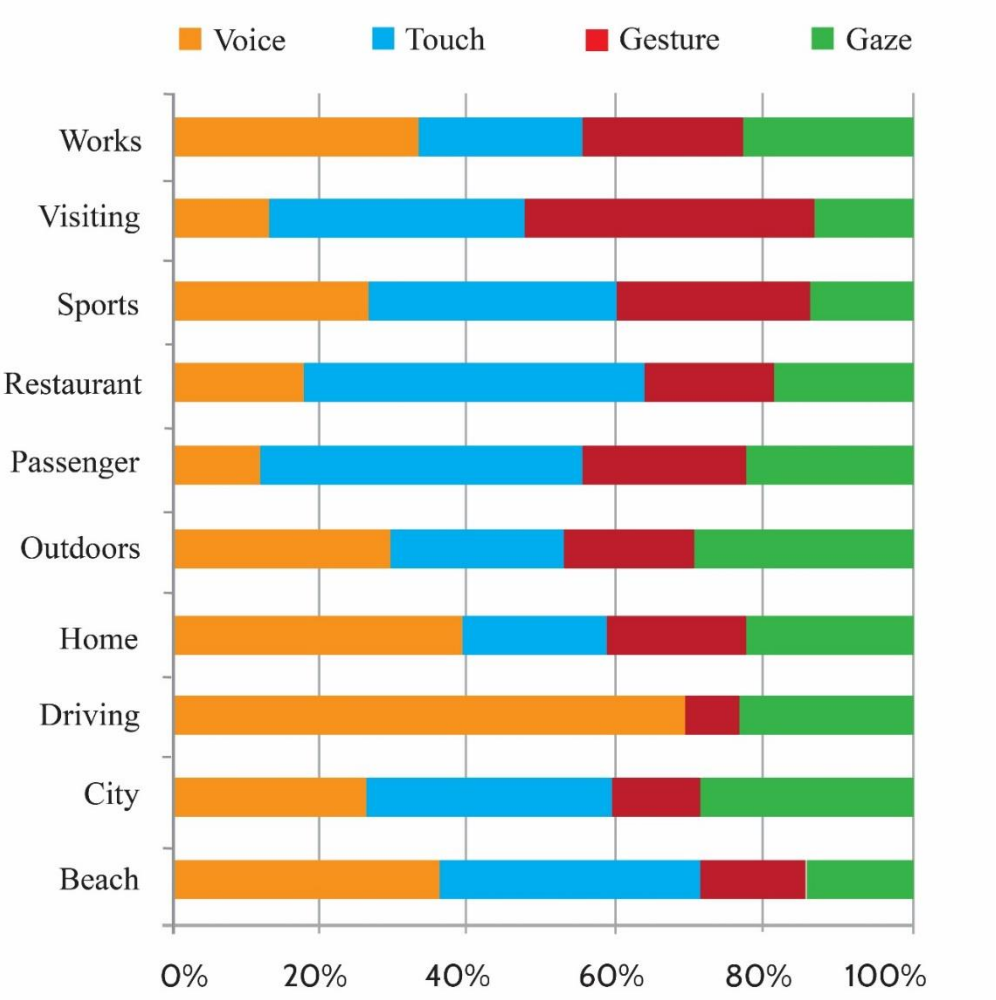


Figure 16. Preferred interaction modalities per location category. Note, participants were able to select multiple modalities in each response.

5.5.3 Expectations with the Technology

Altogether, 2/12 participants regarded the glasses as a replacement for a smart phone, whereas 10/12 saw it as a complementary device. Here, especially the easiness of the hands-free use was again seen as a benefit, as well as the immediate

access to the device, taken that the glasses were already worn: *"It could also be safer than using an old style car navigation, because with smart glasses you can keep your eyes on the road. Maybe it could be useful when jogging or other situations when you can't use your hands, for example replying messages." (User #2)*

Interestingly, some evidence has been found in some expectations of very advanced device features, related to the connectivity and glasses as a universal interaction device. For instance, a voice command to the glass was wished to open a door on the user's path.

6 CHAPTER SIX
Concept design development and evaluation

In this chapter I go through the design process to design different concept for glasses or head worn type wearable computing. The goal is to get an understanding of user's perceptions and expectations of different form factors of this new product and gain qualitative data as a guide for designing the future products. In order to aim these goals the first step is defining the design criteria and specification for this project and the next step is free hand sketching without thinking about limitations and finally selecting the best ideas for further development and evaluations.

6.1 Design requirements

In this section I will briefly explain the design criteria for wearable computing especially in form of a HMD. Furthermore, I explain the design specification for this project.

6.1.1 Design criteria for wearable computing

As mentioned before integrating new technology to everyday life is always challenging especially in case of a wearable device that has to be worn on the face. This gives rise to issues related to social acceptability and ergonomics of the device. Also for a design to be successful it should follow some criteria to hit the market. Some of the criteria related to physical and aesthetical issues of wearable devices will be explained briefly as follow:

- **Acceptability by the user and public,**

Convincing users to carry or wear a new device is not always easy. It can be difficult for many people to accept wearing a new product that looks unfamiliar or brings attention to them. As Dvorak mentions in his book people are keen to follow social conventions, especially in public (Dvorak 2007, 311).So, if a product can break this rule it should bring a great value functionally and aesthetically for the user to encourage them to use it.

- **Comfortability**

Physical comfort is one of the important rules that should considered when designing a wearable device. A comfortable product does not disturb the user or brings physical burden such as difficulty in movement to its user. Size and weight of the device are two important elements that play an important role in comfort of a wearable device. Many people prefer a portable device with minimal bulk and weight (Buenaflor et al. 2013, 109).

- **Safety**

The users should be sure that carrying and wearing a device does not bring harm to their health (Buenaflor et al. 2013, 109). Moreover, as the device will be in touch with the skin, the materials used in the device should not cause problems such as sweating and allergies for the skin.

- **Aesthetic**

Aesthetic and appearance of a wearable device is an important part of a design process and has a great impact on user's acceptance. As a wearable device has an important impact in people's identity; it is a part of the style and appearance of the user, and it effects on their self-image (Dunne 2010, 60). A successful design of a wearable device should appeal the user's taste of beauty and fulfil the need of wide range of customers.

- **Mobility**

One of the advantage of a wearable computers is that it is always with the user, which means it is moving with the user all the time both in inside and outside environments. Users might do many different activities while using the device (Buenaflor et al. 2013.110). They should be able to do activities such as running, climbing or jumping without having the fear that their wearable device might fall down or get wet in the rain (Berzowska 2005, 61). Different parameter such as size and weight and the way it attaches to the body can have an effect on the mobility of the device (Buenaflor et al. 2013.110).

6.1.2 Design specifications

In this thesis I am going to design a frame that can contain the smart glasses component inside. One of the differences of this smart-glasses with google glass is the eye-tracking system which changes the input methods of the device. So during the design process it is expected the smart-glass components include:

- Camera
- Eye-tracker
- Battery
- Wi-Fi or Bluetooth
- Speaker and Microphone(Can be bone-conducting headphone)
- CPU and GPS
- Projector
- Display or prism (Deshpande et al. 2013, 3)

It should be considered that in this thesis the aim is to design a future stick device so the final design would not be restricted to the current state of the art technology.

6.2 Design drawings and evaluation

In this part after free hand sketching, ideas will be evaluated and developed for further evaluations and final concepts will be evaluated by the focus group.

6.2.1 Free hand sketching

Figure 17 shows the first sketches and ideas for the smart glasses concept.

