

# Brain-Computer interfaces: from research to consumer products

Thesis submitted by

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In partial fulfilment of the requirements for the award of:

Doctor of Ethics and Technology

March 2019

## Abstract

Brain-computer interfaces have recently made its way into a consumer setting where it could potentially reach new areas of impact. This dissertation addresses the question of how this change in setting impact the experience of the ethical concerns in researchers and consumer innovators. The concept of responsible research and innovation is a novel attempt at expanding the discussion of ethics to both research and innovation. This thesis argues that research settings and consumer innovation settings have different experiences of ethical concerns, which makes this combination a challenge. This thesis also argues that the brain-computer interface discourse has challenges when discussing ethical because they are not often explicitly addressing the nuances in experience there is between different settings. This dissertation contributes to the understanding of what these differences in understanding are and shows that significant changes can be made to reduce the gap between the two settings. This is done with the usage of the AREA which gives a broad understanding of how the ethical concerns are experienced in the two settings. By describing the nuances in the experience of ethical concerns in the two settings, this thesis discusses the impact on both the brain-computer interface discourse as well as the responsible research and innovation discourse.

### Acknowledgements

This project/research has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under the Specific Grant Agreement No. 785907 (Human Brain Project SGA2).

I would like to thank my supervision team for their excellent guidance and encouragements. Specifically, I would like to thank Professor Bernd Stahl for being a great guide through this journey. A thank you should also be extended to the rest of my supervision team which have provided me with interesting perspectives and input to my research. This thank you is especially extended to Professor Mark Coeckelbergh for guiding me through the initial stages of my research, Dr Stephen Rainey for pushing my ideas for the better, and finally Dr Mark Shaw, for stepping in at the final stages of the research to provide additional knowledge to the room.

I would like to thank the CCSR, and specifically the postgraduate group for always being a great support, and for providing feedback to my work. I want to specifically thank Dr Tilimbe Jiya for his friendship, and for always standing by my side when I needed it.

I also want to extend my thanks to my fellow PhD students, which I have gotten to know as close friends. I want to thank Dr Louise Oldridge for being a never-ending positive spirit in my life, that has kept my days bright, even in the darkest of hours. I want to thank Dr Evi Manola for our talks, and for bringing some normality to the life of a PhD student. I want to thank Dr Cassie Brummitt for sharing my passion for games and structured fun. Finally, my thank you goes to Dr Claire Sedgwick always humouring my desire to debate. You have all made my life more interesting and enjoyable.

My deepest thank you will be going to my friends and family in Denmark. Without your extraordinary support, I would never have dared venture out on this journey. I want to thank my grandfather Harry Lund, for never settling and always pushing your own knowledge. This was truly inspiring and have shaped my life forever. I want to thank my grandmother Kirsten Lund, for being the kindest human being in my life, I hope I will be able to match your kindness in the rest of my life. My mother and father, Mette Lund and Freddie Hansen, you also deserve a great thank you for always supporting me. And finally, I want to thank my friends Morten Eckhoff and Julie Nygaard for always being a supportive voice in my life, and for providing me with a time and place to forget about the PhD even if just for a moment.

## Acronyms and Abbreviations

BCI	Brain-computer interfaces
RRI	Responsible research and innovation
ALS	Amyotrophic lateral sclerosis
EEG	Electroencephalography
fMRI	Functional magnetic resonance imaging
tDCS	Transcranial direct current stimulation
AREA	Anticipation, Reflection, Engagement, and Action

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## Published work

Hansen, C. B. J. (2015). When brain computer interfaces move from research to commercial use. *ACM SIGCAS Computers and Society - Special Issue on Ethicomp*, 45(3), 356–360.

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# 1 Introduction to the research goals

The following thesis is an investigation into the settings of brain-computer interfaces (BCI). The general concept of a BCI, is a device that captures brain data and translates it into a digital signal that can then be processed by a computer. (Wolpaw *et al.*, 2002) This technology was chosen as it is a technology that has recently made the transition from research and medicine, into a consumer setting which provides a unique chance to look at this transition. The overall purpose of the thesis is to provide an insight into the ethical concerns in consumer and research settings regarding BCI technology. This thesis will provide the responsible research and innovation (RRI) discourse with a proof of concept to the differences in ethical concerns that might present themselves in research and consumer settings, as well as a pioneering use of the AREA framework. This thesis will be a qualitative analysis of interviews of both researchers working with brain-computer interfaces and stakeholders working in consumer brain-computer interface companies. The discussion of this thesis will provide insights into the differences and similarities in the two settings identified and how it impacts the RRI discourse. The following sections will explain the gap in knowledge further, what research questions were determined and finally provide an overview of the structure of the thesis.

## 1.1 Gap in knowledge

The discourse of responsible research and innovation is a novel concept adopted by the EU. This novelty is one of the factors that makes it have gaps in knowledge that needs to be addressed. One of these is the issue of defining the differences between research and innovation. While the goal for RRI is to provide both researchers and people in the industry with methods and processes for doing responsible research and innovation, it is not clear what the differences are between the two settings. (See section 2.2) The lack of knowledge on the differences, is one of the gaps this research will fill by providing an example of a technology that is present in both environments. Looking at the brain-computer interface discourse there is a large body of literature describing the ethical concerns with the technology (See section 2.3), however, there is a gap of knowledge regarding the differences between the brain-computer interfaces developed for research settings and devices designed for consumer settings. (See section 2.1) At this stage, it is essential to make it clear that when consumer settings are mentioned, it is a reference to a context where technology is developed for general usage/consumption and not for use in industry. It is important to make this distinction in this thesis as there is a significant commercial sector of brain-computer interface development, however, most of this industry is targeted towards researchers and the medical sector which ethical concerns in many regards have been debated in the neuro-ethics and brain-computer interfaces discourse. (See section 2.1) This clarification is important for the identified gap in knowledge, but also for

the research to provide interesting findings which will be addressed further in the following sections. The next section will be exploring the questions used to fill this gap in knowledge in this study.

### 1.2 Research questions

There are many potential angles to approach the gaps in knowledge identified above. It would be interesting to research the process of which technology moves from a research project to a final consumer project. Another possible approach would be to research which approaches in consumer settings, that could be used by researchers to act responsibly. This thesis, however, will answer the questions that should be the first step in closing the gap in knowledge, which is to understand whether there are any differences in the understand of ethical concerns in the research and consumer settings. By doing so, a groundwork will have been done, which not only strengthen the fundamental understanding of the difference implied by the name responsible research and innovation between research and innovation. But answering these questions will also provide insights into how RRI needs to consider both settings to be able to achieve the goals of RRI. Finally answering this overall question, will provide the BCI discourse with a platform to explore definitions of BCI and thereby understand the ethical concerns in a more well-defined context.

Therefore, this research aims to answer the following question:

- What happens to the understanding of ethical concerns when brain-computer interfaces are moved into a consumer setting?

The overall research question can be further specified with the following set of questions:

- What ethical concerns are there related to brain-computer interfaces?
- How are ethical concerns experienced in research and consumer environments?
- What does these differences mean for RRI and the ethical concerns related to BCI?

These questions were chosen as they would fill the gap in knowledge currently present as described in section 1.1. By answering these questions, there would be created a reliable basis for further research for the RRI discourse and the BCI discourse. Answering these questions would provide a comparison between the two settings, showing any differences and similarities between the two settings. By answering the overall question, there would be further reasons for RRI to continue as a concept as it would be confirmation of the underlying principle that there is a difference between research and innovation. It would furthermore open for further research into the differences and similarities as to which are restricted to the brain-computer interface technology and which can be applied to RRI in general. In the following section, the remaining structure of the thesis will be described as well as the critical points made in these sections. The following section will also include a reading guide, which can be used for guided reading.

### 1.3 Structure of the thesis

Chapter 2 will be an introduction to brain-computer interfaces, the main point in this chapter will be the reasoning for why brain-computer interfaces were chosen as the technology to look at as well as expand on the current gaps in the brain-computer interface literature. Some of these are the current state of the technology in the innovation/adoption process and the identifiable ethical concerns. This is followed by an introduction to responsible research and innovation. Which will provide insights into the objectives of RRI as well as the current state of the discourse. This will give a theoretical backbone to the thesis and will explain the setting of which the thesis is considered a part of. This chapter will also further define the gap in knowledge in the current RRI literature. Once this has been done the next section will discuss the literature selection process of which a basic understanding of the ethical concerns regarding brain-computer interfaces will be made. This basic understanding of the ethical concerns about brain-computer interfaces will be used to formulate the interview questions and analysis of the interviews. Once these sections have explained the background for the thesis there will be a description of why the research questions chosen are justified. Chapter 3 will be going through the different paradigms that were considered for this research as well as potential methods for data collection, and data analysis. Before doing so, the chapter will shortly describe the underlying theory that will be employed regarding generalizability and as such what kind of answers this research can provide. This chapter will also justify why the chosen method of semi-structured interviews and an interpretivism paradigm were chosen. This chapter will be finalised with a short description of the practical steps taken in the data collection process such as the selection of interviewees both in research settings and in the consumer settings. This section will also include a short description of the process of ethical approval for this research. Chapter 4 will be going through the findings of the study and will go through every ethical concern identified, and interesting quotes from interviews will be highlighted. These findings will be discussed in chapter 5 which will explain the differences and similarities between the two settings and experience of ethical concerns as well as the impact on RRI. The concluding chapter will tell how the research questions were answered, how the gaps of knowledge identified were filled and what further research needs to be done.

#### 1.3.1 Reading guide

Chapter 1 is an introduction to the thesis. This chapter provides a context for the study and explores what questions this research tries to answer. This chapter is essential for most readers and could be a quick read for those just looking to verify that this study is of interest for them.

Chapter 2 is an essential chapter for this thesis as it gives an overview of the current state of things in both the RRI discourse and the BCI discourse. This chapter also contains the creation of a list of ethical concerns

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related to BCI devices. This chapter is rather important for those looking for a quick understanding of the study and its results.

Chapter 3, the essential section of this chapter is specifically the data collection section (3.6). While the remaining sections give an important insight into the framework and worldview this thesis is built upon, these sections are not important for those looking for a quick understanding of the study and its results.

Chapter 4 is the analysis chapter, and large parts of this chapter is a rather methodical exercise of analysing the interviews. For most readers it will be enough to read the action, engagement, reflections, and anticipation overview rather than the full analysis.

Chapter 5 is the discussion chapter of this thesis and is essential to understanding the results of this thesis. To fully understand this chapter a minimum of chapter 1, 2, and 3.6 needs to be read and understood.

Chapter 6 is the conclusion chapter, which brings everything together in a summary. This chapter can be useful as a quick read to understand if this thesis is providing any answers that might be interesting to the reader.

## 2 Brain-computer interfaces and responsible research and innovation

The following chapter will be looking at the current literature on both brain-computer interfaces and responsible research and innovation. These discourses will be having significant gaps in knowledge which justifies the research question described in section 1.2. This chapter will also include a methodical description of the literature describing various ethical concerns related to BCI devices. The following section will be defining the concept of BCI in this research, as well as describe the BCI literature.

### 2.1 Defining brain-computer interfaces

There are many types of classifications of a brain-computer interface (BCI), however, the general concept is a device that captures brain data and translates it into a digital signal that can then be processed by a computer. (Wolpaw *et al.*, 2002) The form of a BCI can be many, such as invasive, non-invasive, wet, dry, passive, or active. The devices can also be capturing different type of data such as fMRI, EEG, ECG, and more. (Wahlstrom, Fairweather and Ashman, 2012; Grübler and Hildt, 2014, pp. 7–38; Chan *et al.*, 2015; Lee, Shin and Lee, 2015) These devices can be used to anything from medical applications, meditation tools, to toys. (Kübler *et al.*, 2005; Audette, 2015; Nijholt and Nam, 2015; Muse, 2019a) However, for this study, it is needed to be more specific with the type of devices that will be talked about. While a general look at the whole field of brain-computer interfaces could be interesting to investigate in terms of the two settings, one particular type of brain-computer interfaces has made the transition from research settings to a consumer setting. Specifically, non-invasive, dry EEG hardware has been developed and is being sold to consumers. These range from very simple headbands with a few electrodes, to headbands with 10+ electrodes. (EMOTIV, 2019a; Muse, 2019a) While it could be argued that these devices have been available for anyone with sufficient funds to buy from providers of laboratory equipment, it is important to distinguish the purpose of the device especially in an EU setting as medical devices in part are defined by the intended usage in the medical field. (Council of the European Union Department, 1993) Therefore, in this thesis, when the concept consumer BCI is being mentioned it refers to the devices that are intended for a consumer market. While the price of the device does hold importance, it is found that most consumer BCI falls within the same type of price range between 100 and 500 US dollars. (EMOTIV, 2019b; Muse, 2019b; NeuroSky, 2019; OpenBCI, 2019) When this clarification has been made, it is important to note that in the research literature there are some times very few options to distinguish between the type of device that is being talked about. (EMOTIV, 2019b; Muse, 2019b; NeuroSky, 2019; OpenBCI, 2019) While there are distinctions between the different types of technologies, the research literature is not good at disconnecting them by different terms, which very often makes it appear as if brain-computer interfaces are one type of technology. This conceptual muddle makes it very hard to distinguish ethical concerns by technology types because it is not always clear what studies are referring to when investigating ethical

concerns in BCI technology. To avoid the same problem here, the selection of a specific technology should make it clear what the ethical concerns are for this specific technology. Through the pilot study and the literature, it is also seen that the medical setting and the research setting are in many regards closely connected. Therefore, it is hard to distinguish these two settings in the literature. This particularly comes to show when the research literature is discussing ethical concerns related to BCI usage in the medical field which is a large part of the body of literature currently. (Kübler *et al.*, 2005; Dobkin, 2007; Amantini *et al.*, 2011; Chang, Breshears and Rowland, 2013; Peterson *et al.*, 2015) While the brain-computer interface literature ranges from technical descriptions of the technology and use cases (Chen *et al.*, 2015; He *et al.*, 2015; Jianfeng, Zhendong and Jinghai, 2015; Li, 2015; Nijboer *et al.*, 2015; Savi and Popovi, 2015; Venthur *et al.*, 2015), there is a fairly well-developed discourse on ethical concerns regarding brain-computer interfaces. (Haselager *et al.*, 2009a; Wahlstrom, Fairweather and Ashman, 2012; Nijboer *et al.*, 2013; Hildt, 2015a; Ienca and Haselager, 2016) Some of which are directed at neuroscience as whole, and some of which are directed towards specific types of use cases and/or technologies. (Greely, 2015; Lavazza, 2015; Stein and Giordano, 2015) The literature covers a variety of topics which will be further discussed in section 2.3, but at this point, a few comments will be made to explain some of the common topics discussed regarding brain-computer interfaces in the research literature. Due to the typical use case of brain-computer interfaces being used in a medical setting, a lot of the literature is covering ethical concerns related to this setting. Therefore, much of the literature is covering topics such as researcher-patient or doctor-patient situations, or situations where the technology is used in therapy or diagnosis of patients. (Tamburrini and Mattia, 2011) The area of BCI used in medical settings is obviously a research field that needs to be taken seriously and be considered when developing medical devices. This, however, does leave a gap of knowledge on what ethical concerns are relevant for consumer devices not developed for such use cases and settings. Some research has been done towards the consumer products, however much of this research has been into the accuracy of the devices, and many have been an attempt to clear these devices for research or medical use cases. (van de Laar *et al.*, 2013; Hou *et al.*, 2015) Some research has been done into the usability and acceptance of brain-computer interfaces which ties into the question of the viability of consumer devices (Ahn *et al.*, 2014; Deravi *et al.*, 2015; Ganapathy and Nishavithri, 2015; Lotte *et al.*, 2015; Mathe, 2015; Ibarrola, 2016; Rawool, 2016), but specific research into the ethical concerns of consumer brain-computer devices are scarce which leaves a gap of knowledge that this research will fill. This research specifically will provide the brain-computer interface discourse with an overview of ethical concerns in the consumer setting and provide a comparison to the current discourse as well.



## 2.2 Why settings are important for the Responsible Research and Innovation discourse

This section aims to explore the current responsible research and innovation (RRI) discourse as well as provide the theoretical background the following thesis will be built upon. Responsible research and innovation (RRI) is a concept and idea that has been promoted in the European Commission and elsewhere i.e. EPSRC. The objective for the European Commission with responsible research and innovation, is to create a process for research and innovation which allows for both societal actors and innovators to become mutually responsive (and responsible) for scientific advancements to be acceptable, sustainable, and societally desirable. (Owen, 2013; Schomberg, 2013) Considering this research aims to answer the question of what the difference and similarities between research and innovation settings have on ethical concerns, the RRI discourse provides a theoretical background for discussing this by providing a context to understand the two settings. When the terms research and innovation terms are used in this thesis, it is to be thought of in an RRI discourse, which indicates a difference between academic research, and industrial innovation. This distinction is something which is either directly discussed and critiqued within the RRI discourse (Hansen, 2015) or shown by the distinction of RRI papers often talking about how to implement RRI in either a research or industry setting. (Inzelt and Csonka, 2017; Nulli and Stahl, 2018) This research will be part of the discourses ability to answer some of these critique points and explore what the differences and similarities are regarding ethical concerns. This vagueness in the definition of RRI is something that points to a new discourse trying to find its place. The vagueness is something acknowledged in the RRI discourse (Zwart, Landeweerd and van Rooij, 2014), and is discussed by the general RRI discourse not working on implementing and creating frameworks for RRI in different settings. This general RRI section of the RRI discourse aims to specify and discuss RRI as a whole such as the scope of the discourse, the political impact of the discourse and defining key terms in the discourse such as responsibility(van de Poel and Sand, 2018; Gianni, 2019), innovation(Gianni, Paris and Goujon, 2019), participation (Pataki and Zoltán, 2018). This area of the RRI discourse is where this research aims to provide an applicational analysis of a specific topic to show that the topic of research and innovation (in this research specifically consumer product innovation) impacts ethical concerns. By looking at how ethical concerns are experienced and dealt with in the two settings, it will answer the question as to whether there is a difference between a research setting and a consumer setting. Exploring these differences is important to the RRI discourse as it is meant to be an overarching concept and idea that should embody both researchers as well as industry innovators. (Zwart, Landeweerd and van Rooij, 2014) A combination of both academic research and industry innovation might appear more difficult than first envisioned by the European Commission. The shift in the EU towards RRI emphasises the desire for science to produce marketable products and a more direct connection between research and the public. This shift suggests that academic research directly impacts innovation in

society. This goal has promoted a large portion of the RRI discourse to focus on the research aspects of implementing RRI. This has left the industry solutions rather vague and undeveloped, however, this has recently been picked up and labelled responsible industry (Ceicyte and Petraite, 2018; Tan and Yamada, 2018; van de Poel and Sand, 2018). That an area within the responsible research and innovation discourse has taken the term responsible research, thereby removing the academic research aspect in RRI suggest that there are some things that need to be discussed. The current discourse needs to explore the differences and similarities between research and industry settings, which force this divide. This exploration of the two settings and their impact on ethical concerns is what this thesis will make the first steps towards. While the general RRI discussion is a substantial part of the RRI discourse, another significant part of the discourse is various stakeholders looking at how RRI can be implemented within different areas of research or industry. This part of the RRI discourse is trying to resolve the practical implications of using RRI in different settings. These settings are of a wide variety and appear to reflect areas of research that are hot topics currently for various reasons. These topics range from research areas such as artificial intelligence (Stahl and Wright, 2018), climate change (Kreps and Eds, 2018), renewable energy (Mirsafaei and Yaghmaei, no date), semi-autonomous cars (Baumann *et al.*, 2018) and more (Brukamp, no date; Forsberg and Thorstensen, no date; Study, Technology and People, no date; Bates *et al.*, 2019). While this research will be looking at a specific area of research and innovation with an RRI perspective, it distinguishes itself from this kind of work as the purpose is not to evaluate how well RRI is integrated or attempt to implement RRI in the research and industry settings of BCI development. This research instead uses the RRI framework, known as the AREA framework (EPSRC, no date), to gather insights on both the academic research setting and the industry innovation settings, which the RRI discourse wants to encompass. The AREA framework is not very well defined in terms of when something is considered anticipation, a reflection, an engagement, and an act, which is also something that is true for many parts of the RRI discourse and often a critic of the shift to RRI from previous iterations of similar goals. (Zwart, Landeweerd and van Rooij, 2014) The current literature using the AREA framework directly is also still limited as the AREA framework developed by the EPSRC is a broad framework that can be further developed and implemented in various settings. This study will therefore be a novel usage of the AREA framework, using it to analyse the two experiences of ethical concerns found in both research and industry settings on an emerging technology. Another implementation is the AREA 4P framework (Orbit, no date) which uses the AREA framework to create a set of questions that can be asked by ICT researchers to gain insights into various RRI topics regarding ICT. While it could be useful to use a specific version of the AREA framework developed for ICT or BCI settings, such a framework is not developed yet, therefore by identifying the general AREA framework in the two settings. This research will show whether the general framework is usable in both research and industry settings. By

identifying these general RRI pillars in the settings of research and innovation settings of BCI, it is possible to clarify whether the different settings change how ethical concerns are experienced in these settings. While the RRI setting will be the theoretical discourse this thesis will be built upon, it is required to acknowledge the brain-computer interface discourse and the ethical concerns discussed. Due to the undefined nature of the AREA framework, a definition that will be used throughout this work will be required:

### 2.2.1 Defining the AREA framework

Before defining each element of the AREA framework as it is used in this research, it is important to note that the order of the AREA framework has been slightly altered for this research. The typical AREA framework order is “anticipation, reflection, engagement, action”. However, during interviews, it became clear that often stakeholders would talk about the actions they had taken, followed by reasonings behind these actions. Therefore to follow this narrative the analysis of the interviews will follow the same order. It will also be a recommendation in section 5.2.2 that the RRI community reconsider the order of the AREA framework. Before going forward the 4 parts of the AREA framework will be defined as such:

#### 2.2.1.1 Action

Actions could be defined as a stakeholder performing an action to mitigate or interact with an ethical concern. However, the lack of actions taken can also be useful in describing the experience of an ethical concern. If an ethical concern is not considered worth acting on, it could indicate that a stakeholder does not find an ethical concern relevant, or enough of a concern to be worthy of taking actions. Therefore, for the AREA framework to make sense, it is required to not only consider what actions are being taken, but also which actions are not being taken. The analysis of the interviews in this thesis will therefore consider both actions taken, and actions not taken as these are key indicators of the experience of the ethical concern.

#### 2.2.1.2 Reflection

Reflecting in the AREA framework is used to signify that to solve ethical concerns, there needs to be spent time thinking of solutions to them. This can either be used as a practical tool in a workshop, but also in a theoretical exercise to analyze what kind of reflections a stakeholder has or could have made on a specific ethical concern. In this research reflections are done not only when a stakeholder mentions taking time to think of a given concern, but also when comments made by a stakeholder suggest that reflections had been made. Because reflections are sometimes not mentioned as a direct action taken, this ensures that reflections are identified in the stakeholder interviews. Like how actions were handled in this research, it is

also important to note when a stakeholder specifically mentions that they have had no reflections on an ethical problem, as this can significantly impact the experience of a stakeholder.

### *2.2.1.3 Engagement*

Engagement is used in the AREA framework to promote engaging with stakeholders relevant. Engagement is often considered to be direct stakeholders as well as indirect stakeholders. Stakeholders directly impacted should be engaged with to ensure that they are not negatively impacted by a certain development, and this engagement should be expanded to indirect stakeholders as well. Indirect stakeholders could be lawmakers, family members of a stakeholder, or other similar stakeholders which are not directly affected by the ethical concern. Regarding this research, it is important to note which stakeholders are being engaged with, which methods are used in terms of engagement as well as the outcome of these engagements. This is required to fully understand how stakeholders engaged with the people impacted by their research or technology, and in cases where these engagements are part of the process it is also important, as it could explain why certain actions were taken, or why ethical concerns were anticipated to be a problem.

### *2.2.1.4 Anticipation*

Anticipation in the AREA framework is defined as describing and analysing the impacts, intended or otherwise that might arise. In the AREA framework anticipation is defined as not predicting what will happen but exploring what could be potential outcomes. While prediction is not the intended definition of this part of the AREA framework, this research will include predictions made by the stakeholders. This is done as predictions are often the way anticipation is found to be expressed by the stakeholders in this research. An anticipated concern was often discussed with the disclaimers that stakeholders either predicted a concern to be an issue or not, which then lead to them taking actions, reflecting upon the issue, or engaging with stakeholders regarding the issue. Therefore the anticipation that a concern was either important or not to them, impacted their experience of the concern itself.

## *2.3 Ethical concerns in research*

In the following section, the literature search made to identify ethical concerns will be described. This will be done to show how the ethical concerns were found, but also to provide a base of comparison between the research setting and the consumer setting. By having a strong understanding of the ethical concerns in the research setting, it will allow for a better understanding of the consumer BCI setting and the ethical concerns developers have there. While this does not guarantee a perfect understanding of the ethical concerns in the research setting, it provides a broad picture which should be useful in giving questions and context to the following research. Following the description of the literature collection and analysis will be

a description of the ethical concerns discovered. These ethical concerns will be the groundwork used to develop interview questions for this study.

### 2.3.1 Selection of literature and encoding

The following sections will discuss the selection of articles (2.3.1.1) and how the analysis of these articles were made (2.3.1.2). Following this section, the analysis of articles (2.3.2) will be described, thereby providing a list of ethical concerns related to BCI devices in the literature.

#### 2.3.1.1 Selection of articles

To find the articles used to identify the ethical concerns related to BCI technology several search engines were considered. These include the following: google scholar, DMU summon solution and SCOBUS. Google scholar was immediately discarded as there was no good way at the time of ensuring that the literature found was available in full format. Following this, the DMU summon solution and SCOBUS were considered. While many of the results of SCOBUS and DMU summon solutions were similar in numbers, SCOBUS was eventually used as the format of the website and method of applying filters were easiest to work with. Once the decision was made to use SCOBUS as the main search engine, various filters and search terms were attempted. Various combinations of the terms “brain computer interfaces”, “ethical concerns”, “brain machine interfaces”, “ethic”, “philosophy” as well as using various abbreviations of “brain computer interfaces” as well as different use cases of hyphens were used. This resulted in a total of 147 results, of which 34 articles were available as full articles. Then the term “neuroethics” were used but due to a large number of results, the filter of publications published prior to 2012 was removed resulting in 265 results, of which 61 articles were available as full articles. Combining these results 90 of the articles were unique articles which were read and categorised based on their relevance to BCI devices. This resulted in 31 articles that were identified for further analysis that had relevance to BCI devices. A full bibliography of these articles can be found in appendix 8.1.1. The analysis methods and results of these articles will be described in the following sections.

#### 2.3.1.2 Creation of codes

Before analysing the literature very few coding nodes were created beforehand. This was done to ensure that the literature was the origin of the ethical concerns rather than preconceived ethical concerns. Due to the research questions, three nodes were made beforehand though which were: Ethical concerns, Use case, and solutions and recommendations. These three nodes were then used to gain insight into the context of the ethical concern (the potential use case), what ethical concerns there were (ethical concerns) and potential methods and recommendations that researchers had already identified (Solutions and recommendations).

### 2.3.2 Identified ethical concerns

Through the analysis of the literature the following ethical concerns have been identified, and in the following section these will be explained in detail: Accessibility/digital divide, accuracy/misinterpretation, autonomy/informed consent, enhancement, identity, policy gaps/legal concerns, privacy, public perception, security, side effects, societal. A full list of the identified themes can be found in appendix 0.

#### 2.3.2.1 *Accessibility / digital divide*

The concern of accessibility and the digital divide in the literature is mainly focused around the price of new technology and the support needed for users in medical settings to be able to use it. This concern can be broken down into the concern of:

- Access to research and/or treatment program participation
- Funding for individuals or organisations to buy and support BCI technology
- User groups being unable to use the devices produced

Overall the research literature surrounding this concern is involved in the medical field and providing healthcare or treatment to user groups. At least one article suggests that researchers should be concerned with educating the public on the usage of BCI and neuroscience.

#### 2.3.2.2 *Accuracy / misinterpretation*

Overall the accuracy concern revolves around the accuracy of the data produced for research or medical purposes. Most of the literature does not describe accuracy directly as an ethical concern, but the literature describes how accurate the results were or the implications of the accuracy of the data produced. The literature is related to the accuracy of the diagnostic procedures and is often tied into how BCI can improve the diagnosis procedure and provide a more accurate diagnosis. However, this introduces the concern for misinterpretation and accurately conveying this information to patients. A few articles also briefly discuss the concern of commercial companies not accurately describing the devices they are producing and their use cases.

#### 2.3.2.3 *Autonomy / informed consent*

The topic of autonomy is rather widespread, as it covers the area of disability to regain autonomy through technology, the loss of autonomy by being mind-controlled which is being tied into the concern of informed consent. The topic of informed consent discussion in the literature was mostly connected to research or medical settings and involved topics such as doctor-patient relationships, incidental findings, misinformation, sense of purpose, and vulnerable participants. Most of the topics discussed evolved around procedures that were taken or could be taken to ensure informed consent and identifying problems with getting informed consent that could help other researchers or medical staff to obtain informed

consent. Specifically, a lot of the literature around this topic involved a setting regarding ALS patients. (The ALS Association, 2019) Some of these concerns are not expected to be found in the consumer setting as they are very specific to the context of research (i.e. ALS patients).

### *2.3.2.4 Enhancement*

On the topic of enhancement, the literature shows that the concept of BCI is very wide. When discussing enhancement, the topics range from brain stimulation to controlling things with your brain enhancing the human physical ability. This makes it very hard to discuss the different aspects of enhancement as the concern of enhancement is very different when discussing a transcranial direct current stimulation device and an EEG monitoring system as the effects are very different. Some of the literature is interested in the debate of when therapy becomes enhancement, and some literature is interested in the accessibility of enhancement. Overall the concept of enhancement and BCI is a very complex one due to the inclusion of very different devices. It is very interesting that the topic of enhancement ties into the discussion of BCI changing the concept of identity.

### *2.3.2.5 Identity*

The literature discusses how BCI users could be affecting their identity by using the devices. The effect on identity is in some literature made very problematic, in some of the literature however the question was not whether BCIs would change the identity of people but rather how BCIs could help identify consciousness and whether there was an identity they were communicating with. Especially in the literature focusing around restoring functions for disabled, the concept of identity concerns was interested in how to restore the identity that fit the patient. Such as how do we make it possible for the patient to live out the identity they had. On a philosophical level, some literature discusses how research into consciousness and BCI could change the way we perceive free will which in term could have complications.

### *2.3.2.6 Policy gaps / legal concerns*

Much of the discussion about policy gaps and legal concerns revolve around the topic of liability in research, however, liability is extended beyond research and raised to a more generic level in some cases. The literature is partly driven by legal discussions in the USA discussing the implications of impacts on free will and how to handle cases. It appears to be particularly interesting when a BCI is used to control things or when multiple individuals are considered as the operator. As mentioned though, most of the literature is about handling liability in research or medical teams, and particularly interdisciplinary teams appear to be a concern due to the complications such mixed teams can give in defining who has the responsibility.

### *2.3.2.7 Privacy*

There is a large body of literature concerned with the privacy of the mind in relation to BCI devices. The main concern here is surveillance or rather insight without consent. It appears that much of the literature agrees that brain-computer interfaces provide insight and data that needs to be protected and be covered by privacy protections. Some articles express the concern that unconscious or unknown thoughts might be made available. With this concern is also the concern that such information could be identifiable and as such could be used to identify people although they wish to be anonymous. Overall though the main concern about privacy is not privacy in government or medical settings, but rather commercial setting and advertisers. Some are however also concerned about the usage of BCI as lie detectors.

### *2.3.2.8 Public perception*

When discussing the concern of public perception, the literature talks about the level of accurate information understood by the public. In the sense that they describe the experience of being met with patients or research participants having limited knowledge about how the brain works, and the limitations of BCI and science in the field of neuroscience. It appears to be discouraged to create hype about the technology as the hype often is not accurate to the actual experience of the technology. Part of the concern for public perception is also how it might impact research projects if “bad press” is occurring as it could limit funding or reduce the possibility of participants agreeing to partake in the study. In the same sense, it is recognized that good public perception can increase the odds of funding which creates the risk of researchers being incentivised to push a breakthrough narrative to keep funding incoming. The concern for public perception is not restricted to the technology or research though, but also the concern for the public perception of mental diseases or perception of autonomy. All this tie into various concerns regarding acceptance of the technology which includes the public acceptance of BCI technology, as well as individuals accepting treatment. Regarding acceptance, the literature points out key areas to be aesthetics, comfort, discrimination, longevity, quality of life, reliability, reliance, and usability as the main concerns. All of these are mostly related to patients having to use the devices as communication or control devices.

### *2.3.2.9 Security*

Security is a limited concern in the literature as the two concerns mentioned are BCI controlled devices being hacked and taken over, or implantable BCIs being hacked to cause physical harm on the patients using them. It is important to note that this concern is present and that implanted devices provide an increased risk of security complications.

### *2.3.2.10 Side effects*

Most of the concern regarding side effects is the lack of knowledge regarding physical and mental (side) effects. Side effects is both in terms of immediate effects, but also long-term effects. Since much of the



literature is dealing with medical diagnosis or treatment, much of the concerns here relate to those topics in. Most side effects discussed are physical side effects such as implants impacting the brain or treatments having side effects.

### *2.3.2.11 Societal*

Some of the societal concerns discussed in the literature are the impact society might have on the understanding of the brain and how BCI could change society. Specifically, one article worked with the imaginary case of BCI creating social unrest and conflict. The concerns around the societal changes were in most cases highly speculative. The large-scale effect and the complexity of society could potentially be a reason why this ethical concern was discussed in such terms. One of the topics discussed regarding societal concern was the ability for existing power structures to abuse the BCI technology such as employers monitoring employees. This abuse of power concern also extended to a militarization of the technology and concerns regarding the military using the technology either as a weapon or to desensitise soldiers. A significant part of the militarisation concern was a concern for the military misusing the technology developed for research and medical purpose. Finally, societal concerns were related to the topic of research funding and globalisation.