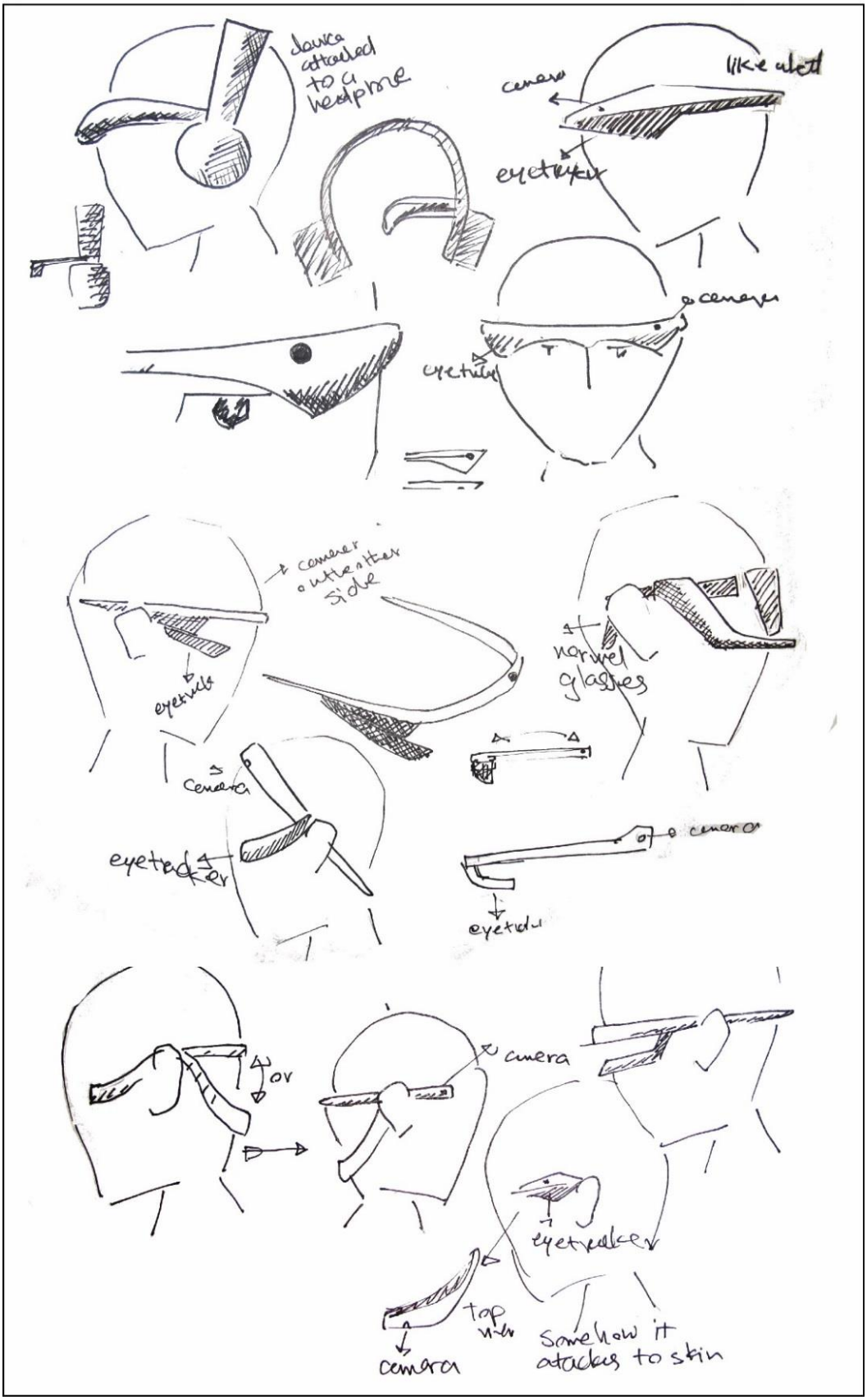


Figure 17. Early sketches and ideas

6.2.2 Drawing with more details

In this stage I try to think about each ideas with more details and using vALUe method to get better understanding of each idea. In order to do that I will answer to three following questions for each ideas:

- What are the advantages of this idea?
- What are the limitations of this idea?
- What are the unique elements of this idea?

Idea #1

The ideas is to have a wearable device similar to a normal glasses. The frame is straight, simple and minimal. The eye tracker and the camera are in different sides of the frame in order to bring balance to the design. Camera is installed into upper left side of the frame. This concept is useful for everyday use. Figure 18 shows the idea #1 and table 2 shows the Value analyze of this idea.

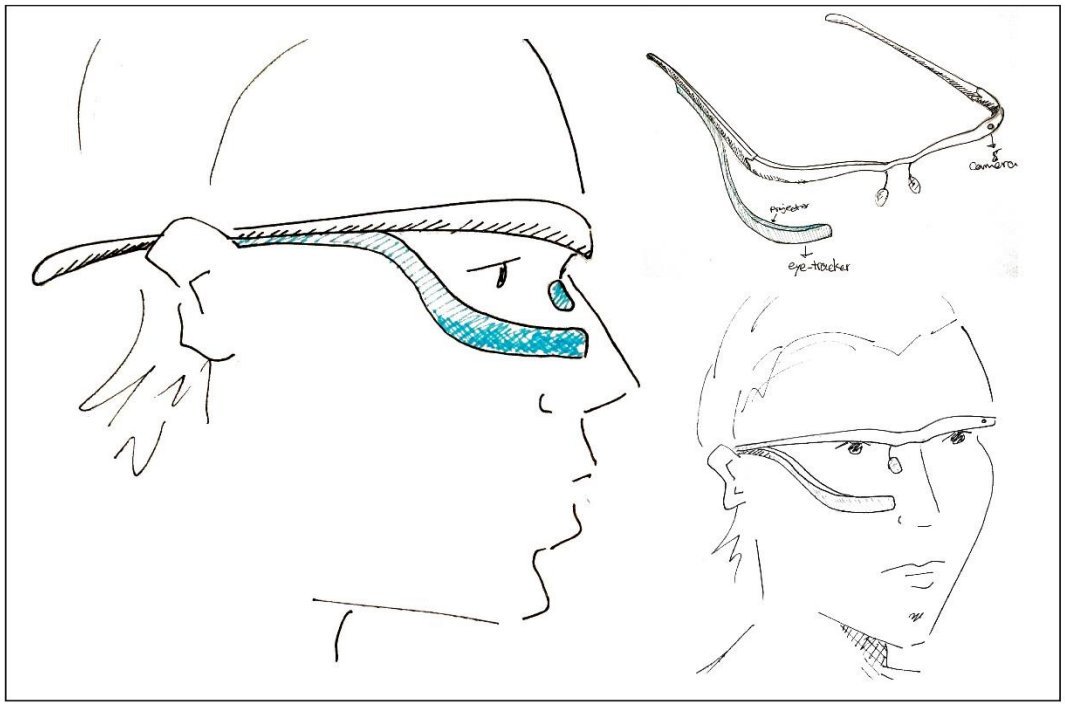


Figure 18. Sketches for the idea #1

Advantages	Limitation	Unique element
It is similar to a normal glasses. Camera and eye-tracker are in different side so it makes the device more stable.	The frame is small especially for the eye tracker. The component with current technology might not fit in the frame. If the user wants to do sport activity it might not be stable enough.	Minimal and simple

Table 2. Evaluation of Idea #1

Idea #2

This design consist of a glasses frame with more sharp ages and sporty looking, eye tracker and camera are in different sides and camera is installed under the left handle. This concept aims to be useful for everyday use for all ages and gender. Figure 19 illustrates the idea #2 and table 3 shows the Value analyze of this idea.

Figure 19. Sketches of Idea #2

Advantages	Limitation	Unique element
Camera and eye-tracker are in different side.so it makes the device more stable. The frame looks more stable to handle the components weight.	The frame is still small for the components. It is more stable for sport activity. However it looks sporty it might still need more support to be stable enough for sport activities.	Sporty.

Table 3. Evaluation of idea #2

Idea #3

This design is inspired by the Bluetooth headset. While this design might be futuristic as the common eye-trackers at the present time are still too heavy to be attached to ear by a hook. The aim in this concept is to design a less noticeable product. Developing this concept requires lightweight materials. Figure 20 shows the idea #3 and table 4 shows the Value analyze of this idea.