## 2.4 Justification of research questions

In the above sections the current knowledge of responsible research and innovation as well as brain-computer interfaces, and the ethical concerns regarding brain-computer interfaces in the research literature have been described. In doing so several gaps in knowledge have been identified, both in the discourse of responsible research and innovation and in the discourse of brain-computer interfaces. A large amount of work has been put into the research setting of the discourse and in defining what RRI is and why it is a novel discourse. Recently this discourse has moved to discussing the industry aspects of RRI. In particular this justifies asking the overall question of what happens to ethical concerns when brain-computer interfaces move from research to consumer settings. This question specifically fills the gap in knowledge of RRI of what the process of innovation and commercialisation does to ethical concerns. To answer this overall question a few additional gaps were identified that needs to be researched before the main question can be answered. The RRI discourse specifically lacks a practical body of work using the AREA framework to analyse and understand the change in ethical concerns for emerging technologies, this research is novel in the usage of the AREA framework as a practical approach to understanding emerging technologies. In the brain-computer interface discourse, a wide selection of ethical concerns was identified. While it could be argued that many ethical concerns are already identified it is also shown that there is a

gap in knowledge regarding how these ethical concerns fit into a consumer setting. By answering the sub-question of which ethical concerns there are with brain-computer interfaces in each settings this will be clarified. Finally, the gap of knowledge in the RRI discourse identified surrounding responsible innovation leaves the question open for how RRI can be used to describe and handle ethical concerns in both settings, and specifically how this research can impact the RRI discourse. Finally, the lack of clear definitions of BCI shown in the BCI literature also justifies the need for this research to investigate how the experience of ethical concern is in each setting, as it could confirm the lack of definitions and provide BCI researchers with groundwork to start this discussion.

### 3 Research methodology and approach

This chapter will discuss the choice of paradigm, methodology and specific methods that will be employed in this research. This chapter will firstly explore various paradigms, methodologies and methods and how these are understood in this research. Secondly, this chapter will discuss why certain paradigms, methodologies and methods will help answer the research questions raised in the previous chapters. The chapter will be structured in layers as depicted in the table below. The table below shows the different layers of methodology considered in this research. The top layer is paradigms which influence all the layers below. The paradigm choice will influence the different research approaches which then will influence the methods chosen for data collection and the data analysis methods.

Table 2: Methodology overview

<b>1: Paradigms</b>	Positivism		Interpretive		Critical Research
<b>2: Research Design Approaches</b>	Ethnographic		Case study	Action Research	Grounded theory
	<b>Data collection</b>				
<b>3: Methods</b>	Literature review	Interviews	Questionnaire	Experiments	Observations
	<b>Data analysis</b>				
<b>4: Methods</b>	Inductive			Deductive	

It is important to note that the choices made in one layer do not restrict the choices available in the layers below, however, it will have an impact on how the layers are interpreted and used. For example, a positivistic inspired case study research will look different than an interpretive case study research. When working in different paradigms there might be a certain world view that guides certain paradigms, however, those do not necessarily have to be incompatible. It can be argued that while it is not easy to combine different paradigms it is possible to acknowledge the productivity and results from different paradigms. And in that sense, if one were to design a research approach it would be useful to consider what paradigm answers those questions with the most likelihood of good results. For example, if I were to investigate the boiling point of water, following the positivistic approach and paradigm have shown great accomplishment in understanding chemical substances. In the same way, can the next layer of table 1 be interpreted, however, if an interpretive paradigm has been chosen, that will change the way that research design approaches are chosen and formed. It is also worth noting that once the paradigm has been chosen, then certain research design approaches could be considered inappropriate or hard to adapt because they

might have been developed in another paradigm. In a similar way as how the paradigm impacts the form of the research design, so will the research design provide changes to the way data collection is performed. Experiments, for example, are very typical in the positivist paradigm. However, interviews are typical in studies following the interpretive paradigm. As mentioned, before it would be very possible to do a positivistic interview study, however, the positivistic approach would impact what kind of questions could be answered and potentially which data analysis method chosen. In the following section the topic of generalisability will be discussed as generalisability is related to how methodological decisions can impact what questions can be answered. A discussion of which paradigm fits this research will be done in section 3.2.

### 3.1 Generalisability

This section will be based upon Lee and Baskerville (Lee and Baskerville, 2003), who discussed the different types of generalisability that a study can participate in. They explain that there are 4 types of generalisability:

- Theory to Empirical (TE)
- Empirical to Empirical (EE)
- Empirical to Theory (ET)
- Theory to Theory (TT)

While the TT, TE, and ET generalisations are typically done, EE is not often considered enough; however, this thesis will be built around the concept of EE generalisability. What this means for the research is that it is not an attempt to build a theory based upon the empirical evidence, it is also not a thesis trying to combine theories, or an attempt to prove a theory based upon empirical evidence. Instead what this thesis is trying to do, is to generalise from some empirical data to other empirical data. Generalising from data to other data, is done to create richer data for others to build upon. Since it has not been possible to find any empirical data on consumer BCI developers and the ethical concerns, it is required for a body of work to be built before theories can be applied. Once an empirical understanding of the setting has been created, it can then further be investigated and the potential of doing TE, ET or TT generalisations are possible. While it could be argued that this research could be constructed as a TE study, that would also require that certain aspects of the settings were already known. Therefore, to provide a base for other researchers to build upon and investigate other types of generalisation, this research will be limited to describing the data and generalising to create more data. The idea behind this is that while this research will not fully uncover the relationship between specific theories and data, the research will describe the data in relation to theories to create richer data. This enriched data can then be used by others to organise additional research to explore the topic further.

### 3.2 Paradigm

The choice of these three paradigms is chosen based on the discussion by Mingers, Becker and Niehaves, Orlikowski and Baroudi. (Mingers, 1979; Orlikowski and Baroudi, 1991; Becker and Niehaves, 2007) It is important to discuss in which paradigm this research is undertaken as the paradigm impacts the understanding of the research question, the methods used and potentially the findings. A paradigm is to be understood as an underlying world view that influences how the world is understood. The paradigm can be influenced by various schools of thought such as the idea that there is an objective world that can be researched or the idea that everything in the world is understood through social constructs created between humans. These ideas are just some of many that could influence your worldview and how research will be undertaken. It is important to this study as it explains why some of the choices were made in terms of methodology as well as it helps explain why the specific research questions were chosen as well as why certain answers were found from the research data. Under a different paradigm, this research would have found other answers and would have engaged in the research data differently. In the following sections, I will explain why the interpretive paradigm is best suited for this research, while also explaining how the research could have been done if a different paradigm had been chosen. The choice of the interpretive paradigm also impacts the approach chosen for data collection and data analysis. The paradigms will be discussed in the order of positivism, interpretivism, and critical research.

#### 3.2.1 Positivism

The paradigm of positivists in this research is defined by the understanding of the world as something you can study objectively and without interpretation. Being able to observe objectively is based on the idea that the world exists without our interpretation and that something is only true if you separate the interpretations of the world from measurable features of the world. *“Such studies serve primarily to test theory, in an attempt to increase predictive understanding of phenomena”*. (Orlikowski and Baroudi, 1991) While this research does have predictive aspects to it in the sense that some results should be repeatable and predictable in the future, the focus of this research is to get a better understanding of what changes regarding ethical concerns and does not focus on improving the predictive ability of any theory as positivistic research often do. The positivistic world-view is popular in information system (IS) research, (Mingers, 1979) however the assumption that it is possible to describe the world objectively and without discussing the interpretive aspect of studying peoples ethical concerns will limit the kind of results this research is trying to provide. Following the paradigm of positivists would provide a limited insight into what ethical concerns there is in brain-computer interfaces (BCI) used in research compared to BCI used in consumer settings. Simply looking at the measurable aspects of BCI moving to consumer settings, would not gain insight into the more nuanced aspects of the ethical concerns and how the changes in the setting

are impacting the concerns. The research question is also more related to discovering how ethical concerns are experienced, or methods of dealing with them, than it is to measure to which extent certain ethical concerns are existent or part of the debate. Therefore, by taking the world-view of positivists would greatly limit the chance of finding answers to the research questions as any novel ethical concerns would be hard to discover by seeing the world as a positivist. While the problems of uncovering novel ethical concerns is the case for this specific research, it is worth noting that there is a lot of future and related work to be done where a positivistic paradigm would be useful to follow. To do so positivists should view this research as groundwork to determine ethical concerns that are existing in the two contexts. And this groundwork can then be used by positivists to investigate questions such as "To what extent is ethical concern X a valid concern for Y?". Such questions are important to ask and will give further insight into practical concerns such as "How many of our stakeholders are concerned about ethical concern X?". While this research does not take a positivistic stance to the world, the positivistic view can still be used to answer some of the questions this research will raise for further investigation. While a positivistic view on these questions could provide some interesting answers such as how many believe privacy is an ethical concern in research and consumer use. These results could then be used to discuss what the differences between ethical concerns in research and consumer use are, however as mentioned before this research seeks to discover how ethical concerns are experienced, which requires the research to interpret what ethical concerns could possibly be hidden behind statements, actions or answers to a survey. For this reason, a positivist view will not be employed in this research, however, a request for such research to be performed will be put forth in section 6.5. If a positivistic world view were to be adopted for this research it would be focusing on quantifiable attributes of the research question such as, how prominent different ethical concerns are in different stakeholder groups. Doing so would make questionnaires an interesting tool to evaluate the number of stakeholders which believe an ethical concern is present in the different settings they are situated in. It would also promote the usage for analytic methods such as statistical analysis.

### 3.2.2 Interpretive

The focus of the interpretive paradigm is to increase understanding by interpreting our shared understanding of the world. (Orlikowski & Baroudi 1991) In that way, interpretive research is influenced by a worldview that whether there is an objective world to study or not, it will be interpreted through the researcher. For this research to provide answers, the stakeholders must be able to provide insights into the topics related to BCI technology. The interpretive paradigm allows for this type of understanding to be explored and allows for concepts previously identified to be discussed with stakeholders. By doing so there is also a chance of finding novel ethical concerns or views on already identified ethical concerns by interpreting the ethical concerns brought up by stakeholders and by analysing their understanding of the

technology. Interpretive research will have the most chance of providing answers to the kind of questions this research tries to answer. By interpreting the different statements, actions or answers to some survey different stakeholders provide it will be possible to find new ethical concerns or viewpoints. By doing so it will be possible to answer the questions such as what ethical concerns are related to brain-computer interfaces (BCI) and whether any of these issues are specific to research or consumer settings. This is the case as by having an interpretive view will ensure that focus is brought upon interpreting why certain responses, actions or statements are made which could result in new understanding of which ethical concerns are there. Due to the nature of interpretive research, it will allow for a more comprehensive answering of questions like the type of questions raised in this research. These types of questions are concerned with the perception and understanding of BCIs moving from research to consumer settings rather than of measurable features of this transition. Therefore, this research will be undertaken within an interpretive paradigm; in the following section the paradigm of critical research will be explored and why the interpretive paradigm is the most appropriate even though part of the critical research paradigm could be applied.

### 3.2.3 Critical research

A critical research worldview focuses on critiquing the current state which could either be social structures, the perception of technology, or assumptions about the world in this case. (Orlikowski and Baroudi, 1991) Taking a critical research approach would require this research to take a stance towards a certain set of principles or beliefs. While the field of ethics is closely related to how and what should be done to create a more ethical world, this research will not be a critique of the current state. Providing a critique is not possible because there currently is a lack of understanding of what the current state is when it comes to the differences between the research and consumer settings. This research will describe the current situation and comment on whether the current situation requires actions, this research aims to understand the current situation rather than critique it. While this research will take elements of the critical research paradigm such as questioning current practices, the perception of brain-computer interfaces, and the methods currently used to be ethical. However the research should not be understood as if it were from the perspective of a critical research paradigm, as the main point of this research is not to critique a certain perspective, but to provide insight into the current state. The research will, however, attempt to create a change to the world through a better understanding of it and will be based on an interpretive approach, which suggests what further research could be done through the critical research paradigm to change the current state to be better. If a critical research approach were to be adopted, it would require that there was a reason to believe data could be collected to support the critique. Whether this is true is however not possible to know at the current state of research into differences between research and consumer

development of BCI. A critical research paradigm could, however, be useful once this research is complete to critique the findings this research will provide on what ethical concerns are related to brain-computer interfaces moving from research to consumer use and what is currently being done to handle these concerns.

### 3.1.4 Paradigm summary

In this section, three paradigms were discussed and how they would change this research. An interpretive paradigm was chosen as it would be the best way to answer the research questions. It is, however, noteworthy that both positivistic and critical research paradigms could be applied in further research to provide additional insights to the topic of BCI devices. Due to the lack of knowledge on this topic however, an interpretive probe into the subject seems most appropriate.

## 3.3 Research Design approaches

This section will discuss various research design approaches. These approaches include various methods of data collecting and analysis. This section will explore how this research would look using these research design approaches and what purpose they would fulfil. These are to be considered approaches that direct the research from start to finish and is, therefore, more than simply a data collection or analysis method. In some scenarios, these could also be considered data collection methods, however, in this section, they are to be considered a full research approach which is to guide the selection data collection and analysis method as it is layer 2 in the methodology overview.

### 3.3.1 Ethnographic

Ethnography is a systematic approach to learning about the social and cultural life of communities, institutions, and other settings. (LeCompte and Schensul, 2010) While it could be argued that this study is a study in the cultural differences between two settings, this study does not attempt to understand those cultures in a traditional ethnographic sense, but rather what those cultures think about certain ethical concerns. While some techniques and methods used in ethnographic studies would be applicable to this research, it would not help in answering the research questions regarding what happens to the ethical concerns in the two settings. It could be argued that to understand the ethical concerns it is needed to look at the cultural and social setting in which they are discussed; this goes beyond the scope of the research question as it is possible to discuss how the ethical concerns are perceived in the different settings without investigating the two settings cultural and social structures in the depth an ethnographic approach would require.



### 3.3.2 Case study

Doing case studies is the study of humans in a specific setting in the real world. (Gillham, 2010) Using case studies as a research approach is about studying the subject of research in the natural setting. A single case can be used for the study, or a study of several cases can be made. While it can be argued that this research would suit well for a case study due to the small number of research subjects available in the consumer developer setting (see more in section 3.6.1), it could make it hard to compare the two settings. Another problematic approach with a case study approach would be to select which companies and or researchers to focus on as some ethical concerns potentially could be missed if the selected case studies do not cover a large enough variety. Another concerning aspect of the case study approach would be to get a strong connection with the research subjects in either setting due to the location of most consumer brain-computer interface companies, which would require most data gathering to be done in digital media rather than physical interaction. The limited access would reduce the amount of data possible gathered in each case, which makes the case study approach less useful in answering the research questions.

### 3.3.3 Grounded theory

Grounded theory can in many ways be understood as both a research design approach and a set of methods used. The main point about grounded theory as a research approach is to create a theory from the material being investigated. So rather than applying theory to new material, the objective of a grounded theory approach is to come up with new theories that are supported by the empirical work. Much of the grounded theory methodology is about reiterating certain elements of the study such as the empirical data collection or the analysis of said material. While it could be interesting to create a theory regarding this research area, this research approach has not been chosen as the goal of producing theories on a very selective field has a high likelihood of providing either insufficient theories or theories not supported by the empirical data which would go against the idea of grounded theory. Grounded theory as a research design would also be working directly against the goal of generalisability mentioned in section 3.1.

### 3.3.4 Phenomenology

Phenomenology is the study of phenomena and specifically the human experience of said phenomena. The key aspects of phenomenology that this study will use is the focus on exploring the experience stakeholders have. By using this research approach, it ensures that the stakeholders' thoughts on the ethical concerns will be explored and described. More specifically, a phenomenology research design is a research approach that attempts to understand people's perceptions of a specific situation. (Gray, 2004, p. 21) In such sense, this research is following a phenomenology design approach as it is attempting to understand the perspective of both research and consumer stakeholders. Specifically, will this research focus on the experience of the ethical concerns of BCI devices be explored, whereby the phenomenon explored is BCI

devices in a consumer setting and a research setting. These differences in the phenomenon of BCI will be the core of what this research explores. This means that the data collection method chosen must be able to give insights into the experience of the developers of consumer BCI products and researchers working with BCI devices which will be explored in the following chapters.

### 3.4 Data collection methods

The following section, explains what data collection methods possible, how the study would have evolved if that method had been chosen, and why the used method is chosen. Specifically, the topics of literature search, questionnaires, experiments, observations and interviews will be discussed in terms of how they could be used in this research.

#### 3.4.1 Literature search

Using a literature search method could potentially have given insight into the perspective of brain-computer interface developers, however, the available text would be expected to be relatively low as that would require them to keep a blog or public forums from which literature could be collected. This overall seemed unfeasible as it would give very limited insight into their perspective. It is, however, a valid approach for exploring researchers' perspective, which is why a literature search was done to provide background and grounds of comparison. The literature search approach used in this research has been clarified in section 2.3.1 and what this method provided to the research in terms of background for interview questions.

#### 3.4.2 Questionnaire

Questionnaires could be used in this research to gain a large sample size of opinions of ethical concerns. This could possibly increase the chance of finding novel ethical concerns, however, the risk of using a questionnaire in this kind of investigation is that there is not the same general notion of key concepts. Making sure there is the same definition of a consumer BCI and what an ethical concern is will be hard, and even if a great effort is made to make sure of that, it is hard to evaluate whether that is the case based on the responses of a questionnaire. There is a risk of getting many responses which are generic and uninteresting as participants could be inclined to give the obvious answers such as privacy, without taking the time to find more unexpected responses. If a questionnaire were to be used, it would have to be a questionnaire with open-ended questions, and most questions would require respondents to fill in their own answers instead of selecting from a predetermined list of answers. (Walliman, 2010, p. 98) These questions should also be very open and without leading the stakeholders to make sure that the provided answers are not a result of how the question was asked. This, however, is in direct conflict with any efforts made to explain what is meant by consumer BCIs, and ethical concerns. If a questionnaire were to be used

it could be used to estimate which ethical concerns are most present in the mind of stakeholders or to quantify which ethical concerns are of the biggest concern by stakeholders. By presenting a questionnaire with various ethical concerns, and stakeholders are then asked to rate them. By doing so it will be possible to determine which ethical concerns stakeholders' rate as the most pressing. The benefit of using a questionnaire would be the ability to use the snowball effect and have initial contact persons spread the questionnaire to their company. The risk with this method, however, is the uncertainty of anyone engaging with this type of approach, as well as the loss of control in terms of who is filling out the questionnaire. The main issue with a questionnaire though is the lack of ability to follow up on answers. The inability to explain questions or to provide context for an identified ethical concern will be a major problem if there is no clear idea of what ethical concerns will be present in the setting. Therefore, due to the before mentioned problems with questionnaires, it does not seem to be the best approach to answering the questions set out for this research.

### 3.4.3 Experiments

Experiments are used to test variables in a given setting and could provide insights into how stakeholders interact with BCIs or how providers of consumer BCIs interact with the ethical concerns of BCI. (Walliman, 2010, p. 103) Experiments could be used to test how much ethical concerns are present when stakeholders are presented with the option of using consumer BCI. By asking stakeholders to use a BCI it could be interesting to evaluate whether any ethical concerns are enough of a presence to make them not want to participate in an experiment. This, however, wouldn't answer the question of which ethical concerns are present with the change from research to consumer BCI. It would also be hard to set up an experiment that evaluates a true consumer setting as it would be a research setting by default, so while it could be interesting using experiments to answer the research questions, it seems inefficient. The major concern about using experiments in this research is with external validity as it will be difficult to establish an experiment that truthfully would simulate a consumer setting or a setting like a real consumer setting. Therefore, the usage of experimental setups will only be to gain insight into how the technology works and to let interviewees or other stakeholders know what is meant by consumer BCIs. A way of making a BCI experiment would be through the help of consumer BCI developers. By having them participate in a consumer setting and by observing how users react to their products it would be in a consumer setting while making it possible to gather information about what ethical concerns mean for the potential end user. This, however, would most likely be an inefficient way of gathering this information as end users might not express what ethical concerns they have while participating in a consumer setting and in front of the developers of the product. Considering this research is also directed at stakeholders working in the

industry, it is to be expected that they are already familiar with the concept of a consumer BCI, so introducing them to the technology is less of an interesting consideration.

### 3.4.4 Observations

Observational data collection would be interesting as it could potentially provide insight into how stakeholders work in the consumer setting. The main problem for this research would be to gain access to obtain observational data. It could also be questioned whether observational data would reveal the depth at which ethical concerns are considered by stakeholders. While it could reveal interesting aspects of how stakeholders deal with ethical concerns that are brought up in the day to day business of developing a consumer BCI, it might not fully reveal ethical concerns that are an underlying knowledge in the developer which is not manifested in actions or discussions between developers. This adds a large amount of interpretation which could become a problem. If observational data would be combined with interviews or surveys, this could provide a unique view on the ethical concerns of consumer BCI developers, however, due to lack of access to both researchers and consumer stakeholders, this method of data collection will not be used.

### 3.4.5 Interviews

Interviews in an interpretivistic paradigm and phenomenology research design would be a good way to provide insights into the perspective of consumer BCI developers. Interviews whether structured, semi-structured, or unstructured would give the stakeholders the ability to clarify their positions and give personal accounts of how they perceive things. It would also provide the interviewer with the ability to clarify questions they might not completely understand. The problem of using interviews will be making sure that the interviews are analysed correctly, as the interpretation of the interviews could change depending on the coder, however this critique is rather a concern with the interpretivist approach, rather than with interviews as a data collection method. Another problem with interviews is reaching larger amounts of people, so getting a good representative of the stakeholder group investigated could become a problem in terms of the area to cover being too big. However, for a study in a rather small field of companies, the number of interviews should not prove to be a problem. Due to the multiple approaches interviews can be taken, it will be explained how structured, semi-structured or unstructured interviews would apply to the research.

#### 3.4.5.1 Structured

A structured interview would limit the data which could be gathered about the questions raised in this research. By having a set list of questions and order of questions (Gray, 2004, p. 215), the ability to investigate novel ethical concerns or aspects of commercialisation is greatly limited and therefore a structured interview wouldn't be the most fruitful way of investigating the questions. A structured

interview setup would limit the answering of research questions by removing the ability to ask follow-up questions. The questions would also be harder to construct as they would need to ensure the flow of the discussion, but also ensure that all aspects of the ethical concerns be covered. The benefit of using a structured interview would, however, be to ensure that the same questions would be put to all stakeholders and ensure that comparability between the interviewees was kept. The risk of missing novel ethical concerns outweighs the benefit of a structured interview in this case, as novel ethical concerns in a consumer and researcher settings are one of the key interests of this research and potentially diving deep into a specific concern could be the way to uncover interesting differences between the two settings.

### *3.4.5.2 Unstructured interviews*

Using an unstructured interview method would allow for interesting topics to be brought up, however, the unstructured format would also make it hard to ensure that all topics were covered, and the interview could be extended to a length which is unproductive, and some research questions might be left unanswered. (Gray, 2004, p. 217) Some would argue that this could be an indication that certain ethical concerns or certain aspects of the research are not of interest for the stakeholders. This, however, does not have to be the case as an unstructured interview quickly can delve into a topic and never get out of this topic to explore more meaningful concerns. The main concern regarding the use of an unstructured interview format would be the loss of direction and ensuring that a wide spread of ethical concerns is covered. Therefore, this interview format is not appropriate for this research study.

### *3.4.5.3 Semi-structured*

A semi-structured interview would allow for the benefits of a structured interview, however, would also allow for the novel ethical concerns to be explored if such concerns show themselves during the interview. (Gray, 2004, p. 215) By having a semi-structured interview form it will keep the comparability high between research and consumer setting stakeholders and any deviation from the planned questions could be a testimony of differences between the consumer stakeholders or researchers. Therefore, by having semi-structured interviews with different stakeholders it will be possible to answer the research questions. A semi-structured interview also has the benefit of being adaptive to exploring possible solutions to ethical concerns which is important to understanding the full aspects of the experience of ethical concerns. Due to these characteristics of semi-structured interviews, this data collection method was chosen. In the following chapter, will the analysis methods be discussed, specifically what the purpose of the analysis method is, and whether an inductive or deductive approach will be applied.

### 3.5 Analysis methods

This chapter will describe the purpose of the analysis and what type of purposes various analysis methods have and how they would direct this research. Following this, a section on the different impacts an inductive or deductive analysis method would have on this research and what is best suited for being used in this research.

#### 3.5.1 Purpose

The purpose of the analysis method chosen is to enrich the interview data in such a way that they can be used to answer the research questions. Various methods could be used to do so, methods such as creating a narrative of the experience, breaking the content into themes, describing how the data fits into a theory or using a hermeneutic circle to compare individual pieces to the context. The main purpose of this research is to analyse the differences and similarities of the experience of ethical concerns between two settings. While the AREA framework can be used to enrich the interview data and provide context on the different approaches to ethical concerns in the two settings, simply looking at the 4 perspectives of the AREA framework does not provide a detailed enough picture of the two settings to allow for a comparison between the settings to create theories that afterwards can be tested in other settings. Analysing the interviews using the AREA framework would be considered content analysis, which expands on the understanding of the two settings. To further enrich the data each perspective of the AREA framework needs to be analysed into themes so that for example actions that were taken towards a certain concern can be compared rather than actions in general. A strict analysis method could be applied such as using grounded theory analysis methods or a strict hermeneutic circle could be used to ensure the material was worked thoroughly and systematically. However, for this research, the methods applied are already well described, iterative and repeatable so applying a specific analysis method does not appear to add value. It is, however, important to describe how the methods applied are used and whether the applied methods are inductive or deductive in nature as it will influence what type of findings will be found to answer the research questions.

#### 3.5.2 Inductive and deductive

This research will be using both inductive and deductive analysis methods. The deductive methods will be used to apply the AREA framework (See section 2.2, 0, and 5.2.2) to the interviews and investigating whether the AREA framework can be used to explain some of the aspects of the experience of ethical concerns in the two settings. While the expectations are that this will be the case, the framework does not directly explore the themes that might appear within the different aspects explored in the AREA framework such as action and engagement. To explore what type of actions are conducted or what kind of ethical concerns are anticipated by different stakeholders, an inductive analysis will be done to let these themes

emerge from the interview data. This will allow the themes to be derived from the data rather than attempting to apply themes based on an existing framework, as there could be ethical concerns in a novel technology or setting, that have not yet been described in existing frameworks. This is done by first classifying interviews based on the AREA framework via NVivo, and then organising them into themes through the analysis of coded citations (See chapter 4).

### 3.6 Data collection description

In the following chapter the method of collecting data will be described, this will be a description of the practical steps taken as well as the reasoning for decisions made during the data collection process. Overall, the sections will deal with the topic of selecting interviewees, selecting interview questions as well as the process of ethical approval.

#### 3.6.1 Selection of interviewee

Before selecting interviewees an understanding of the consumer market needed to be created, this was done by first doing a search for consumer BCI products. This provided an initial list of companies that were providing consumer products, which were products that were intended for consumers to buy, and with a price that seemed appropriate for a non-medical device. Following this initial search the Wikipedia page for consumer BCI was discovered which had a list of consumer BCI products and their differences. (*Consumer brain-computer\_interfaces*, 2016) This supplied additional companies to the list of interesting interviewee targets. At this stage, some of the already discovered literature were consulted as some researchers had provided comparisons on the technical aspects of consumer devices, which provided additional companies identified. At this point, the list was made public in a forum for BCI interested stakeholders on Facebook, which were asked if there were any companies to supply to the list already formed, which resulted in no new additions to the list. At this point, the initial list of interesting companies was set. This list, however, was narrowed down by according to the following: Firstly, any company that was no longer operational were removed from the list as contact with these companies were unlikely to produce any responses given that there were no official ways of contacting them. Additionally, a few companies were removed as their product was not intended for consumers but were directed towards universities or institutions wanting to showcase BCI technology. All remaining companies (a total of 10) were contacted either through email, phone, contact form or all the options mentioned. After the initial invite 5 companies responded, however through months of trying to set up an interview only 3 interviews were successfully completed. To increase the number of interviewees a snowball effect was attempted as well, however, this did not result in any additional interviews. To further increase the interview, count an participation in a workshop followed by a conference in Israel, resulted in 4 additional companies and interviewees being identified, however, only 3 ended up proceeding with the interview process, which ended the total number of interviews at 6. These

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companies were of a wide spread of nature and include some of the big companies in the consumer BCI field, as well as small companies, and companies that are planning to but have yet to enter the industry of consumer BCI devices.

Following this process, members of the BCI research community were identified for interviews. These stakeholders were identified via google scholar alerts to identify research stakeholders engaging with consumer devices. This was done to ensure that the researchers interviewed were familiar with the kind of devices considered consumer devices for this research. The rules used for the scholar alerts were the combination of known consumer BCI devices (MUSE, Neurosky, Myndplay, Kokoon, Emotive) and the term BCI. While other BCI devices could have been used, these companies were identified as the companies that were still available, which would increase the availability of the devices as it must be assumed that devices that are currently being sold and developed would be the ones used by consumers. The alerts from were then processed to make sure the articles referenced did, in fact, consist of articles that mentioned working with consumer BCI devices, therefore only alerts that allowed full access to the article were considered. The 37 in total researchers identified were then contacted by email resulting in a total of 7 interviews with researchers ranging from senior professors to bachelor students. One interview included a senior professor as well as one of the professors' students that had done a project on consumer BCI devices. Overall the spread of interviewees was very well as it includes most major regions of the world except Asia, which proved to be difficult to setup interviews with. A number of interviews also fell through after contact had initially been set up and agreed upon. Specifically, an Australian interviewee and a UK senior researcher never managed to be part of the research due to no responses to attempts of contact. While these could have been useful to the study, the interviewees used in the study is of a good range of backgrounds. As seen by the table below, consumer stakeholders included various regions as well as various stages of BCI development. The companies these interviewees were employed by also ranged from very small companies to bigger companies in the consumer BCI scene. While 13 interviewees are not a significant number to make broad theories about all BCI developer stakeholders, it will be sufficient to gain insights into the usage of the AREA framework, as well as enriching the current data currently developed on ethical concerns on consumer BCI devices in both research and consumer settings. It was also found that during the interviews, many of the interviewees started to repeat what has already been found in previous interviews, which shows that some level of saturation of the data was met.



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Table 3: Interviewee table

Reference	Expertise/title	Region	Notes
Consumer 1	CEO- Therapy background	Europe	Has consumer products on the market
Consumer 2	Team Leader - Physiology researcher	(North America)	Has consumer products on the market
Consumer 3	Sales/Marketing - Hardware Engineer	(North America)	Has consumer products on the market
Consumer 4	CEO - Microbiology	Middle east	Has research/medical device on the market – planning on expanding to consumer markets
Consumer 5	Developer - Neuro-psychologist	Middle east	Has no product on the market but previously looked at expanding into BCI market but decided not to do so
Consumer 6	Researcher – Computer science and neuroscience	Middle East	Working on deploying research into consumer products
Researcher 1	Senior Researcher – Human-Computer Interaction	Europe	Goal is to provide smooth and efficient user experience
Researcher 2	Researcher – Human-Computer interaction	North America	Just finished a PhD on BCI – Wanted to add to the psychology side of BCI research as most of it was technical
Researcher 3	Bachelor Student – Human-computer interaction	Europe	Tested the usage of BCI without prior experience and training
Researcher 4	Researcher – Industrial Engineer/Human-Computer Interaction	Europe	Brought one of his master’s students to the interview as the student had done a BCI project
Researcher 5	Researcher – Bioinformatics	Europe	Has a master’s degree in biomedical engineering and is focusing on designing a commercial BCI to move a robotic arm
Researcher 6	Researcher – Electronical Engineering	South America	Has a bachelor’s degree - Worked on a project to create a BCI movable arm to help people take their medicine
Researcher 7	Masters Student – Informatics	Europe	Worked on a BCI project to create a BCI alphabet which were better suited for BCI communication

### 3.6.2 Interview questions

To make sure that interviewees had an opportunity to respond to all the ethical concerns identified in the literature the interview questions were structured using this analysis. While not all ethical concerns in specificity were asked to avoid the interviews getting too long, the major concepts were added as questions. What this means is that the topic of policy concerns will be explored, whereas the specifics such as liability concerns within policy concerns will not. Overall the questions were made as open as possible, but some of these had to be exemplified to the interviewees to give them context. While this might drive the discussion in a certain direction when possible the examples and directions were the same throughout all the interviews. The topics chosen were: Accessibility/digital divide, accuracy/misinterpretation, autonomy/informed consent, enhancement, identity, policy gaps/legal concerns, privacy, public

perception, security, side effects, societal. While some concerns were asked directly, such as the privacy concern, some were put into a context of a consumer product such as societal concerns which were intended to be part of the initial question “What do you hope your users will use your BCI for?”, which were followed up by the question of “Through history we have seen technology be used in ways that weren’t intended for example as what happened with the internet, is there any such use of your BCI that you might have concerns about?” which were an opportunity to uncover whether they saw any potential societal changes or misuse of their products they worried about. The structure of the questions was laid out in a way that offered an easy transition between the topics such as the question of accuracy and misinformation leading into public perception which naturally relates to each other as misinformation or inaccurate data can lead to changes in the public perception of the technology. Throughout the interviews, the structure of the questions proved to be effective and the flow of the interviews felt natural with minor overlaps between the topics. Some interviewees managed to answer questions to other topics when answering initial questions, in such cases, the topics were not brought up again to avoid the interviewees repeating themselves. The question of security and privacy could possibly have been separated in terms of when they were asked, as it proved to be hard to make the interviewees understand the security question as something else than a question regarding privacy concerns. It could potentially have been improved by asking the security question after the question of side effects which would have made the question of security to avoid physical harm easier to understand as it was discussed in the literature. The risk of making the questions based on the major topics of the literature rather than all specific topics discussed is that specific details or topics get lost and not discussed in the interviews. This meant that topics such as militarization or incidental findings were not discussed as the topics were not largely discussed in the literature and were considered as specific concerns in bigger overall topics.

### 3.6.3 Ethical approval

Ethical approval for the research aims and methods were done through the DMU ethics board. For approval the ethics form was completed that describes the research aim and methods, as well as procedures prepared for potential concerns. Following this, the ethics board were given a copy of the information/invitation letter as well as the consent form provided to participants. It was important to ensure that anyone participating in the study was informed about the aims of the research as well as the procedures used. It was specifically important to make sure they knew they had the ability to withdraw at any time before anonymisation of the data had been completed and that no identifying information would be published as well. This was to ensure that they could speak openly about the concerns or problem they have about the industry or the company they work for. Ethics approval was lastly given on the 18/05/2018 and amendments were made throughout when the information/invitation letter was changed to

accommodate the recruitment at workshops/conferences. The consent form and other procedures were kept the same throughout the research study.