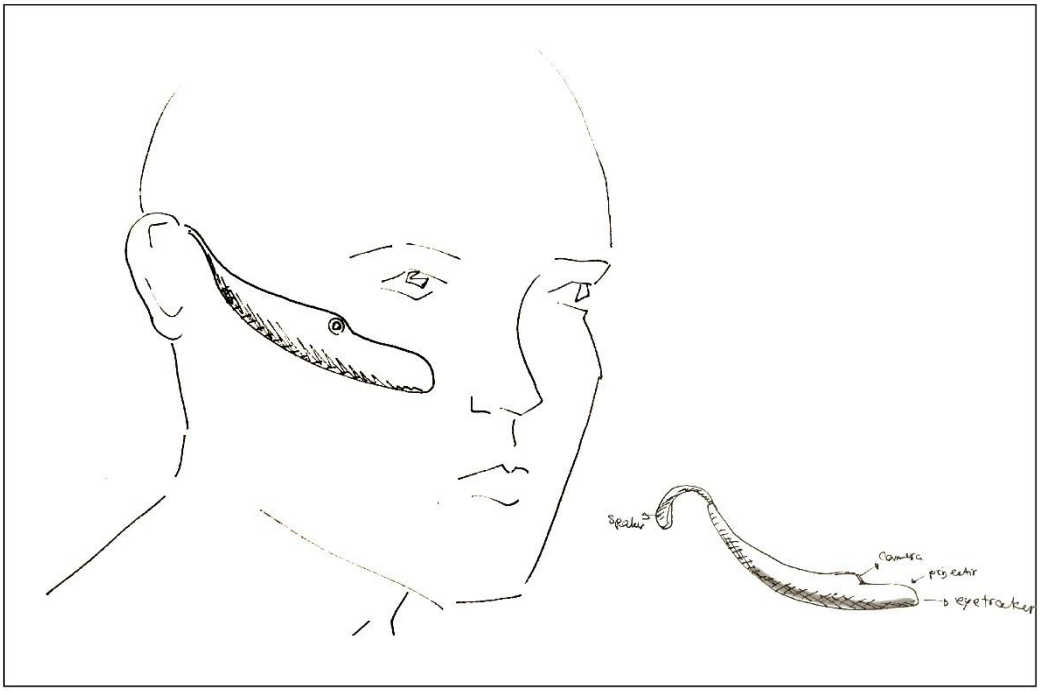


Figure 20. Sketches of idea #3

Advantages	Limitation	Unique element
It is small and minimal. It does not cover the face and it might be useful for people who does not like to where glasses.	It is difficult to attach the device to the ear by a hook.	Small and minimal.

Table 4. Evaluation of Idea #3

Idea #4

In this design, I tried to develop a concept that can be attached to ordinary glasses. Same as design No.3. The wearable product should be light weight so it won't disturbs the balance of the glasses. Figure 21 shows the idea #4 and table 5 shows the Value analyze of this idea.

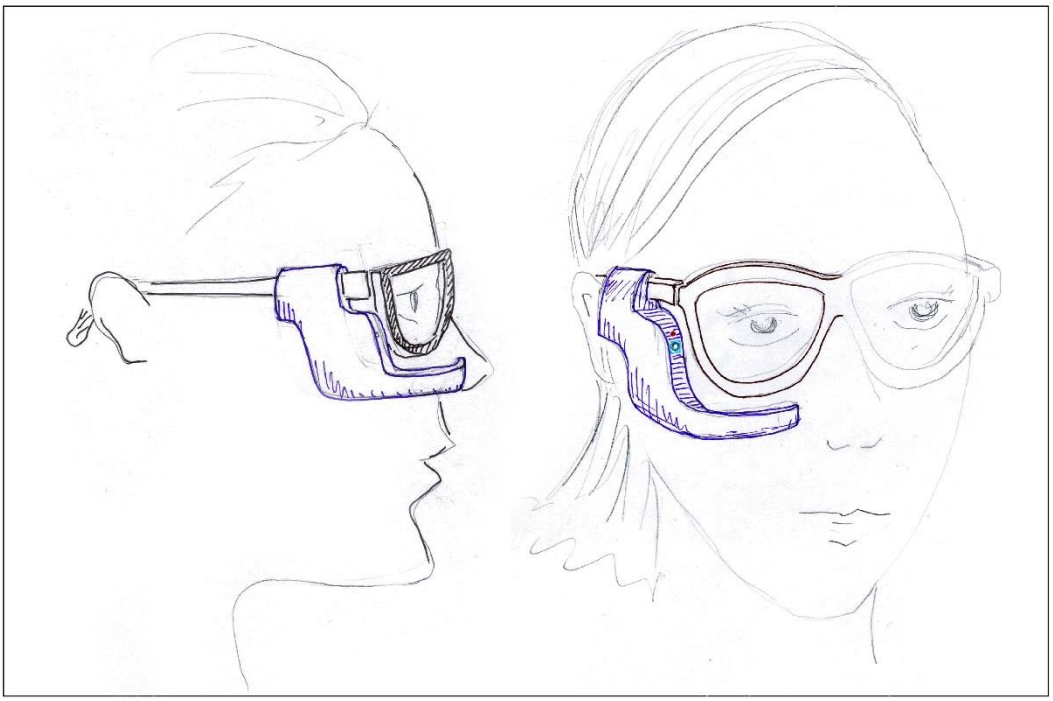


Figure 21. Sketches of idea #4

Advantages	Limitation	Unique element
It can be attached to normal glasses so people with visual impairment can use it while using their glasses.	I should find a solution for people who don't have a glasses.	New solution for attaching the device.

Table 5. Evaluation of Idea #4

Idea #5

In this concept the wearable device located on the forehead. So it is easier to carry heavier device. The camera and eye-tracker can be in same side as the balance is not an issue in this concept. It's more fixed to the head so it is possible for the user to move fast. Figure 22 illustrates the idea #5 and table 6 shows the Value analyze of this idea.

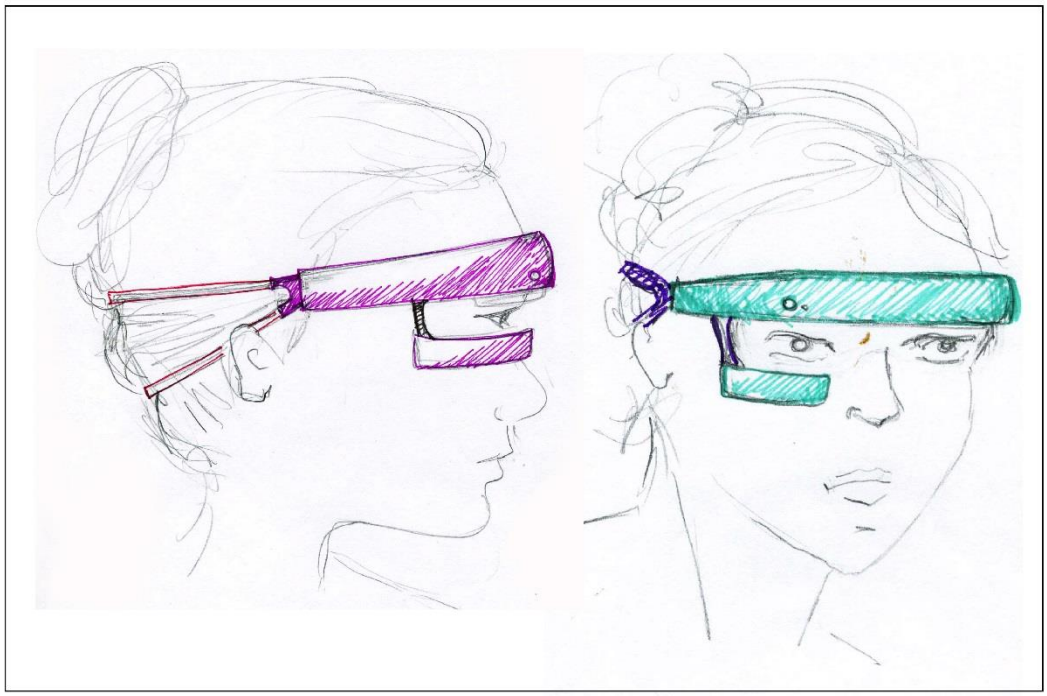


Figure 22. Sketches of idea #5

Advantages	Limitation	Unique element
It is stable so it is suitable for active people or sport activities. As it attaches like a head band the weight of the device would not hurt the nose.	It covers the face too much	It is a new solution for attaching the device to head.

Table 6. Evaluation of idea#5

Idea #6

In this concept, the eye tracker is foldable so user can bend it when it is not needed. This concept also is suitable for sport activities and it is well fixed on the head. Figure 23 shows the idea #6 and table 7 shows the Value analyze of this idea.

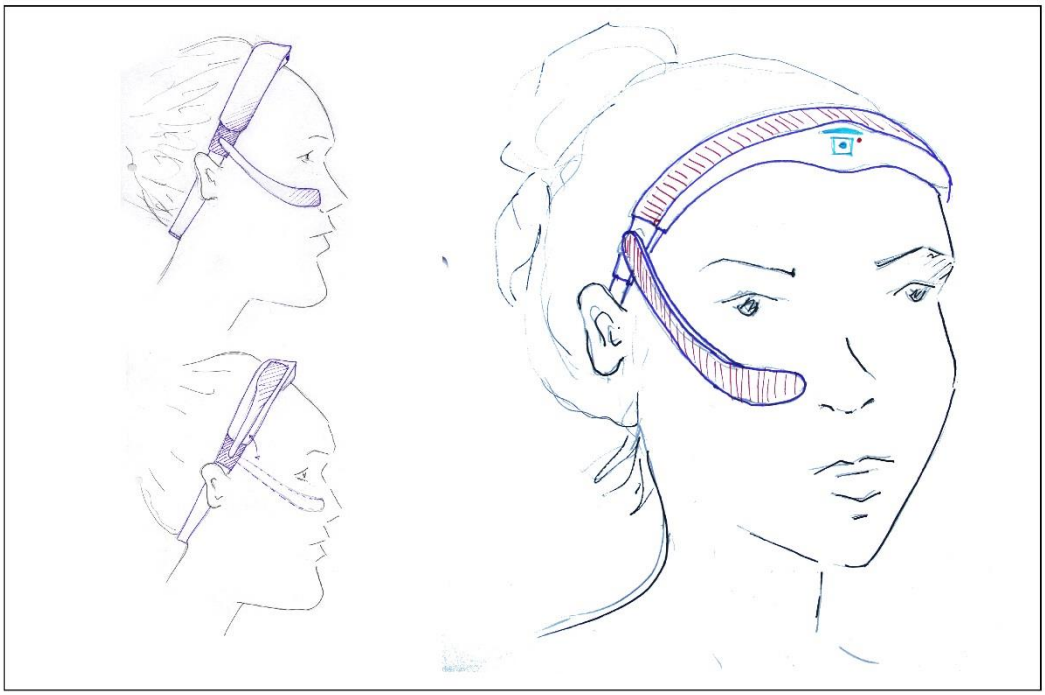


Figure 23. Sketches of idea #6

Advantages	Limitation	Unique element
Suitable for sport activities as it is stable. The foldable eye tracker can be advantage if you don't use the device all the time.	The design might look feminine to some people	It is a new solution for attaching the device to head Foldable eye-tracker

Table 7. Evaluation of idea #6

Idea #7

This concept aims to be attachable to other devices like headphones or normal glasses. It is useful for everyday use. Especially for people who always use headphones. Figure 24 shows the idea #7 and table 8 shows the Value analyze of this idea.

Figure 24. Sketches of idea #7

Advantages	Limitation	Unique element
It is attached to headphone so we don't need to be worry about the weight or disturbing the glasses balance.	It is impossible to use it without your headphone.	It is a new solution for attaching the device.

Table 8. Evaluation of idea #7

Idea #8

In this concept, camera and eye tracker are in same side, it is possible to use it as sunglasses. The frame can be from shiny metal, and the electronic parts from colorful or transparent materials. Figure 25 shows the idea #1 and table 9 shows the Value analyze of this idea.

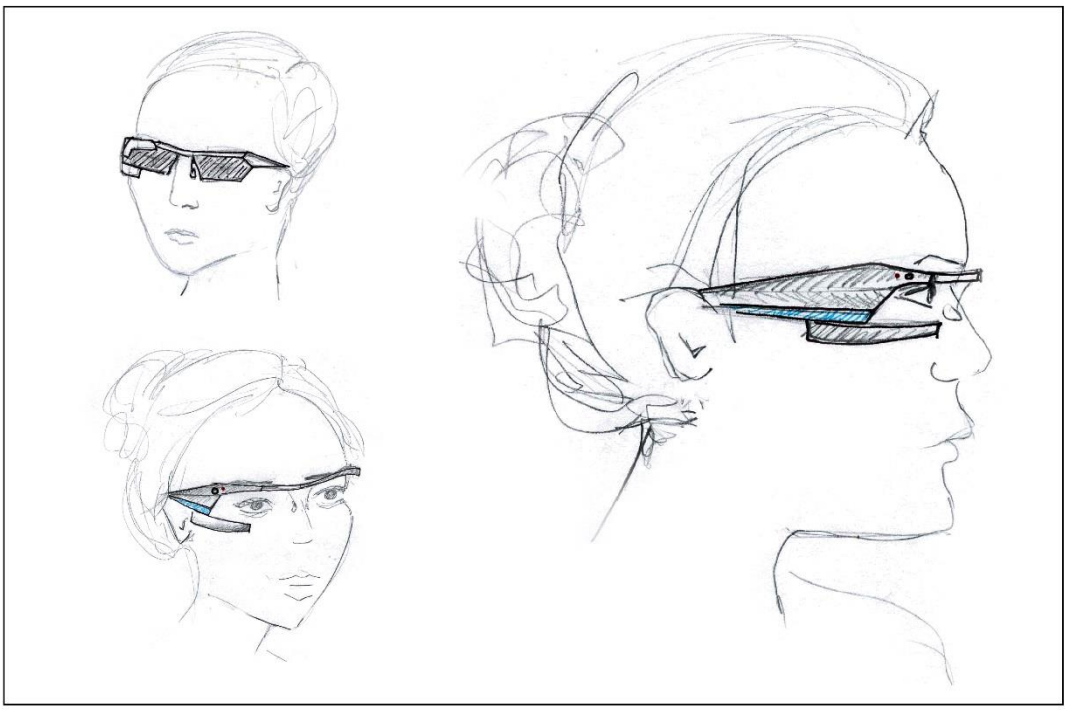


Figure 25. Sketches of idea #8

Advantages	Limitation	Unique element
It is possible for people with different status (with or without glasses) to use it.	As all the component are in same side the balance might be a problem.	You can attach lenses to the frame or use it as sunglasses.

Table 9. Evaluation of idea #8

6.2.3 PMI evaluation:

To apply the PMI method for evaluating the ideas, I will ask myself three questions as shown in table 10. The answers to first question are plus and to second questions are minuses and for the third questions are interesting aspects that can turn to a plus with more development (Boeijen 2014, 145).

Idea	What is good about this idea?	Which aspects would you need to improve?	What makes the idea interesting?
1	Simplicity(+) It is not awkward(+)	Stability(-) It is too normal(-)	()
2	It is not awkward(+)	Stability for active people(-)	()
3	It is small and simple (+)	The attachment system should be improved (-) It looks like a Bluetooth headset. (-)	It is a new form factor for this device bur it needs improvement (I)
4	It solves problem for people with glasses. (+) It has innovative solution for attachment(+)	The deign should be improved (-)	New solution for attachment but it should improve (I)
5	It is stable (+) New solution for attachment(+)	It might look big(-)	()
6	Stability(+) New solution for attachment(+)	It looks feminine(-) It might look big(-)	Foldable eye-tracker (I)
7	New solution for attachment(+)	Always should be used by headphone(-)	New solution for attachment but it should improve somehow so it can

			be used without a headphone(I)
8	Suitable for everyone (with or without glasses)(+) You can add different lenses or shades to the frame or detach it(+) It is not awkward(+)	Stability (+)	()

Table 10. PMI evaluation for the early ideas.

For the next step different ideas will be chosen for further evaluation by the focus group. The aim is to understand people's expectations of the device especially towards the size, shape and attachment solutions. In order to do that four concepts will be chosen from the best ideas or combination of those ideas according to vALUe and PMI methods.

Theme 1: ordinary glasses with normal noticeability

In general idea #1, # 2 and #8 are in same category. They all are similar to a normal glasses frame. In idea #8, it is possible to add shades to the frame and they are useful for everyday use which is a positive value. According to PMI table idea #8 got more plus than two other ideas. So it will be selected for the next step.