### 3.7 Process of the research

Having described the decision process for the methodical approach, a short summary of the process undertaken will be described in this section. The research started with a literature review to gain an initial understanding of the project and the current state of knowledge on the topics related to the research question. This literature research was then directly used to form the interview questions so that the results could later be compared to the literature. Before initiating the full invitation to interviews, ethical review was granted, and a small pilot study with an interview of a commercial stakeholder. This interview confirmed the direction to focus on consumer grade products as the interview showed a large overlap between the commercial stakeholder and the ideas presented in the literature suggesting a strong tie between the research community and commercial stakeholders working closely with medical staff and researchers. This strong connection could be subject of further research to determine how general this kind of connection is present and to what extent. Following the pilot study, the full set of interviews were performed and analysed using the AREA framework. The interviews were transcribed by Christian Hansen, the transcribing method were not verbose and focused mainly on the meaning of what was said, rather than every sigh and pause by the interviewees. This decision was made by the pilot study which were transcribed more verbose, but without providing additional insights to the interview. The pilot study was also analysed using a slightly different coding set, however it was not very useful to answer the research setting, which were also why the AREA framework were chosen for the full study. The AREA framework was initially applied through NVivo, and then further categorised based on the themes discussed. The results of the analysis were then (in chapter 5 and 6) compared to the literature found in the literature review and discussed to further enrich the findings. This was done to relate the findings to the current literature, but also to confirm that novel findings were made.

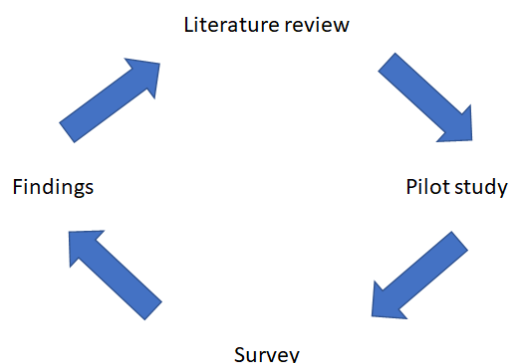


Figure 1: Visualisation of process

## 4 Reflections and analysis of stakeholder comments

In this analysis, the starting point will be the references coded with Acting as this gives insight into what consumer stakeholders or research stakeholders have done. This will also provide insights into differences in the context the two stakeholders exist in. This will be followed by the analysis of engagement as this will provide further insight into the context of the stakeholder by giving insight into who they are engaging with, and how they are engaging with them. This will be followed by an analysis of reflections, which will provide insight into how stakeholders reflect upon concerns and finally an analysis of anticipations will be made providing insights into whether they anticipate a topic to be of concern or not. Each analysis will start with a comparison of each stakeholder group, followed by a description of differences and similarities between the two stakeholder groups in details. Before moving into the deeper analysis of the stakeholder comments, a small overview of the coding will be discussed.

### 4.1 Analysis overview

While this study is not following a quantitative methodology a short look at the numbers can improve the initial understanding of the data set which will be done before a deeper analysis of quotes will be done. This overview is in no way a statistical analysis of the meta data but is purely done to provide some description of the data being worked with. As mentioned in section 3.6.1, the data consist of 13 interviews of which 6 are commercial stakeholders and 7 are researchers. The commercial stakeholders are of various positions ranging from CEOs and founders to hardware engineers. The research stakeholders range from established professors to bachelor students, however all of them have recently had academic work published in which commercial BCI products have been used or mentioned. After transcription the commercial interviews consist of 35.105 (47,63%) words whereas the transcripts of research stakeholders consist of 38.595 (52,37%) words which gives an average word count of 5851 and 5514 words respectively. Throughout coding a total of 606 references were made using 4 codes of Anticipation, Reflection, Engagement, and Acting. Anticipation were coded a total of 331 times equivalent of 54,62%. Reflection were coded a total of 144 times, resulting in 23,76% of references. Engagement were coded 48 times, resulting in 7,92% of references. Finally Acting were coded a total of 83 times and of such 13,70% of references were coded Acting.

Anticipation	%	Reflection	%	Engagement	%	Acting	%
331	54,62	144	23,76	48	7,92	83	13,70

Looking at research and commercial stakeholders separately it shows that many anticipation references are from research interviews and many of the engagement and acting references are from commercial

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stakeholders. Reflection references appear to be evenly distributed between commercial stakeholders and research stakeholders.

	<b>Anticipation</b>	<b>% of all</b>	<b>Reflection</b>	<b>% of all</b>	<b>Engagement</b>	<b>% of all</b>	<b>Acting</b>	<b>% of all</b>
Average Employees Total	21,17	6,39	12,50	8,68	4,83	10,07	8,50	10,24
Average Employees Total	127	38,37	75	52,08	29	60,42	51	61,45
Average Researchers Total	29,14	8,80	9,86	6,85	2,71	5,65	4,57	5,51
Average Researchers Total	204	61,63	69	47,92	19	39,58	32	38,55

While the data is not statistically representative of the population of neither research stakeholders or commercial stakeholders, it is interesting as it gives a picture of the research data available. It indicates that the research data might show more references of commercial stakeholders describing their actions to deal with ethical concerns whereas researchers appear to be more inclined to make anticipatory statements regarding ethical concerns. The fact that more engagement statements were made by commercial stakeholders is also interesting to take note of. It is important here to note that while there is a difference between the amount of references coded to different nodes, both stakeholder groups provided statements to all codes, and that these tables are not to be used to draw any conclusions about either stakeholder groups due to the small sample size, and the issue of having only gone through 1 coding iteration with 1 encoder. For this to be useful in any statistical sense, more stakeholders would be required, and more than 1 coder and coding iterations would have to be employed. What these numbers does provide though, is a sense of the coding results and what will be discussed in the following sections of this chapter.

### 4.2 Action comments

This section the comments that show stakeholders taking actions towards ethical concerns will be described. These actions will describe what stakeholders have done to eliminate or reduce the consequences of ethical concerns identified by stakeholders. The section will also include comments suggesting that stakeholders decided to not take any actions.

#### 4.2.1 Action overview

In this section will the overall summary of the section be described. The themes identified in the sections below will be put into a table to improve the overview of the actions described by stakeholders. The further discussion of what these findings mean will be described in chapter 5.

Table 4: Action overview

<b>Consumer stakeholders</b>	<b>Research stakeholders</b>
<p><b>Perform experiments</b> Consumer stakeholders perform experiments to improve systems and discover new use cases.</p>	<p><b>Create new systems</b> Researchers try to create new systems to improve the usability of the products already developed, or to fit a specific use case the researcher has.</p>
<p><b>Change materials</b> Materials were changed to ensure no side effects and this process can go through iterations fast.</p>	
<p><b>Software development</b> Software development was done to increase usability and find new use cases.</p>	
<p><b>Customer experience</b> Overall the focus on customer experience was actions taken to make the devices easier to use, the data more accurate and the data understandable for the users.</p>	<p><b>Handle data accuracy</b> Making sure data accuracy was kept high and misinterpretations were kept low was used as justification for taking actions.</p>
<p><b>Follow policy/guidelines</b> Policies and guidelines are largely used as justification for actions taken.</p>	<p><b>Gather consent</b> Researchers gathered consent depending on the settings they were in. Some universities had policies about which settings their researchers should engage in.</p>
<p><b>Privacy enhancement</b> Following guidelines and introducing encryptions were actions taken to ensure privacy.</p>	<p><b>Ensure privacy</b> Only two comments were made, which both mentioned that the technical solutions did not store brain readings.</p>
<p><b>Improving life</b> Improving the life of humans were used as a justification for taking actions.</p>	<p><b>Improve people's lives</b> Actions were taken to improve peoples' lives by increasing their autonomy.</p>
<p><b>Transparency</b> Actions were taken to ensure that companies were perceived as transparent. Either through marketing or through implementing data rights for consumers.</p>	

Overall researchers and consumers engage in some of the same actions but with different justifications. A good example of these different justifications is developing the BCI devices which in researcher settings often revolve around a specific use case already identified, consumer stakeholders though try to develop their systems to discover new use cases that can be used as justification for consumers to buy their product. What this analysis of the actions show, is that consumer stakeholders both perform experiments, change materials and do software development. Similarly does research stakeholders try to create new systems for BCI usage either by modifying existing systems or by using them in new use cases. While both

## Reflections and analysis of stakeholder comments

groups of stakeholders were taking actions to handle data accuracy, consumer stakeholders were more focused on improving the user experience when dealing with data accuracy where research stakeholders were more concerned with the data accuracy itself. Data accuracy is one of the areas where the difference of context shows between the two settings, as consumer stakeholders are in a setting where making the devices easy to use takes priority over the data accuracy which is crucial in a research setting. On the topic of privacy enhancement actions taken these difference were also shown as only a few mentioning's were made by research stakeholders on steps taken to ensure privacy whereas consumer stakeholders were keen to express some of the steps they had taken to ensure privacy for their users. On the topic of improving lives a minor difference were also found, as research stakeholders specifically mentioned using BCI as an action to improve the autonomy for people who had no other way of enacting their will upon their surroundings whereas commercial stakeholders more in general using the act of improving people's lives as a reasoning for taking specific actions. Lastly, consumer stakeholders also mentioned taking specific actions to improve the transparency of the technology. This was something research stakeholders did not specifically mentioned, which shows that consumer stakeholders had to take specific actions to try and be seen as trustworthy by consumers.

### 4.2.2 Consumer Stakeholders

Consumer stakeholders' comments on actions they have taken, ranging from performing experiments and doing research to creating non-profit entities to deal with ethical concerns regarding BCI devices. In this section will these comments be analysed.

#### 4.2.2.1 Perform experiments/research

These experiments are used to improve BCI technology and to reduce the negative consequences of BCI technology. That consumer stakeholders are performing experiments is shown in comments as seen below:

*"You know we did an experiment, a commercial experiment, a paid for commercial experiment, for a company called [COMPANY] that makes soap."*  
(Consumer 1 - Founder/CEO, October 2016)

The type of research they do appears to be research that can help them improve the product they are developing. For example, some companies are doing research to reduce skin irritation, whereas others are experimenting with ways to use their product in "out of office/lab" situations. What they are doing with the research data is either to publish papers themselves or work with researchers to publish papers, as shown by the following reference:

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*“We have published papers that have used our technology to work out it's efficacy. We test everything thoroughly, but most importantly we are completely honest in the fact that technology has limitations.*

*Accept it, but be grateful for it's progress so far”*

(Consumer 1 - Founder/CEO, October 2016)

A reason for publishing research is to get peer-reviewed confirmation of the products they are making. Stakeholders wanting peer-reviewed confirmation is shown in the following quote:

*“And I think, we, we have an opportunity to lead by setting the tone and, you know if enough people see what we are doing, and see that it's backed by real peer-reviewed science. And use the device and have a positive experience and find that it works.”*

(Consumer 2 - Chief Scientist, November 2016)

The comments in this section show that consumer stakeholders perform research to improve BCI technology. The research leads to changes made to the technology, and some of these actions to change the devices will be described in the following sections.

### 4.2.2.2 *Change material*

As described in the first quotes about doing research, actions have been taken into finding out what materials the products should be using. Actions taken is something we see in multiple quotes as something stakeholders have taken actions to work on.

*“once we looked into it, I mean we definitely thought, oh man, we should definitely follow the medical standard. And when we thought that there was a stainless steel that for a medical grade, or like oh we definitely should use this, and that's how I think we went through it.”*

(Consumer 3 - Technical sales, November 2016)

What they also showed is that once a solution is found to a problem, the solution can be implemented quickly. One consumer stakeholder mentions that once a problematic material has been identified, it could be changed within a product cycle. While a product cycle does not have a specified length, it is safe to assume that the ability to act upon new data is present for consumer stakeholders.

*“And then you change your manufacturing practices or you change your software of whatever that you need to change. Very quickly and you can improve that in a single product cycle.”*

(Consumer 2 - Chief Scientist, November 2016)



Another way consumer stakeholders mention they change their products is by developing software that accompanies the hardware they use.

#### 4.2.2.3 *Software development*

Overall there were a few comments mentioning software development, and what is common for some of them is the direction they have taken their software development. For example, some of the consumer stakeholders has mentioned that they targeted their software to a specific group of users. These group of users range from psychiatrists, polygraph users, and games for anger management training.

*“Yes, and specific applications that we could approach, like mobile app for people with depression, so, for now, we did not develop it as a mobile app, but a research tool for psychiatrist.”*

(Consumer 4 - CEO, April 2017)

One interesting reference from consumer stakeholders was the software direction they were taking to give users more meaningful data. Specifically, they were noticing that people were getting attached to numbers and scores and changed their development direction, so numbers were hidden, to change user behaviour.

*“So we have been gradually walking our users away from numbers, and towards self-reflection.”*

(Consumer 2 - Chief Scientist, November 2016)

Overall this section and the section on material change shows that consumer stakeholders are willing to change the materials used to reduce the concerns. The changes made to materials and software mainly serve the purpose of increasing the usability of the technology. This is also the most frequent action commented on by consumer stakeholders, which is the topic of improving customer experience.

#### 4.2.2.4 *Customer experience improvement*

Consumer stakeholders talk about taking actions to improve customer experience, these improvements range from improving the accuracy of the data provided or the ability for users to understand the feedback that is given to them, to providing additional support for users that are not technically savvy.

*“People who are 30 it's very intuitive for them, all the technical aspects, and people who are 60, they have to get a lot of assistance until they are able to apply the systems in their clinics, so I think the point is, how are you going to help people who have a hard time learning.”*

(Consumer 5 - Neuropsychologist, April 2017)

## Reflections and analysis of stakeholder comments

What appears to be a common theme when consumer stakeholders talk about improving usability in the quotes above is making things simple and easy to use, and that different users might require different usability improvements, which the following quotes show further:

*“The big problem I guess supposing consumer EEG is that we, we have done a lot of user experience work to develop a means of having a naive user put an EEG system on their head and figure out how to get the right connection and the right signal.”*

(Consumer 2 - Chief Scientist, November 2016)

*“So what we are going to do is using machine learning, AI, and basically advanced modelling we will be producing very very simple output, very simple readable output, from the sophisticated data that we extract.”*

(Consumer 6 - Academic commercialising, May 2017)

These comments from consumer stakeholders indicate that the technology is complicated to use, and the data generated with BCIs are complicated to analyse and understand. The solution to these problems appears to be using artificial intelligence and technical analysis as shown by the reference above and the following reference:

*“We did actually look at [critical INAUDIBLE] analysis very objectively of measuring strength.”*

(Consumer 3 - Technical sales, November 2016)

It is also interesting that this approach to one consumer stakeholder is no different than what is going on in other technologies according to consumer stakeholder 6:

*“So that's the key in doing the statistics correctly, what's called validation, model selection, and deduction. That has to be, there are various tools for doing that, and there is nothing different when looking at data coming from the brain. For the same purpose.”*

(Consumer 6 - Academic commercialising, May 2017)

The method of making sure the steps taken have improved the user experience is using user feedback and have ways for people to provide feedback.

## Reflections and analysis of stakeholder comments

*“We also see that after we launch a product, we get a lot of feedback from users, we prioritize the feedback, and we try to implement some of the requests.”*

(Consumer 5 - Neuropsychologist, April 2017)

What is clear from the way user feedback is used, is that not all feature requests are being implemented in the products. One consumer stakeholder did however also say that all the software they developed were software requested by users. This consumer stakeholder did also point out that not every single feature request could be implemented.

*“And actually every thing, every piece of software that we've build, has been something that somebody has asked for. But it's like I said, you have to be selective, because otherwise you spend all your time doing that, and you don't actually sell anything.”*

(Consumer 1 - Founder/CEO, October 2016)

One reason for not implementing all the requested features is hinted at by one stakeholder, by saying that not all requests were useful:

*“So we did all of that, where it was actually useful”*

(Consumer 1 - Founder/CEO, October 2016)

What is interesting about this statement is that user requests mentioned by the stakeholder as useful were things like optimising their app-store with most used apps, and not features such as making the product available in different colours. Some consumer stakeholders not only took feedback from consumers on ways to improve their practices and products, one consumer stakeholder anticipated ethical concerns to be something they needed to proactively engage in, and formed a non-profit organisation for other stakeholders to work together in.

*“The one of the ways we have worked around this. We have anticipated as a challenge, so we created something called the [NAME OF INITIATIVE], which is a non-profit entity, with a bunch of members of the industry.”*

(Consumer 2 - Chief Scientist, November 2016)

## Reflections and analysis of stakeholder comments

The goal for this consumer stakeholder was to make sure they acted upon the challenges that might appear for BCIs and to set an example for other consumer stakeholders in the practices of developing consumer BCIS.

*“And we try to set up best practices, so we have some philosophers from the University of [CITY] who are [INAUDIBLE], you know, they concern themselves with ethical concerns around privacy among others.”*

(Consumer 2 - Chief Scientist, November 2016)

While this shows that some consumer stakeholders are willing to take BCI development in a certain direction, other stakeholders appear to be more willing to just following the rules. This shows that while some actions will be taken by consumer stakeholders to improve the technology, it is important for some stakeholders to take actions that the rules force them to do so.

### 4.2.2.5 Follow policy/guidelines/law

Not unsurprisingly none of them say they had concerns about their practices being illegal or problematic when it comes to following policy and guidelines. One of the consumer stakeholders even suggested that they obviously “played by the rules”.

*“Obviously when we do any medical research we get informed consent, and if you are not able to get there are ways to approach [diabiant to get release one] informed consent, so this is obviously something we. We play by the rules.”*

(Consumer 4 - CEO, April 2017)

It was also clear that while consumer stakeholders weren't always referring to the same guidelines, which could be explained by different contexts, most referred to existing guidelines which BCIs could be used under.

*“When it is converted to medical information and medical conclusions [INAUDIBLE] then suddenly this consumer data becomes to be falling, or maybe not now, but we believe that it should be changed, to be falling under the medical regulations of data privacy etc etc and we are taking this approach already.”*

(Consumer 6 - Academic commercialising, May 2017)

What the quote above and the following quote also shows, is that consumer developers in many cases treat BCIs as a medical device even though most companies did not consider the application of their product to be for a medical purpose.