Theme 2: attachable – less noticeable

Ideas # 3, #4 and #7, all are required to be very light weight. So it is possible to attach to the glasses frame, ear or headphone. They are different in the functionalities and the target groups. It's not possible to use idea #3 if someone does not use glasses and design #7 is useful for people who regularly use headphones. Concept #4, due to the weight might make the ear tired and might has problem with balancing. Idea #4 and #7 had more positive values according to PMI

method and as they are so different in style and methods of attachment both will be selected for the further evaluation.

Theme 3: attached to the head – fixed - most noticeable

Idea #5 and #6 are in same category. They both are bigger and more visible. They attached properly to the head so they are useful for work and sport related activities. As the idea #5 got better result in PMI method it will be selected for further evaluation.

6.3 Final concepts unfold

To evaluate the concepts, four different themes with different size, style and design direction are selected for further development. Each design is different in size and noticeability, wearable platform and visual style.

Concept #1

This design (Figure 26) is the most visible and noticeable device. In this design, the device sits on the forehead instead of the nose. The camera is on top and the eye-tracker beneath the eyes. It's fixed on head so it is stable. This is the most noticeable design and biggest in size. Target groups can be people who use the device at work and for doing activates that needs fast movement.

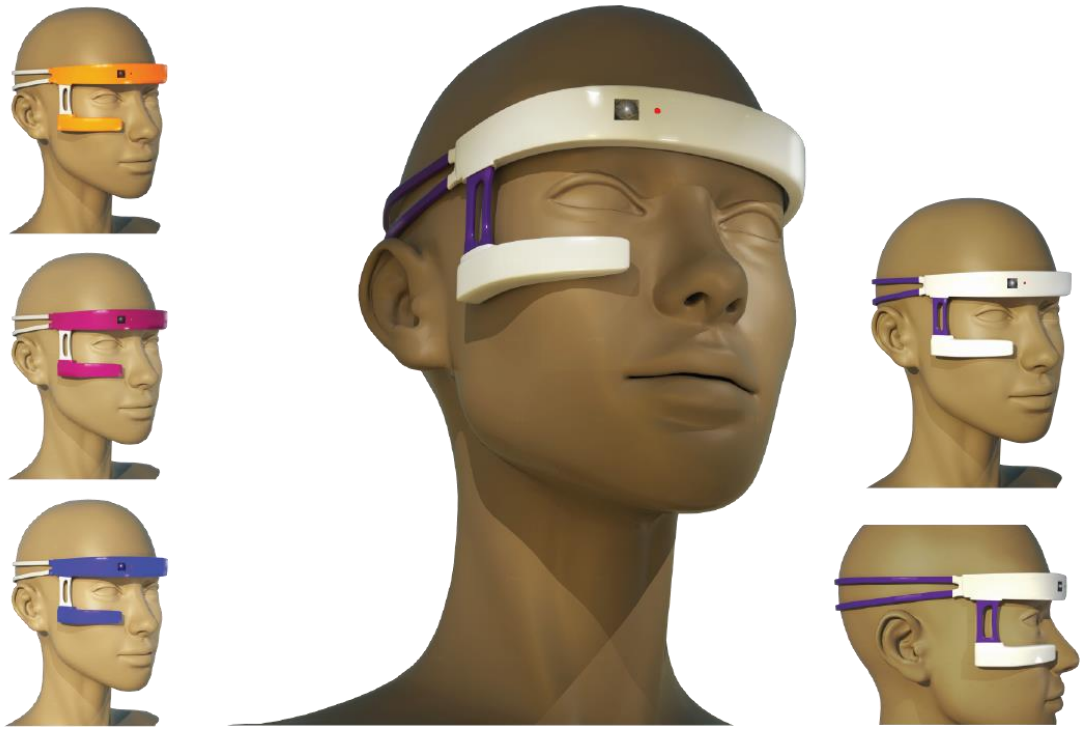


Figure 26. Rendering for the concept #1

Concept #2

It is similar to an ordinary glasses with normal noticeability. In this Design (Figure 27), the device sits on the nose, it has camera and eye-tracker on one side. The camera is situated above the right eye and the eye-tracker is beneath the eye. This design is suitable for regular everyday use.

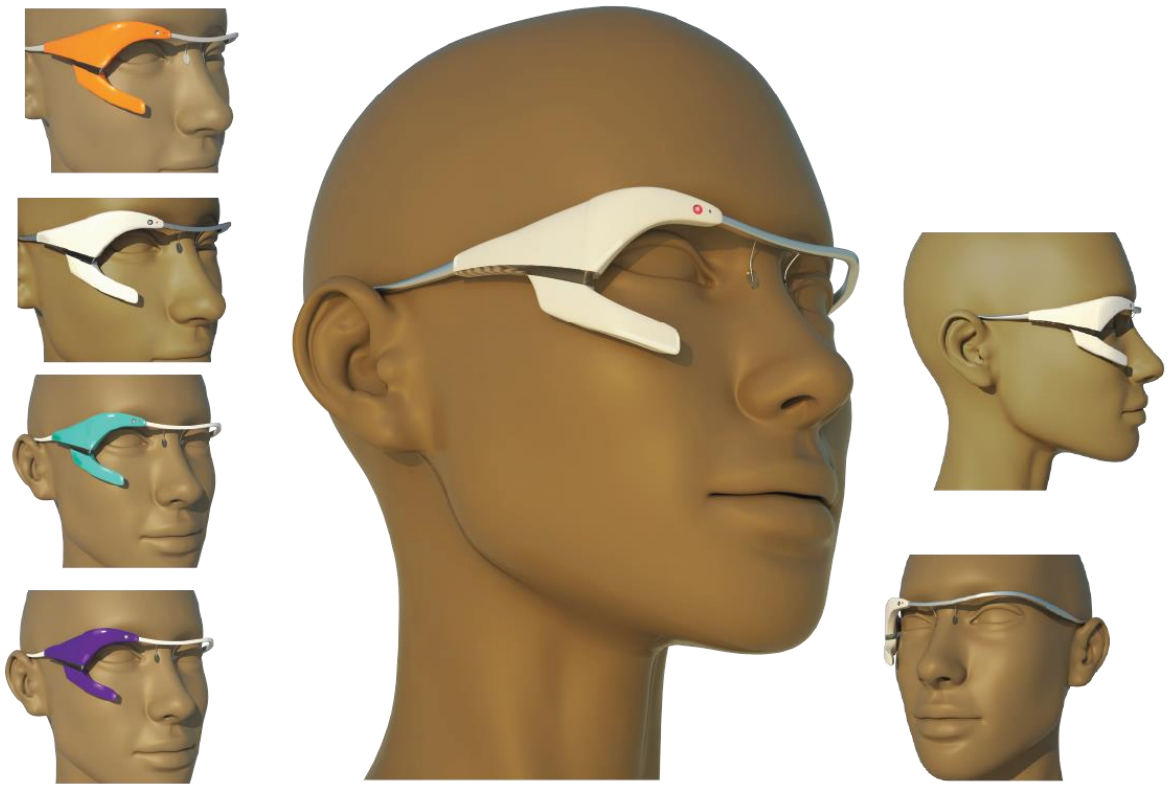


Figure 27. Rendering for the concept #2

Concept #3

The camera and eye-tracker are in one part that can be attached to the headphone. With little bit of change in structure of the attaching part it can be possible to hang it from the ear so it is possible to use it as a separate device. It is not very noticeable as it is similar to a microphone. See figure 28.