## Reflections and analysis of stakeholder comments

*“So we are taking the approach of starting and validating our device, really in the medical market where, the regulation, the conditions are, the requirements are much much higher.”*

(Consumer 6 - Academic commercialising, May 2017)

The statement above can either be a precautionary approach to BCI development, or an attempt at increasing the potential market for where the product can be used. The application of standards appears to cover topics such as material choices as well as data handling, as is shown in the following statement.

*“once we looked into it, I mean we definitely thought, oh man, we should definitely follow the medical standard. And when we thought that there was a stainless steel that for a medical grade, or like oh we definitely should use this, and that's how I think we went through it.”*

(Consumer 3 - Technical sales, November 2016)

In general, the consumer stakeholders want to ensure that they are following the rules, and the comments in this section show that their actions are guided by the rules that are present. Some even use the anticipation of rules to guide their actions which shows that rules are a key driver to some of the actions taken by consumer stakeholders. The last statement above also indicates that there for some stakeholders appear to be a desire, to be honest with customers and ensuring consent.

### 4.2.2.6 Transparency

From the consumer stakeholder references, it appears that there is a concern about spreading false information about the possibilities of BCIs (overpromising) and the fear of consumers not understanding what the product can do. Concerns for the spreading of false information is shown in some of the quotes for example the one below:

*“The claims that we are making are really just, with our technology are just that we, we will help you learn how to meditate and help you to build a habit and build motivation to do it.”*

(Consumer 2 - Chief Scientist, November 2016)

What these two quotes seem to indicate is that the consumer stakeholders had been faced with the problem of having to explain what their product was doing and ensuring that they weren't doing something else. During the pre-interview research, it was noticed that one stakeholder had a certain phrase on their website which indicated that they were trying to make sure that no one could mistake their device for a mind-reading device, and this was brought up to the stakeholder in the interview which confirmed this:

*“I thought that was interesting that you made that distinction. I sensed that this was sort of trying to combat this public awareness and how people are perceiving BCIs as you know, thought reading. E: Yeah,*

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*that is correct.”*

(Consumer 3 - Technical sales, November 2016)

The quote above is interesting because it was a direct action taken towards a concern that other developers had faced as well and indicated that at least in some situation's consumer developers were interested in taking actions. One stakeholder also wanted to emphasise that they were not developing a polygraph which is another use case that has been made problematic in the research literature.

*“we sometimes emphasise that it is not polygraph, but it is something to help improve wellness.*

*The other thing that we do, is participant centric consent, based on the safe bionetworks model, where we ensure that users know that they own their data. “*

(Consumer 5 - Neuropsychologist, April 2017)

This stakeholder also mentioned that they made sure users were aware that the data provided by the BCI was their own. This appears to be an additional step taken which is not required by policy. Other stakeholders, however, appeared to be more focused on following policies when it came to informed consent as per the following statement:

*“Obviously when we do any medical research we get informed consent, and if you are not able to get there are ways to approach [diabiant to get release one] informed consent, so this is obviously something we. We play by the rules.”*

(Consumer 4 - CEO, April 2017)

While one stakeholder reference mentioned having users owning their own data, another reference talks about making sure stakeholders knew their data would be shared in a responsible way.

*“You have to be responsible about it, so we have sort of two layers of data sharing.”*

(Consumer 2 - Chief Scientist, November 2016)

The same stakeholder also made a comment about the reasons as to why they decided to share data in the first place which was to find new applications for BCI data:

*“And we did that very intentionally because we wanted lots of people to use it for lots of different applications, and push and see where it went and.”*

(Consumer 2 - Chief Scientist, November 2016)

Sharing data and working with external partners appears to be a common theme for consumer stakeholders as seen by the following statement as well as the previous statements about data sharing:

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*“So that in a sense is the challenge that, we have tried to address by partnering with [ORGANISATION] to help them. And they have actually developed some courses on you know, how to interpret a BCI.”*

(Consumer 2 - Chief Scientist, November 2016)

While the previous statements talk about partnering with people for gains that appear to be directly related to the consumer (developing new apps or use cases, or building courses to help people interpret BCI data), some partner with others to gain other benefits such as legal advice or to gain scientific credibility:

*“And, I think, scientific credibility is who you are working with and what they are doing with your technology. And what, developers can do, and who the developers are, and what, you know. So there are a variety of, there are a variety of ways we are addressing this.”*

(Consumer 2 - Chief Scientist, November 2016)

These statements from consumer stakeholders indicate that partnerships can both be an addition for customers that want improved products as well as security for the companies. This section has shown that consumer stakeholders are interested in being perceived as being transparent and have taken some actions to be more transparent with their users. Some of these actions are directly informing users of their data rights and others are making their marketing clear on what type of technology they are providing.

### 4.2.2.7 Privacy enhancement

When talking about privacy enhancement actions there were two ways of dealing with privacy concerns. Two different policies or guidelines were suggested for dealing with BCI data and two different technical solutions were suggested.

*“Obviously and we take the measures that are accepted in the industry, which means the HIPAA compliance for mobile app, and this [INAUDIBLE] that we collect.”*

(Consumer 4 - CEO, April 2017)

The quote above shows that BCI data was collected and handled so that it was in compliance with the HIPAA (Health Insurance Portability and Accountability Act) regulations. Being in compliance with HIPAA means having taken measures towards various aspects of data security. It however also shows that the stakeholder classifies the data collected from a BCI as health data. The following quote considers that the data from BCI should not be covered by medical regulations, however, that if the data were used in certain ways, the classification should change.

## Reflections and analysis of stakeholder comments

*“When it is converted to medical information and medical conclusions [INAUDIBLE] then suddenly this consumer data becomes to be falling, or maybe not now, but we believe that it should be changed, to be falling under the medical regulations of data privacy etc etc and we are taking this approach already.”*

(Consumer 6 - Academic commercialising, May 2017)

The quote above shows that it could be a potential problem for consumer stakeholders to classify BCI data depending on the usage. The consumer stakeholders mentioned two technical solutions to privacy concerns one being encryption of data and the other being obfuscation of data.

*“So we do, we are concerned with it, and we take certain steps in order to keep the privacy you know like encryption of the data and this is something that does concern us.”*

(Consumer 5 - Neuropsychologist, April 2017)

*“So that those are the things that are probably named, but then all the other information like name, those are obscured by putting some ID numbers, that people can, that's already done with all of the internet technology. So, I think we use [INAUDIBLE] security systems that we have, simply where other, other security systems. We can use those actually help keep it, security for the identity of the people.”*

(Consumer 3 - Technical sales, November 2016)

Both references above indicate that the technical solutions applied were the same solutions applied to other data. Consumer stakeholders have shown in this section that they have taken actions to improve the privacy of the data collected on their users. These actions were following policies and guidelines to privacy enhancement, and technical solutions such as encryption.

### 4.2.2.8 *Improving life*

Finally, some consumer stakeholder references mention ways they try to improve people's lives in various ways. One stakeholder was talking about how they work with people having disabilities and trying to solve different problems for them.

*“And if we can do that with a consumer product, so from their perspective they will be playing a computer game or any other game. But at the same time we should be enhancing their brain, then we catch two birds, in one hand.”*

(Consumer 6 - Academic commercialising, May 2017)

The above quote however also shows the double focus of a consumer stakeholder creating a consumer product, and secondly improving brain performance.



## Reflections and analysis of stakeholder comments

Overall the references from consumer stakeholders show that they take a wide variety of actions from encrypting user data to set up experiments. The actions taken appear to be in the direction of increasing user experience either by directly focusing on the user experience or by limiting problems for the user.

### 4.2.3 Research stakeholders

In the following sections, references from research stakeholders will be described. The actions performed from researchers have a lot to do with handling data accuracy, gathering consent from participants, and creating new systems or modifying consumer systems to fit the needs of a researcher. Less of their actions is about verifying the claims of consumer systems and keeping ethical concerns in mind when developing systems. Finally, some of the researchers were talking about improving the lives of their research participants or improving treatment for people in need of medical treatment.

#### 4.2.3.1 Handle data accuracy

A lot of the references to actions taken by researchers were how they handled concerns with data accuracy. This could be a reflection on the requirement for researchers to explain their experimental design and keeping scientific validity in mind. The following comment shows how a research stakeholder prepared the participants by encouraging them and calming them down.

*“Basically I just try and to mentally prepare them for what is coming and not to be extremely sad about, if it doesn't go their way or don't like, just because it works from my experience, it works the best when you are calm. So ,so yeah things like that.”*

(Researcher 3 - Bachelor Student, December 2017)

The following reference talks about a similar action taken to reduce accuracy problems with the experimental setup.

*“We tried, because it didn't work, for example for the training with the blink. With blink it, I record my blinks, and my [boyfriends] and another friends, we trained with a blink and we tried to put in the same metrics but it didn't work, it was a totally mess so. We conclu[de], we did training before use it, everybody so. It was, it was a [INAUDIBLE] time. But, at the end it worked.”*

(Researcher 6 - Bachelor Student, February 2018)

The above quote also shows some trial and error testing is used to find a setup that works. The reason for such emphasis being put on the experimental system design to increase data accuracy could be because of the many variables that can affect the BCI results such as described by the following stakeholder:

## Reflections and analysis of stakeholder comments

*“I have tried to talk to the people, like to express, like what they should do, what they should [INAUDIBLE]. And there are certain things that, that can basically like, you eat. The EEG signals right so, there are things that, can have bigger impact because like, the stuff like swallowing and tongue movement and eye movement is way stronger because it's closer to brain than, moving my thumbs or something.”*

(Researcher 3 - Bachelor Student, December 2017)

The experimental setup, however, must be a realistic setup as mentioned by the following stakeholder:

*“I mean, you try to make the environment good enough so that the, basically the, the experiment goes well, but I mean, in a natural way. You don't use bad data to create good results.”*

(Researcher 3 - Bachelor Student, December 2017)

One stakeholder suggests that this is a good system design by the following statement:

*“And you have to build systems which embrace that uncertainty so for example the systems I am building or studies that I do always take that into account.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above shows a willingness to handle data accuracy and building systems to reduce the impacts of data inaccuracy. Overall this section shows that research stakeholders are taking actions to reduce the impact of data inaccuracy. The steps taken are largely instructing the users in the correct usage of the devices and limiting the actions taken with the devices. Only to some extent explained by research stakeholder 1 were technical solutions used to create new systems that could handle the data accuracy used.

### 4.2.3.2 Create new systems

In the following section references will be described that refer to actions research stakeholders have taken that suggest they were developing new systems or changing current systems to develop new use cases for the technology used. Some of these references suggest that the current consumer systems were not providing research stakeholders with what they needed to perform their desired tasks.

*“So and I guess at that point we said, okay maybe, well. If we are to, [INAUDIBLE] with raw data why don't we just continue to try make something ourselves.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The references above is an example of such, which particularly reference the desire to use raw data which was not provided by the consumer product. This was a reason for multiple stakeholders to create new systems or hacks to existing systems in order to get raw data.

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*“So we have to do what I did is little trick with a protocol that it use for the to the music, the synthesisers. They, is a open [INAUDIBLE] protocol. That they actually translate the signal from the brain, who open sound control protocol. And that, it was suitable for the Arduino board. So in my research there is no raw data, there is no database, that holds the data acquired from your neurons. The privacy was not a problem.”*

(Researcher 5 - Masters Student, February 2018)

In this comment above, it is also worth noting that the while raw data was used, no raw data was collected for further analysis. An additional observation from the references is the desire for researchers to make something that is usable and realistic. This comes across in the following statements:

*“And really come from both sides and find, where does these actually match. So I think, so for my research I am always, I am always looking for such situations where you could really build an application or have something which is embedded in a, in a realistic user experience setting.”*

(Researcher 1 - Senior Researcher, November 2017)

The above references suggest that research stakeholders dealing with consumer BCI technology has in mind that the technology they develop must be usable by users, and not only researchers or other expert stakeholders. The ability to solve usability issues of current systems (in this reference other interaction devices) is also a purpose put forward by research stakeholders.

*“And I think that this is something many people can connect to which, tries to solve an actual usability short coming of current systems.”*

(Researcher 1 - Senior Researcher, November 2017)

The method for building these systems was also described in a previous comment as by trial and error, but as the following statement suggests, also by talking to people and figuring out what they need and want out of a BCI system.

*“So basically number one as a actual answer to your question, number one would be talking to people, what they think they want, what they lack, how they would see it, and number two would be observing it from the side, with some more or less a clear mind and without too much knowledge about this particular area. And sometimes you can get ideas or insights which are, which would not be so obvious when, when you are someone who has [AUDIO CUTTING OUT]. Than. That would be it.”*

(Researcher 7 - Masters Student, February 2018)

## Reflections and analysis of stakeholder comments

The comment above suggests that creating new systems is driven by a need from the users, whether these users are the researchers themselves or someone else. Overall the research stakeholders are making new systems when the current systems do not handle what they need them to. This can be because the system is not accessible and usable for the specific use case researchers have. Working with users as described above should require the gathering consent, and in the following section will action references regarding gathering consent be described.

### 4.2.3.3 Gather consent

The most talkative regarding actions taken towards the concern of gathering consent was researcher 2. Researcher 2 was working with locked-in patients which could be an indication of why as locked in patients inherently are in a situation where gathering consent can be difficult. Some of the actions taken by researcher 2 was limiting their research group which appears to be an easier solution to dealing with people where consent can be difficult, the limitations are described in the comments below:

*“I think it depends on the country in a lot of ways too. I know for example our university is fairly strict about consent. I mean right now we are actually only able to experiment with people who are not completely locked in, so they can actually themselves give consent.”*

(Researcher 2 - PhD, November 2017)

*“I guess for us, we restrict ourselves to people who have spouse or close family members who are able to give consent on their behalf.”*

(Researcher 2 - PhD, November 2017)

While the above shows what the researcher did to limit the concerns of gathering consent, the same researcher did suggest that working with people who cannot give consent might be the way to allow these people to give consent:

*“Which if you are saying, well the point of experimenting with this BCI on this test group who cannot by themselves give consent, is because we want to develop a system which will actually allow them communicate for the first time in years maybe.”*

(Researcher 2 - PhD, November 2017)

The other researchers did not appear to put so much emphasis on gathering consent from participants, the following quote makes it sound like a very simple and easy concern to deal with:

*“And [NAME OF R2] said okay, but then, we need some test persons, and I said, okay we will find some, so we found some test person, but then we had to prepare the BCI headset, because you had to have some*

## Reflections and analysis of stakeholder comments

*cline fluid, in order to, you know, to make contact with the sensors, then you had to ask the participant, can we you know, wet your hair, can we wet you at all?"*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The casual approach to gathering consent of the above statement is echoed in the final statement:

*"I: No worries. So, when you did your experiments and stuff like that, did you do anything in particular to make sure that the people who tried the BCI and stuff like that, were well aware of what was going on?"*

*19:16 R: No, I didn't."*

(Researcher 6 - Bachelor Student, February 2018)

Based on these statements it appears to be crucial in which setting consent is gathered. For those working in a settings where gathering consent is rather simplistic, no specific actions were taken to ensure that the purpose of the research was understood.

### 4.2.3.4 *Improve people's lives and knowledge of the brain*

In the following section researcher 2 mentioned the improvement in people's lives by giving them the ability to communicate in the following statement:

*"Which if you are saying, well the point of experimenting with this BCI on this test group who cannot by themselves give consent, is because we want to develop a system which will actually allow them communicate for the first time in years maybe."*

(Researcher 2 - PhD, November 2017)

Researcher 2 does however also emphasize that while building these systems that can be good for locked in people, there needs to be an understanding of how people's lives might change with increased knowledge of the brain:

*"I think the best we can do is kind of be conscious of those concerns and address them. Incorporate those concerns somehow in the development of the technology, because some of those will be very legitimate and real concerns, that maybe we will only understand why they are important after the fact. It's better to try and integrate those concerns and understand them before these technologies are deployed wide scale."*

(Researcher 2 - PhD, November 2017)

Another researcher, however, has a more direct approach to improving the lives of people who could benefit from BCI technology:

*"If it makes sense, if you know that you can improve it. If some, if some, if your audience, target audience I don't know, thinks that this is a good idea and they personally would use it, then [INAUDIBLE] do it*

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*basically. “*

(Researcher 7 - Masters Student, February 2018)

Researcher 2 has been tied with locked-in patients and in the same way, researcher 2 talks about actions taken to improve the treatment of people that suffer from a locked in state:

*“One of the people I work with, is well known for having developed a system which can detect whether someone in a coma, who is apparently in a vegetative state is actually conscious or not conscious. Which of course effects dramatically how we treat those patients.”*

(Researcher 2 - PhD, November 2017)

Other statements were made from other researchers about helping people with limited movability, although these were focused on people that were not locked in, which could be the reason for them not talking specific actions dealing with concerns gathering consent.

*“So if a person with paralysis for example have again the ability to use everyday stuff. To not be excluded from the general public the outcome is that I with that I don't have any disabilities, I feel a better person, that I've helped that.”*

(Researcher 5 - Masters Student, February 2018)

In the above statement, it is also interesting to note that working on such issues give the researcher a sense of doing something good, which could be a motivational factor for taking the actions they did. Researcher 6 shows in the following statement that the reasoning for doing the research was to help improve the lives of people with disabilities.

*“The idea, the main idea of the project was help with people with limit mobility. For, the robotic arm was made for.”*

(Researcher 6 - Bachelor Student, February 2018)

Overall a lot of actions were taken to improve the life of people either by improving the treatment they were getting or by improving their ability to do every day things such as communicating or taking their own medicine.

### 4.2.3.5 *Ensure privacy*

Overall the issue of privacy was not one that brought up a lot of actions taken to ensure privacy. This could be related to statements by research stakeholders, that some of the systems developed by the researchers were not storing data as shown by the following statements:

## Reflections and analysis of stakeholder comments

*“So we have to do what I did is little trick with a protocol that it use for the to the music, the synthesisers. They, is a open [INAUDIBLE] protocol. That they actually translate the signal from the brain, who open sound control protocol. And that, it was suitable for the Arduino board. So in my research there is no raw data, there is no database, that holds the data acquired from your neurons. The privacy was not a problem.”*

(Researcher 5 - Masters Student, February 2018)

*“I: Yeah. If I am understanding your device correctly, it didn't actually store any data as well? It was purely mechanical so you made it do something, but it didn't store any of that data right? R: Yeah”*

(Researcher 7 - Masters Student, February 2018)

The other reason why the actions taken to reduce privacy concerns for researchers weren't brought up could be because the researchers can be obligated to not share the data with any third parties to get ethical clearance, which reduces many privacy concerns. Overall the researchers talked mostly about gathering consent, building systems, and ensuring data accuracy. Most of the reasoning behind these actions appear to be improving the lives of people as this was the fourth big topic for researchers to talk about. In the following section references by consumer developers and researchers on engagement will be described. The differences and similarities between the actions described above will be discussed in chapter 5.

### 4.3 Engagement

This section presents the comments by consumer and research stakeholders that relate to engagement be analysed. Unlike the previous section that organised the comments around themes, the following section will organise the comments in the groups of engagement the stakeholders engage with. As such the section will be organised to give insights as to what groups stakeholders engage with, and what they said about these engagements. Firstly, the comments by consumer stakeholders will be analysed, and secondly comments by research stakeholders will be analysed.

#### 4.3.1 Engagement overview

In this section will the overall summary of the section be described. The themes identified in the sections below will be put into a table to improve the overview of the engagements described by stakeholders. The further discussion of what these findings mean will be described in chapter 5.

## Reflections and analysis of stakeholder comments

Table 5: Engagement overview

<b>Consumer stakeholder</b>	<b>Research stakeholders</b>
<p><b>Users</b> Consumer stakeholders use user engagement to get feedback on products and use this feedback to improve their products. For some stakeholders, there is a sense of pride in user engagement.</p>	<p><b>Users</b> Engagement with users is largely dominated by a requirement to inform users of the technology and making sure they understand the capabilities of the technology. Once this has been established the goal is to find use case and/or improvements to the technology.</p>
<p><b>Universities</b> Engagement with universities is used to validate products and to find use cases for their products.</p>	<p><b>Researchers</b> Only based on one stakeholder but mentions the overweight of technical researchers in the BCI discourse which influence the research done with BCI.</p>
<p><b>Organisations</b> Engagement with other organisations is largely driven by economic, regulatory, or knowledge benefits for the companies.</p>	

Overall the stakeholders engage with mostly the same users, however, the engagement has different intentions with the engagement. Research stakeholders mention a heavy focus on explaining users the technology and a concern with the amount of technical expertise in the research community which might push the discourse in a specific situation. Consumer stakeholders, on the other hand, mention the benefits they get from engaging with different groups such as validation of technology or feedback from users. While this difference in engagement is rather minor, the engagement appears to be more prominent from consumer stakeholders as they also mention engaging with other organisations and their engagement with universities seems more pronounced than for research stakeholders. The engagement from consumer stakeholders also appear to be driven by both a desire to engage with users to improve their products, as well as a need to engage with regulatory bodies to ensure the future for their products.

### 4.3.2 Consumer Stakeholders

Consumer stakeholders discussed 3 different groups they engaged with, universities, users and other organisations. The comments on these 3 different groups of stakeholders will be analysed. Firstly, the topic of university engagement, followed by the topic of user engagement and lastly the topic of organisational engagement.



## Reflections and analysis of stakeholder comments

### 4.3.2.1 Universities

A few consumer stakeholders talked about engaging with stakeholders from universities. Two of the stakeholders talked about interacting with universities to either improve or validate the accuracy of their products as shown by the comment below:

*“But in terms of accuracy, what do we do, so we partner with a number of universities, we also supply tech to a number of universities.”*

(Consumer 1 - Founder/CEO, October 2016)

It is interesting that another stakeholder explicitly called the partners they worked with for “open-minded”:

*“Some of our open-minded partners, and we got a lot, we got probably 200 university research partners. Some of our more open-minded partners are saying “hey how did you figure this out, can we use this in our lab?”, and the answer is yes of course can.”*

(Consumer 2 - Chief Scientist, November 2016)

It is also interesting that this stakeholder is working with an estimated number of 200 universities which indicate a significant interest either from the stakeholder to work with universities or for universities to work with this specific stakeholder. The following comment might indicate that the reasoning for the consumer stakeholder to work with universities is to expand the use case of their product:

*“You know, I think that, we are, one of the reasons we work with so many researchers, is because we want our technology to be pushed in as many directions as possible. But in a rigorous way, that has, you know the [INAUDIBLE] of peer-reviewed researchers to back it up.”*

(Consumer 2 - Chief Scientist, November 2016)

The final stakeholder reference is a mentioning of not engaging with university stakeholders, but more specifically it's about not following the literature on BCI.

*“Depends what they are saying you know, and I didn't go into the literature, explore. If they have anything smart to say, I mean it's.”*

(Consumer 4 - CEO, April 2017)

The following statement was made regarding the topic of enhancement specifically which was a topic the developer had not thought about, which could be the reason for not engaging with the literature around this topic. Overall the engagement with universities appears to be a way for consumer developers to increase the usage of their products as well as validating the products so that it can be used for either promoting the product or if enquires are made about the validity of the products.

#### 4.3.2.2 Users

Consumer developers are interacting with their users in a variety of ways. In the following section, some of these references will be described. Firstly, consumer developers are engaging with their users to develop features for their products, such as is described by Consumer 1 in the following quote:

*“And when it came to the software, we had people saying look [NAME], you know we really want to add a marker in, or can I have a second headset connected, and can your player allow me to record.”*

(Consumer 1 - Founder/CEO, October 2016)

Some consumer developers talked about using user feedback to increase the user-friendliness of their products:

*“I mean, it, people would say probably like I am expecting this to happen, but the other thing is happening. So it's like you really have to fix that as in terms of like user-friendliness.”*

(Consumer 3 - Technical sales, November 2016)

While these developers talk about using user feedback to increase usability, one developer talks about his experience with different types of users:

*“I am also developing some biofeedback equipment for the clinics and when people, when I see huge difference between people who are 60 years old and people who are 30.”*

(Consumer 5 - Neuropsychologist, April 2017)

While the developer here notices a difference in the age of people, another consumer developer mentions the difference in origin and their concerns about BCI technology:

*“Actually not in Israel and not with Israelis and not in the US. With people from China, Korea, this is something that was brought up as an issue.”*

(Consumer 4 - CEO, April 2017)

Another consumer stakeholder mentions that engaging with early adopters might give a false impression of privacy concerns:

*“You know, it's been brought up by a few of our users, but I think we still have a lot of early adopters. Who are maybe a little bit less [resident] to share their information.”*

(Consumer 2 - Chief Scientist, November 2016)

When talking about engaging with the customer base and their concerns, one stakeholder also gave a brief story about his interaction with one user that was unable to use the product and showed signs of concern:

## Reflections and analysis of stakeholder comments

*“So I went up to him, and I said, what is wrong? And he said, is there something wrong with my brain? I said, what do you mean? He said, well, how come everybody else could do it, but I couldn't do it? Does that mean that there is something wrong with my brain? So I took him back to the stand, and I said, well actually no, it just means that you haven't understood the control mechanism of your brain.”*

(Consumer 1 - Founder/CEO, October 2016)

While this was the only description of such episodes, other stakeholders did talk about having to explain the technology and what was going on to their users such as the following quote show:

*“mean most of the people recognise it after they try it. Once they recognise that what we are looking at is a white scribbling line that is coming off of the screen, and like how do you read peoples credit card numbers from this line. That's like virtually impossible yet.”*

(Consumer 3 - Technical sales, November 2016)

While the above quote do not appear to be as critical of a situation as the experience was for consumer stakeholder 1, it does appear that engaging with users bring forward situations where the technology has to be explained. The requirement to explain the technology was something which consumer stakeholder 5 also noticed:

*“Yes, well what we explain is that there is nothing intrusive, or we are not like transmitting any electricity inside their body, we are just collecting information from their body.”*

(Consumer 5 - Neuropsychologist, April 2017)

While the above quotes by research stakeholder 2, 3 and 5 are very different in context, it appears that multiple consumer stakeholders have had an experience where they had to explain the product to a user. A couple of consumer stakeholders talks about using testers for their products, previously consumer developer 2 talked about this, but testing their products on users is also the case for consumer stakeholder 4 and 5:

*“Usually, first of all we have beta testers, always, so beta testers give us a lot of input after we have developed something. What it does to them, and how to improve.”*

(Consumer 5 - Neuropsychologist, April 2017)

*“Okay so, not yet, we don't have so many [free] users I would say. So we have, we did market research, so we basically asked the 300 subjects that elected to specific products and [INAUDIBLE] one product for the consumers. So we simply gave to friends and families and some advisers and we get the feedback [INAUDIBLE].”*

## Reflections and analysis of stakeholder comments

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 5 talks about beta testing which seems more of a typical structure for releasing products, whereas consumer 4 talks about using family and friends as a test group for their products. In the following comment consumer stakeholder 2 talks about the speed of getting user feedback and the ability to react to it:

*“But that I think is not so much as an ethical issue as a design challenge, you know it's. You get user feedback, in the consumer space you get user feedback very quickly on if there is a problem.”*

(Consumer 2 - Chief Scientist, November 2016)

This quote is specifically about picking out materials for their products and how that was considered less of an ethical challenge compared to a design challenge. Finally, when consumer stakeholder talks about engaging with users of their products one stakeholder said the following:

*“So of course, that's rule number one, is listen to the customers.”*

(Consumer 6 - Academic commercialising, May 2017)

While consumer stakeholder 1 to some extent appears to agree with this statement, consumer stakeholder 1 has limitations to when he will listen to the users of his product:

*“You are always going to have people want different things, but I am quite involved with my customer base personally.”*

(Consumer 1 - Founder/CEO, October 2016)

Which indicate that sometimes the feedback users have given was not always implemented in their products. Consumer stakeholder 1 does claim that all the features in the product was developed based on suggestions from users through which could indicate a large degree of user involvement in the development:

*“And I took feedback actually not from anyone in the industry, I took it from my customers as well. Is this better, is this a better experience for you, like is there anything else you want me to add. And everything that we have had come back, that's reasonable, gets implemented. Not just in our website, but in our software.”*

(Consumer 1 - Founder/CEO, October 2016)

In the last statement about user involvement consumer stakeholder 1, mentions the lack of interaction with the industry for taking suggestions on product development.

## Reflections and analysis of stakeholder comments

### 4.3.2.3 Organisations

Three of the consumer stakeholders mentioned engagement with other organisations such as other companies, regulators or event organisers doing hackathons. When engaging with other companies consumer stakeholder 1 mentioned working with a company that wanted to have a better understanding of mothers' emotional response:

*“And they wanted to look at how a mother reacts emotionally, so in terms of relaxation and pleasure whilst doing things with their children versus doing things on their own.”*

(Consumer 1 - Founder/CEO, October 2016)

This engagement appeared to be a shorter study where the results were shared with the organisation whereas an engagement they had with a prison appeared to be a long working relationship where they delivered both software as well as hardware to the prison:

*“We work with private prisons as well [PRISON NAME] and in [PRISON NAME]. And they use our system as part of a program called [PROGRAM NAME]. And they use our technology to show at first, how weak their emotional control is.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 3 also mentioned working with other companies, however, their engagement with other organisations was related to developing a product with the other company:

*“So they, in the beginning, they were asking us if, how do we recreate [CONCEPT] in terms of, like in this real world. And we went, why don't we use the attention level.”*

(Consumer 3 - Technical sales, November 2016)

The following engagement resulted in a shared product release. From the statement above, it appears that BCI developers are approached by others that find interest in the product, which is also the case for consumer stakeholder 2 that mention being approached by people who organise hackathon events:

*“So we kept getting these requests, can we borrow 10 [PRODUCTNAME] can we borrow 20 [PRODUCTNAME]. So we started doing that, and every single time, at the hackathon, someone would produce some stupid thing that didn't work.”*

(Consumer 2 - Chief Scientist, November 2016)

The above statement, however, suggests that these engagements are not always a positive experience for consumer developers. Consumer stakeholder 2 does, however, advocate for different stakeholders getting together, especially when it comes to regulation as the following quote shows:

## Reflections and analysis of stakeholder comments

*“And so, there has to be a balance between public interest and regulation and innovation. And getting that right is very tricky, that's a question as much for health policy makers as it is for technologists. The most important thing is that everyone, everyone gets together and talks in the right forums.”*

(Consumer 2 - Chief Scientist, November 2016)

The obvious benefit for consumer developers for doing this is being able to influence and keep track of regulations that might affect them, which the following statement also supports:

*We, you know, we're regularly in contact with regulators and making sure that we got, that we are on the right track and you know, if we have a question about what kind of claims we can make or where regulation is going.*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholders show that they engage in a wide range of organisations from prisons, to companies as well as regulators. This provides them with access to both business opportunities as well as regulatory opportunities and the main driver for these engagements is the benefits provided to the company either in knowledge generation or being able to influence decision makers.

Overall consumer stakeholders engage with 3 groups of people based on the above quotes. Users appear to be the group of stakeholders mostly talked about being engaged with, however, an engagement was also shown with regulators and other organisations. Universities were engaged with for validation and improved use cases for their products.

### 4.3.3 Research stakeholder

It is interesting to note that while all consumer stakeholders mentioned some form of engagement, 2 research stakeholders did not have any references regarding engagement. All other researchers did, however, mention either having engagement with a stakeholder or the intent of engaging with stakeholders. In the following section these references will be described.

#### 4.3.3.1 Users

When talking about engagement with the users, research stakeholders mentioned the need to explain the technology, or how engaging with the public made it clear for the people they were engaging with about what stage the technology is at, such as with research stakeholder 3:

*“It's usually like, I think that most people realise that if there is some, like if they actually know what a BCI is then, then they realise that it's in the baby steps, it's in the you know, in the cradle like they don't expect it to, to work too well right now.”*

## Reflections and analysis of stakeholder comments

(Researcher 3 - Bachelor Student, December 2017)

Research stakeholder 2 also mentioned engaging with the public, however, research stakeholder 2 mentions that this engagement should be done when it is clear what the technology is capable of:

*“For me it is more, what are the possible, given what we can actually detect or read about the brain, what are the possible applications out of this. And then, what can we identify, I agree ideally in collaboration with the public, is the best or most positive application out of this set. That we think we can create. And trying to take it that way. Because right now I think we are at stage where, what we can detect about the brain is very limited and that is what limits the kinds of applications we can actually develop.”*

(Researcher 2 - PhD, November 2017)

This statement also proposes that engaging with the public should be used for getting a consensus on what type of applications the technology should be used for, and what limits should be set for the technology. The two comments above show that engaging with the public, in general, directs how engagement with users will happen. It being directed by the public, is because the engagement with the public will influence what thoughts people have about the technology when engaging with the research stakeholders:

*“And there are a few people who actually were concerned, okay what's, I have no understanding of, of what's in there, and what you can get out of that.”*

(Researcher 1 - Senior Researcher, November 2017)

*“You know, and they had all kinds of remarks on it. Are you gonna suck my brains now with the data and so yeah, there is also a lot of, let's say, misinformation, also stuff that, are, is not known and that is, what I said earlier like, that is hidden, because there are, there are different agendas at play I think.”*

(Researcher 3 - Bachelor Student, December 2017)

The above quotes show that the same concerns researchers face when dealing with the public carry over to their engagement with users of their systems. Users expectations of what the devices can do and how they work are something both research stakeholder 1 and 3 needed to address in their engagement with users. Research stakeholder 1 mentions that using BCI in a human-computer interaction setting focusing on the usability of the product is something his users connected with.