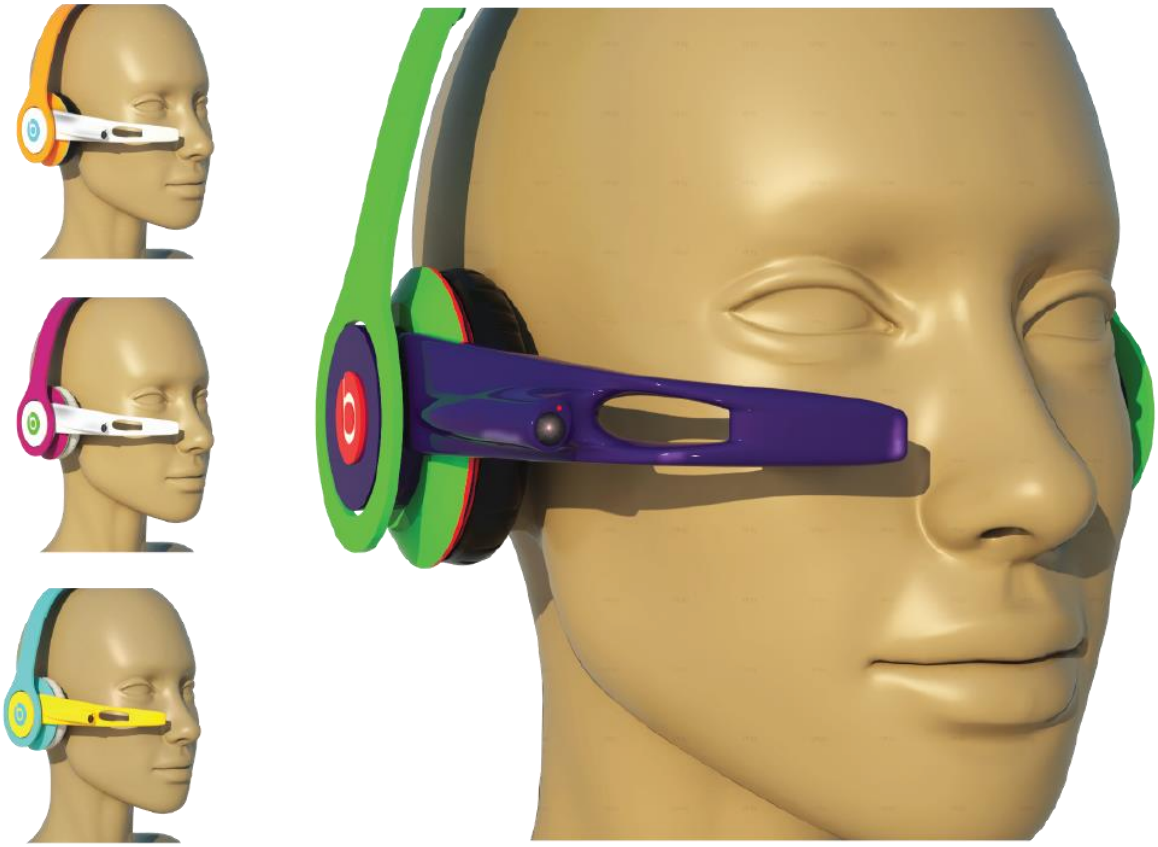


Figure 28. Rendering for the concept #3

Concept #4

This design (Figure 29) is suitable to attach to the glasses. So the target group are people who always wear glasses. It is the smallest design and least noticeable one.

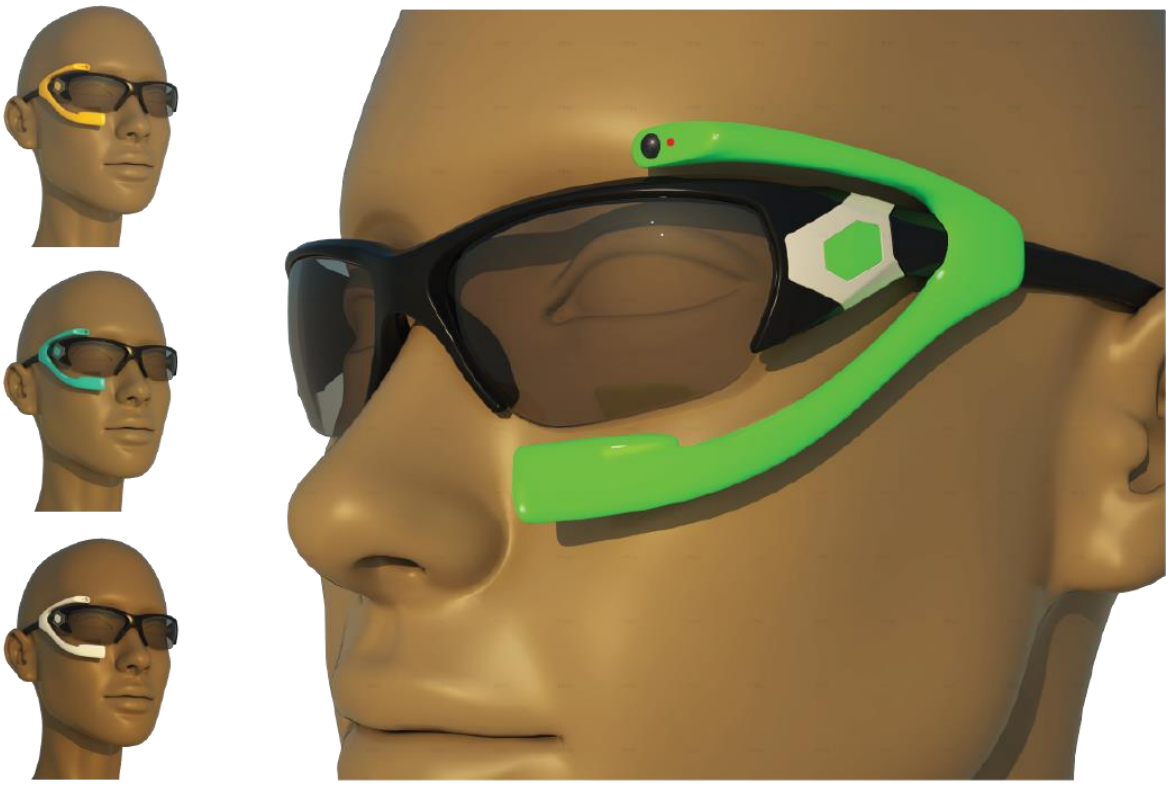


Figure 29. Rendering for the concept #4

6.4 Evaluating the concepts by Focus group

In order to assess the different designs a focus group study was conducted to evaluate the concepts. As it stated in chapter 3 focus groups are group interviews that brings possibility to discuss about particular or set of issues. In a focus group the members communicate with each other to generate the information and it helps to collect information from several people in a short time (Milton & Rodgers 2013, 70).

Also, a focus group is a tool to acquire information about people's attitudes and perceptions and to find out about their values and desires (Kuniavsky, 2003 – 203). It can help the designers to understand the user's interpretation and point of view about the designed products; what interesting features and problems the designed products might have.

6.4.1 Conducting the Focus group

For this purpose a study of three focus groups was conducted. In total, 14 participants (6 female, 8 males) aged 20-23 (M=26.4, SD=2.8) were chosen as a target group. The focus was on young adults with an active user profile in mobile technologies and social media.

In the beginning the focus group participants were asked about their familiarity with the google glass or any other AR glasses and a video about how such a device works and possible applications of it were shown for better understanding of the concept. After that four different contexts (Public, private, work, bar) were shown to participants and they were asked how they would use the glass in those situations, what might be the problems and benefits and what would be their reactions if other people use the glass in that situations.

In the next step four different designs, as illustrated in figure 30, were shown to participants and they were asked about their practicality, social acceptability, style and their overall opinion about each design. Finally each design was evaluated within the group and openly discussed about the shape, color, functionality, comfort and attraction of each design.

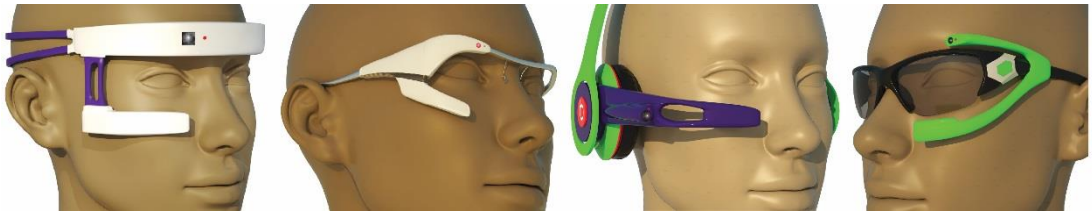


Figure 30: different concepts that shown to participants in focus group

6.4.2 Focus group results

Overall 10/14 participants selected concept design No.4 as their favorite, with design No.3 being preferred by 3/14 and No.2 by 1/14.

- **Context of use**

In the following mind-map (Figure 31.) one can find detailed results of the user's opinions about different context of use;

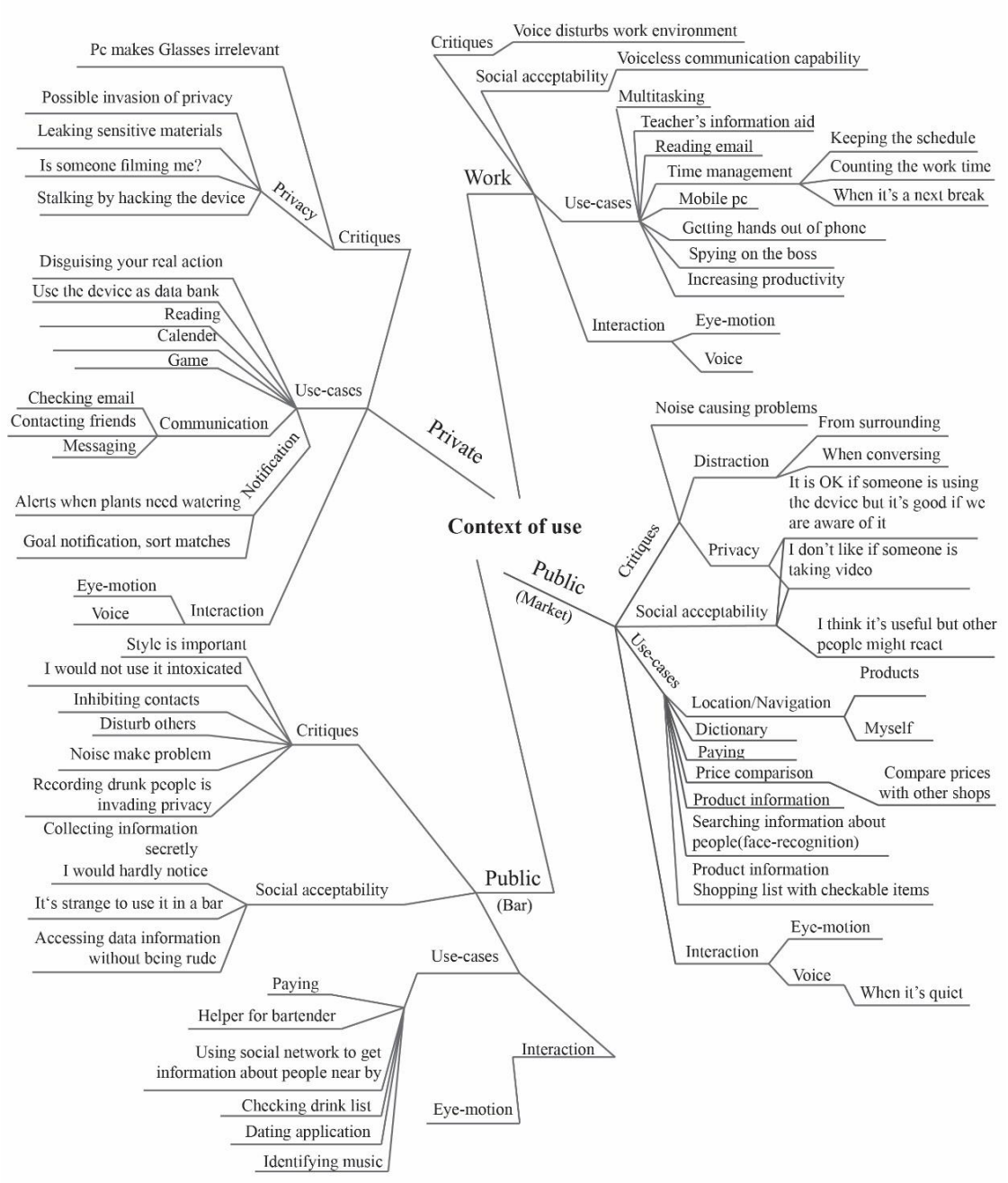


Figure 31. Mind map illustrating participant's opinion about using the glass in different context

The most important use-cases for the glass was helping people multitasking. For example, doing activity such as using calender, checking email or using social network while hands are busy with other activities. Users were intrested in photo searching with the device for example scaninng an object for checking the price in the shop. One of the intresting features was that some participants considered the

device as a help at work, such as getting content information when teaching at the class.

About the interaction of the device users preferred the use of eye-motion in public places and voice control both in private and in public when it is not noisy or they are not disturbing others. Participants were concerned about their privacy especially being recorded in places like a bar or being regarded as impolite when conversing with others while using the glass.

- **Design alternatives**

Concept #1

This concept was considered big and bulky for everyday use but suitable and practical for industrial site or hospital use for instance participant #F2 mentioned "*This looks suitable for working, so it does not have to be aesthetically pleasing.*" Also problems such as getting a sweaty head and ruining the makeup came to some participant's mind. Also issue of wearing corrective spectacles same time with the device was mentioned by one participant. Related to social acceptancy and privacy some participants thought it is too visible and can disturb others. However, one participant consider this a positive fact related to privacy in public as #M1 mentioned "*It's good consider to privacy! Everyone can see you are using it!"* Also other participants believed that using the device covers the face too much and it is socially unacceptable.

Concept #2

Generally this was considered comfortable. However, several participants felt the design with all the functional elements on one side was too radical. For example, participant #F1 commented "*The asymmetrical one-sided design is disturbing".* Also some participants thought that it would be good idea if they can detach the lower part of device (the eye-tracker). Also some concern about how to put on your corrective spectacles was raised for example user #M1 mentioned *"I like the design but it is good if you don't have glasses"*

Concept #3

Some participants felt concerns about the style of the device that does not look like a real working device. Also the colors can make it appealing just for young

teenagers as participant #F2 commented "*Looks most familiar, does not separate from the crowd."*About the social acceptability it raised divided opinions, with some considering it would draw less attention in public than glasses based concepts. For example one participant comments: "*Looks most familiar, does not separate from the crowd." (#F2) whilst* others held an opposing view as participant #M4 mentioned "*Useful at home, not outside as not socially acceptable."*

Concept #4

Participants who wore corrective spectacles preferred this concept, however issues of using it without glass were raised for instance participant #M1 mentioned "*It's good to add a small device to your glasses and I like the design But what if you don't want to use the glasses."* Also, the idea of removing the functional elements when not needed or carrying them in a pocket until needed, was proposed by participants. Most of the participants assumed that the design is socially acceptable as the device is not too big and it does not draw attention in public.

7 CHAPTER SEVEN
Discussion

In this chapter I go through the results and findings of the thesis and answer the research questions. Also strengths and weaknesses of the research method and challenges in the user study will be discussed.

7.1 Answering to research questions

In introduction chapter, the questions "What are the most commonly emerged concerns and benefits the user perceive for using glasses type HMD?" and "What are the social aspects related to the device (imaginary) use, and what kind of reactions their use provokes?" and finally "What are the expectations with the interaction modalities and functionality of the device?" were stated. Based on the data derived from the user research, the following answers emerged.

The following results were also published in two papers by (Vahabpour et al. 2014) and (Häkkilä, et al. 2015). The most commonly perceived benefits from using the glass was when the user was able to search information and interact with the device when the hands were occupied and hands-free usage was required. Users considered the glass as a useful device for everyday life especially complementing smartphone use and making more convenient and quicker actions. For example, the glass can be a shortcut to the screen so that the user does not need to take the phone out of the pocket or a handbag and unlock it to start to use.

The most common social concerns related to use of the glass was the feeling that others thought the user was doing something unethical with the glasses such as taking photos without asking. People were concerned what might be the bystander's reaction of using the glass or they might look suspicious if they use it in public places. It is worthy of note that none of the users got negative comments while using the glass in the public.

Also, the possibility of cheating with unnoticed use of device was another social concern. Moreover, in face to face interactions the glass was seen as a hinder due to the interruptions and in a public place it can cause suspicions towards the user.

The preferred use for modalities and interaction with device was connected to the social aspect and the context of use. For instance, when the hands were occupied users preferred to use voice command or eye gaze and in public places they tended to use touch input instead of using voice commands. In general users preferred to use small and subtle gestures in public to be less noticed.

Also, most of the users did not expect the glass as a standalone device but a complementary for the smartphone. The user's perceived smart glasses more useful

in active and dynamic environment where there were more possibilities to use the glass in different ways.

7.2 Design Direction

Design direction of the study was aimed to evaluate reactions to different styles and visual appearance of a HMD type of a smart device. Through evaluating the different style and design, different reaction towards the style and function of the device were perceived. The reaction to visual design and size of the device was different related to functionality of the device and context of use. For instance people considered the more bulky and visible concept as a tool in workstations or hospitals and the smaller concepts as a device for everyday use.

The methods of attaching the device to body should be universal which means it should be possible for all people with or without corrective spectacles to use the device. Also, people with a different head shape or size should be able to use it comfortably and without feeling pain or getting sweaty.

The ability to take off the device easily and carry it when it is not in use was another important issue for the user. Also visibility of the system status was important to bring trust in public showing that the user is not doing something unethical. Such issue brings the necessity of an indicator in such a system.

The style is important especially for the devices that are supposed to be worn in head. People prefer to have personalized design and colors that suits their style.

7.3 Methodological notes

In this thesis the aim was to discover the potentials of the glass, finding the new usage and potential applications and users expectation of such a device. It is why a design probe was used instead of functional prototype. It this way the users were not limited by the available application and technology. However, a more realistic prototype can help to get more accurate results of public reaction to the device.

The ESM triggered study took 5 days for each participant and it was expected that users get tired with time and as it was expected the number of answers per participants decreased during the study. However, in the start of second phase which was without the prototype it temporarily increased.

This thesis was limited due to its small sample size to extract quantitative data. However, as the study was qualitative in nature, it was possible to extract interesting findings from data that helps to understand user perceptions and expectations on this topic. It can contribute to the design and development of the next generation of wearable computers.

8 CHAPTER EIGHT
Conclusion

In this chapter briefly I go through the research process and mention the key findings of this thesis and the possible future work around this topic will be discussed.

This thesis included two stages, user-study of a wearable computer in form of a glasses and study the design direction of such a device. The user study has been conducted with help of a design probe and Experience Sampling Methods (ESM). Participants (n=12) attended to this study for 5 days. They were asked to try the Mockup after receiving the trigger text message and imagine themselves using the device in the current situation. In total 234 diary entries and 134 photos have been collected and complemented with interviews with each participants. For the next stage, four different industrial design concepts were designed and evaluated by 3 focus group (n=14). The aim was to perceive the user's expectation of the visual design and usability of the device in different context.

In general, smart glasses was considered as a useful device especially in situations that hands were occupied with other activities and the smart glasses could help the user to multitask and be more productive. Also, it helped to enhance the use of a smart-phone with using the phone application without taking the phone out of pocket.

Moreover, issues related to privacy and social acceptancy of the device raised the participants. In public situations participants were concerned that bystanders might think they are doing unethical activities with the device. Also issues such as cheating with getting extra information was raised by some users.

About the social acceptability of the device. Participants were concerned that using the device might cause misunderstandings about them during social activities such as interacting face to face with someone. Also using the glass in public can make other suspicious about them. However, nobody got negative reaction about the smart glasses in public.

Evaluating the different concepts shows that the people's expectations for style and size of device is related to functionality of the device and for everyday use-cases they prefer the less visible and smaller device that also is easy to detach and carry when it is not in use. Also, participants preferred to have personalized style and color for such a device.

The visibility of a system status was also an important issue related to privacy of smart glasses.

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List of figures:

List of Tables

List of acronyms:

AR – Augmented reality

CPU – central processing unit

ESM – experience sampling method

GPS – Global positioning system

HMD – Head mounted display

IoT - Internet of things

RFID – Radio frequency identification

VR – Virtual reality

Appendices

Appendix 1: **Background information form**

(User-study and Focus group)

Gender: male female

Age: _____

Do you have a mobile phone? Yes No

Do you have a smart-phone? Yes No

Do you have a tablet? Yes No

Do you have any smart wearable devices? Like smart glasses or smart watches?
Yes No

What devices you usually carry with you? _____

Have you used head mounted display or Google glass before?

Yes I have tried No

Have you used augmented reality mobile applications?

Yes I have tried No

Do you used mobile devices for social media?

Never Sometimes Often

Have you ever customized your mobile devices? (Outlook, own ringtone. Etc.)
Yes No

Apendix2: **Diary questionnaire of user-study**

As soon as possible after you receive the text message…

1) Put the smart glasses on for at least 30 seconds and look around the environment

2) Take a photograph of where you are

3) If possible take a photo of yourself wearing the smart glasses

4) Answer the questions below…

Date /time	
Where were you?	
What were you doing?	
What would you use the smart glasses for in this situation?	
Would you have liked to take a photo with the smart glasses in this situation?	
Was there anything around you that you would like to get information about? Take a photo of it.	
Would you have liked to connect to social media e.g. Facebook using the smart glasses? What would you use it for	
Approximately how many people were around you? What was their reaction?	

How useful would the smart glasses be in this situation?

No use at all 1 2 3 4 5 6 7 Very useful

Comments:

_____

_____

_____

_____

How did you feel using the smart glasses in this situation?

Very Uncomfortable 1 2 3 4 5 6 7 Very Comfortable

Comments:

_____

_____

_____

_____

_____

_____

How would you prefer to interact with the glasses in this situation?

Voice commands / Touching the glasses / Hand gestures in the air / Using my eye gaze direction

Comments:

_____

_____

_____

_____

Other comments

_____

_____

Appendix 2: **Post study questionnaire**

(Interview questions)

1- **Did you feel embarrassment during using the smart glasses?**
2- **Did you have any uncomfortable feelings during using the smart glasses?**
3- **Did you feel that you were invading other's privacy?**
4- **What where the people's reactions when you used it?**
5- **Would you use this kind of product again?**
6- **What moments could be potential for the use of this kind of product?**
7- **What's the biggest benefit you can get from using a product like this?**
8- **What was your most embarrassing moment of using smart glasses if you had one?**

More comments:

Appendix 3: **Focus group plan**

Approximate time 120 min

Part 1

Introduction (15 min)

- Welcoming the participants and introductory briefing and explaining the time table
- Explaining purpose of focus group:

Comparing different wearable devices designs. From the devices that show their function very visible to devices that try to hide their functionality.

- Explain how they will operate during focus group
- Ask for any questions or issues that need clarified.
- Giving out the consent form and background questionnaire to participants

Part 2 (20 min)

Discuss participant's prior knowledge and experience

Sample question:

Have you heard about Google glass or other AR glasses?

- What do you think it does?
- What is your feelings about it?
- Would you buy one?

If someone used/seen anyone using it?

- How was it used?
- What was the reason to use it?
- How was the social reaction?
- How did it looked and feel while using it?(cool-silly- easy- difficult-practical-useless…)
- How was the experience?
- Choose one best thing and one worst thing about the experience!

(More questions can add depends on the answers)

Part 3 (25 min)

Google glass video and discussion around the cases shown.

Video links:

Part 4 (30 min)

Usage contexts

- Place 4 context pictures on the wall

    1. Public: (A market area full of people)

    2. Private (at home)

    3. Work (at office)

    4. At bar (dark , people, beer)

- Participants write post-it notes and stick them on each picture

Focus should be on:

- What would you use the device for and how?
- What problems do you see with using the device here?
- How would you react / feel if other people use it?

- (Review the answers and elaborating more ideas)

(Do we have hardware constrains here or can participants let their imagination run wild?)

Part 5 (30 min)

Review of designs

- Give each participants the designs, one per page. Contains:

- The picture of the design
- Likert scale questions:

1- How practical is this design? Very impractical 1 2 3 4 5 6 7 very practical
2- How socially acceptable is this design? Very impractical 1 2 3 4 5 6 7 very practical
3- How stylish is this design? Very impractical 1 2 3 4 5 6 7 very practical
4- What us your overall opinion of this design? Very impractical 1 2 3 4 5 6 7 very practical

- Field for ranking number of the design (1-5)
- Field for Participant number

- Collect all the papers in and then discuss the designs on by one by projecting slide show!

Discussion focus could be on:

- What is their opinion about:

Shape- color-size- comfort – functions- attraction – etc…

- What would they change if they can change one thing in each design?
- What is the best think and worst thing about each design?
- What is unique about each design?

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