*“And these usability, these HCI settings are usually of something people can connect to.”*

(Researcher 1 - Senior Researcher, November 2017)

Working with BCI and the users of BCI to improve the usability of the devices were also something research stakeholder 7 mentioned regarding the engagement with users, as the following quote shows:

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*“You see a problem, you know that you can actually improve it, you talk to people and then say, hey it could be really awesome if I could, I don't know. Control some mechanism with my eyes instead of my hands because I cannot use my hands.”*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 also mentions that this type of work usually happens when the stakeholder is engaged with users:

*“So is, this would be such a typical way to see if some, and if you know that you can improve it and you get this idea then you talk to people. As you typically to the people who would actually be using your system or whatever you are developing.”*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 does, however, mention that being too engaged and emerged with the users for too long can limit what kind of improvements that can be made:

*“So I assume that, it would be intuitive to say that if I was for example a disabled person I would give you 50 ideas of how this can be improved. And usually it is like this, but this is not the entire story, and usually when, if I use something for the next, for 20 years, I can't always say. Can't always give any radical new perspective responses.”*

(Researcher 7 - Masters Student, February 2018)

It appears based on the above comment that according to research stakeholder 7 new people must be brought into the group of people engaged with the technology to avoid improvements being limited. It is interesting though that research stakeholder 7 also mentions that the stakeholder did not follow any methodology to ensure that develop the technology:

*“I am not sure if there are any, like okay. There are, there are of course much more formal ways to analyse the [INAUDIBLE]. I am not, I know that they exist, personally I am not familiar with them and it is not something which. It is not something which I personally have used.”*

(Researcher 7 - Masters Student, February 2018)

The following statement also shows that research stakeholder 7 recognise that methodologies for engaging with users throughout development must exist, even though the stakeholder did not employ any for the research. Knowing of formalised methods existing is also true for research stakeholder 1:

*“And I wouldn't say we have a formalised method for doing that, of course there is participatory development, which we, which we sometimes use.”*



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(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 2 mentions that the entire point of his research is to bring the user into the development of technology, however even so the stakeholder appears to use more of free interaction with the technology than a structured methodology for developing with the users:

*“And so a lot of my work is on kind of bringing the user into the picture, in a deeper way. Perhaps that, I don't know, alleviates that issue a little bit. Although my work is more on say, here is what the system does interact with it freely in a way that makes sense to you, rather than saying, here is the brain activity you need to learn how to modulate in order to control the system.”*

(Researcher 2 - PhD, November 2017)

When it comes to the kind of technology developed from the research mentioned by the stakeholder, research stakeholder 2 mentions that at this point the development of BCI in terms of use cases are less about what users want and more about what is possible with the data provided by BCIs:

*“But... in terms of developing applications that people would actually want, I think it is more of an issue of what kind of brain activity or cognitive processes or emotional states can we actually successfully detect in real time and then, what array of applications can we develop from that. So it is less here is an application that we want to develop, and have we interacted with the community to say, to determine that this is an application that people want.”*

(Researcher 2 - PhD, November 2017)

The ambiguity of BCI data is also a concern mentioned by research stakeholder 1 when talking about engaging with users:

*“And you can't explain to people what's happening in the data and what you see there, basically everything that you can get out from the data, needs to be interpreted or pre-processed very heavily and then the connection is, people basically have to trust you that these components actually do what you say that they do, and I think that, that makes it harder for people to, to trust that the system is actually decoding only what you, what you guarantee that it is decoding and nothing besides.”*

(Researcher 1 - Senior Researcher, November 2017)

The above quote specifically shows that engaging with users revealed the concern of being able to explain for users what a BCI does, and for research stakeholders to explain what the technology is capable of. Research stakeholder 2 does mention that engaging with users will eventually show that some users will approve of the technology and uses cases, whereas some will not:

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*“Because I think that you will always be able to find a sample of people who are, who will approve of that application and a sample of people who don't approve of that application.”*

(Researcher 2 - PhD, November 2017)

The second statement above suggest that even professional users might not be entirely positive about the use cases of BCI technology as it might change their workflow and make it more complicated.

### 4.3.3.2 Researchers

While only research stakeholder 7 mentions engaging with other researchers, the stakeholder mentions the number of IT people working with BCI development.

*“In the perfect case it would be something with a degree in IT or something similar and a psychologist something similar but mostly the people who do it right now again based on my experience are more IT people. Who not always have enough empathy to deal with people in general. And not. when we talk about elders or disabled people it becomes even worse. But I, I do not have any horror stories about this.”*

(Researcher 7 - Masters Student, February 2018)

Based on the comment above, the number of IT people working with BCI is a concern for research stakeholder 7, however, in the following comment, the stakeholder mentions that making sure there are ethical policies in place for researchers could be a potential block for research to happen.

*“Let's say I work in a mental hospital, or a hospital in general, I have this really nice idea about doing a study. I have the people I need, who agrees with it, I have some person in the hospital which can, which knows a bit about the policy stuff. It is, there is this really big barrier about actually going ahead and doing this.”*

(Researcher 7 - Masters Student, February 2018)

The above statement shows that for research to happen there is in the case of research stakeholder 7 multiple stakeholders involved such as other researchers, as well as ethical policy personnel.

## 4.4 Reflections

This section analyses consumer and research stakeholders comment and reflections. Unlike the previous section this section will be organised by the themes derived from the stakeholders. Firstly the comments by consumer stakeholders will be analysed, followed by the comments from the research stakeholders.

## Reflections and analysis of stakeholder comments

### 4.4.1 Reflections overview

In this section the overall summary of the section will be described. The themes identified in the sections below will be put into a table to improve the overview of the reflections described by stakeholders. The further discussion of what these findings mean will be described in section 5.

Table 6: Reflections overview

Consumer stakeholders	Research stakeholders
<p><b>Market Projection</b> The BCI market is in the early adopter stage which limits the current use cases. Overall confident in their projections.</p>	<p><b>Projections</b> Research stakeholders mainly look at projections as uncertain and some of the projections were mentioned as being not useful due to the uncertainty.</p>
<p><b>Finding use cases</b> Due to the current market projections finding use cases is important which is done through pilot studies and engaging with the technology.</p>	<p><b>Concerns about commercialisation</b> Largely directed by consumer stakeholder 2 and 4 and is reflecting upon the roles of consumer stakeholders in the BCI industry as being a problem and driven by greed.</p>
<p><b>Technology maturity</b> BCI is a vulnerable technology because it is not very mature, and for some stakeholders survival in the industry takes priority.</p>	<p><b>Technology maturity</b> Only two stakeholders commented on the maturity of the technology not being very developed, which could be a subject of concern for these stakeholders.</p>
<p><b>BCI different from other technology</b> BCI technology in consumer settings is less problematic than other brain technology.</p>	<p><b>BCI compared to other technology</b> BCI technology should not be considered different than other technology.</p>
<p><b>Privacy</b> Privacy concerns were not specific to BCI technology and solutions were already found and applied such as technical and informed consent solutions.</p>	<p><b>Privacy</b> Similar to the topic on BCI compared to other technology, the stakeholders were of the opinion that privacy reflections are part of the world and must be had.</p>
<p><b>Potential solutions</b> Some of the potential solutions are technical implementations, but policy solutions were also mentioned.</p>	<p><b>Solutions</b> Some of the solutions to potential BCI problems are technical, regulatory, and one stakeholder also mentions that consumer stakeholders have a responsibility to find solutions as well.</p>
<p><b>Company responsibility</b> Companies are responsible for informing their users, however, when the technology has been transferred into another setting, this responsibility can be transferred to 3<sup>rd</sup> party individuals.</p>	<p><b>Community responsibility</b> Various responsibilities were identified such as responsibility for informing the public as well as a general societal responsibility for not using invasive technology unless a necessity.</p>
<p><b>Customer feedback</b> Customer feedback is helpful, especially public reviews can be used to improve sales. A balance has to be achieved though between customer feedback and personal concerns.</p>	

## Reflections and analysis of stakeholder comments

<p><b>Improvement of brain understanding</b> BCI can provide additional information about us, which may affect us. To what extent and whether this is a concern or not is however debatable.</p>	
	<p><b>Accuracy</b> The level of concern for accuracy is based on use cases and the solutions are varied depending on the use case as well.</p>
	<p><b>Humans are the problem</b> Some problems with BCI technology is caused by bad human intentions, or ability to develop useful products.</p>
	<p><b>Consent</b> Consent should always be achieved, and in some cases, BCI technology could be the only way to achieve consent.</p>
	<p><b>Regulation</b> More regulation is required, however, the regulation required is equally oriented towards BCI or society and technology in general.</p>

Overall stakeholders commented on many of the same topics. Some of these topics had differences based on the settings stakeholders existed in. For example, on privacy research stakeholders were focused on the general concern of privacy in society and not specifically on the technology, and consumer stakeholders were focused on explaining how the general concern for privacy affected their specific technology. On the topic of projections which both stakeholders comment on, the difference lies in the certainty of the projections. Researchers in general were struck by the uncertainty of projections whereas consumer stakeholders were more confident in their projections. This were partly due to the type of projections made, as researchers were looking more into the future whereas consumer stakeholders were projecting on the current status and what would naturally follow. Both stakeholders agreed that BCI technology was not very mature and this was a challenge for the technology and stakeholders involved with it. This also showed by statements that consumer stakeholders were still eager to find new use cases for the products to make them more attractive to their customers. This desire to increase the number of use cases and thereby the potential markets for BCI technology was also a concern reflected upon by some of the research stakeholders. The concern was largely upon the motivation of consumer stakeholders being greed, and what that could potentially mean for the future of BCI technology. Both stakeholders have also reflected upon BCI compared to other technologies. Consumer stakeholders commented that BCI technology was less problematic compared to other brain technologies, and research stakeholders believed BCI technology were like other technologies in terms of the problems it might propose. On the topic of

## Reflections and analysis of stakeholder comments

responsibilities both stakeholder groups identified responsibility of the BCI developers. Consumer stakeholders identified the responsibility of informing their users of their products truthfully, however once a 3<sup>rd</sup> party were involved, that responsibility was transferred to the new stakeholder. Research stakeholders also identified the need for informing the public about BCI devices and that various stakeholders had that type of responsibility. Consumer stakeholders also reflected upon the usage of customer feedback and mentioned that some customer feedback were usable and some were merely personal preferences. Consumer stakeholders also mentioned that BCI could provide additional information about us, however whether this was a good or bad could be debatable. Research stakeholders on the other hand mentioned that often humans were the cause of the problems, rather than the technology. The other topics research stakeholders reflected upon were the need for gathering consent before BCI usage, the various levels of accuracy and how different methods could be applied to solve this concern depending on usage, and finally that regulation were required, but that the regulation potentially should not be BCI specific as the problems extended beyond BCI technology.

### 4.4.2 Consumer stakeholders

Consumer stakeholders comments show they have reflected upon ethical concerns ranging from technology maturity to privacy. They also commented on reflections made on market projection for BCI devices as well as the use cases and the process of finding use cases.

#### 4.4.2.1 Market Projection

Three consumer stakeholders reflected on the BCI market and where it might be heading or things that could be pushing the technology in a certain direction. Consumer stakeholder 1 mentions that the current state of the BCI market mainly attracts researchers, athletes or people working in making treatments better for people that work with mental health:

*“But in the meantime, I think that the core market is researchers, athletes and people within the area of mental health who are looking at alternative ways of treating people.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 2 also reference the current state of the BCI market, however, consumer stakeholder 2 mentions that the production and availability are of BCI products have already reached the knockoff industry:

*“You know, and there are already knock off versions of [PRODUCTNAME] in China, that costs less.”*

(Consumer 2 - Chief Scientist, November 2016)

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The statement above could suggest that the BCI market has reached a certain maturity where there is a market for those that are willing to buy cheaper products than the established products. The topic of technology maturity will be discussed further in section 4.4.2.3. Consumer stakeholder 1 also comments on a trend in the BCI market with people trying to replace drugs with BCI device experiences:

*“So you know there are people that are trying to replace drugs, and I think, if you are trying to do that, you are always going to have a bad, a bad beginning and a bad ending with any technology.”*

(Consumer 1 - Founder/CEO, October 2016)

While consumer stakeholder 1 is in disagreement with this development, consumer stakeholder 6 comments on another development in the BCI community which he mentions is part of science:

*“And part of science is to improve on that, not [sub] and to make the medical tests more and more accurate, be more and more sensitive etc and of course the same goes for reading the brain.”*

(Consumer 6 - Academic commercialising, May 2017)

Consumer stakeholder 6 also talks about the development of BCI products in terms of medical safety with neurofeedback devices. Consumer stakeholder 6 considers this to some extent uncertain as it is a “huge topic”.

*“I didn't want the paint to be toxic, I didn't want the thing to break in my hand and maybe injure me. And now we are talking about medical safety, but it's not a medical safety in the sense that the medication is toxic or dangerous, it's a medical safety in terms of providing you say for example with a neurofeedback that can cause trouble. That is a huge topic, that will unfold in the next several years, many years as technology gets into more and more fields. But we can really see where it can take you.”*

(Consumer 6 - Academic commercialising, May 2017)

Consumer stakeholder 2 mentions that BCI users currently are early adopters:

*“I think there is a real opportunity given the level of interest. I think, you know, brain-computer interfaces are still not in the mainstream. They are still in the early adopters stage and they probably will be for another 5 years. Because we don't have, we don't have a widespread super compelling use case for everyone to have one.”*

(Consumer 2 - Chief Scientist, November 2016)

The main reason for this lack of mainstream adoption given by consumer stakeholder 2 is the lack of compelling use cases for mainstream users. Consumer stakeholder 6 suggest that when BCI technology eventually will be adopted, it will have side effects on society.

## Reflections and analysis of stakeholder comments

*“And yes, if the communication method will change dramatically, yes there will be side effects, but I would prefer nowadays a person that types on the keyboard very very fast without errors, in comparison to a person who writes beautiful handwriting.”*

(Consumer 6 - Academic commercialising, May 2017)

The above comment, however, shows that the use case could be a new interface, and adoption of such an interface could lead to new advantages for finding a job for those that are good at using the new interfaces. Overall consumer stakeholders are of the mindset that BCI technology is still in early adopters' state with the potential to move into several different use cases.

### 4.4.2.2 Finding use cases

Several consumer stakeholders mention that finding use cases is part of the industry. This section analyses comments that show reflections upon this topic. For finding use cases consumer stakeholder 5 mentions that pilot studies are used:

*“Sometimes when we do pilot studies, we understand that, what we have developed can be used in a different way. So, we also shift the strategy like, say in another, in another product that I am developing.”*

(Consumer 5 - Neuropsychologist, April 2017)

It is interesting though that the use case sometimes ends up being something different than what was originally intended. The same kind of hands-on is described by consumer stakeholder 6:

*“I have done a lot of more conventional EEG and fMRI kind of research, and I then realised that one can do a lot with just two or three electrodes. Which is what I have been recently working on and now trying to commercialise.”*

(Consumer 6 - Academic commercialising, May 2017)

The above comment shows that engaging with the technology is key to finding new use cases or improvements in the technology.

### 4.4.2.3 Technology maturity

All the consumer developers appear to agree that BCI is a new technology which still is not in a mature stage of development. Their reasoning for these reflections varies though which will be described in this section. Consumer stakeholder 1 mentions that while the technology is new and not fully developed, it should not be a reason for talking BCI products down:

*“Where as if we keep knocking the technology, before it has had a chance to develop and on the slip side, keep overselling the technology. Everyone thinks well, I might as well wait until it gets to that level.”*

## Reflections and analysis of stakeholder comments

(Consumer 1 - Founder/CEO, October 2016)

While consumer stakeholder 1 does not suggest talking the product down, the stakeholder emphasises that it is also important not to oversell the technology. It is however also clear that consumers thought about BCI products is important as he mentions that over or under-selling the product could impact adoption. Consumer stakeholder 2 also mentions the impact on adoption regarding the maturity of the technology:

*“And I think that we haven't over promised and under delivered to some extent. So, I think that in, in many respects many of the ethical concerns of the industry take a back seat to this risk. This sort of existential risk that, the whole industry gets ruined by the technology not working the way it's supposed to. And making claims that can't be backed up.”*

(Consumer 2 - Chief Scientist, November 2016)

While consumer stakeholder 2 mentions that the stakeholder does not believe that they have under-delivered on their promises about the technology, however, he also mentions a key thing in that the BCI industry might be under prioritizing the ethical concerns that surround the technology due to the potential existential risk of their companies. Consumer stakeholder 5 also mentions that the immature state of the technology is keeping him from diving into the industry:

*“That is why I think that, that's why I haven't invested a lot of, too much effort into understanding it deeply at the moment and I am waiting for it to be in a more consensus you know about regarding, protocols and the effect of protocols. For heartbeat and heartbeat variability it's much easier.”*

(Consumer 5 - Neuropsychologist, April 2017)

The lack of protocols described by consumer stakeholder 5 is something that could be the reason for consumer stakeholder 2 commenting on the lack of productivity from hackathons with BCI devices:

*“And so, no one was making good apps at hackathons, and the reason why was, if you have a 48-hour window to make an app, and you are starting from scratch on brain-computer interfaces you are not going to make anything good.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 also mentions that to combat this they had an app developed to teach developers about BCI devices:

*“And then what we realized was this is actually a really good tool for our end users.”*

(Consumer 2 - Chief Scientist, November 2016)



## Reflections and analysis of stakeholder comments

The lack of good apps and use cases based on BCI technology is also something which concerns consumer stakeholder 3 as shown in the comment below:

*“Well I think a lot of researchers look at, try to create new metrics, like, but then I feel like there is no specific use case yet or like looking at specific [INAUDIBLE] ones. So I think that, that's one thing that I think researchers should look at.”*

(Consumer 3 - Technical sales, November 2016)

While looking to create new metrics could very well be useful for developing new use cases for the BCI industry, it indicates that there is still room to grow as a technology. Consumer stakeholder 4 also mentions that the immaturity of the technology makes it so that there are still uncertainties about the misinterpretation of the metrics provided by BCI technology:

*“Yes. Not in the stage that it is now. Like we can continue and develop it to a stage where we will not be concerned about misinterpretation, it's not there yet.”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 6 adds to this comment by consumer stakeholder 4 by saying that our current lack of understanding of the brain impacts the BCI industry:

*“So this is the state of medicine now a days. We know when the kidney is not functioning, we know when we do not produce insulin, but when we come to this very sophisticated organ, which is our brain. Currently that's the state of chaos, we don't know.”*

(Consumer 6 - Academic commercialising, May 2017)

The comment above shows that consumer stakeholder 6 is aware and has reflected on the public understanding of the brain and how the maturity of the technology and the insights provided by it is currently lacking. The lack of insight is further problematic according to consumer stakeholder 6 due to media coverage of the technology:

*“You know, sometimes there are this confusion, is being created because of people are not accurately trying to describe what it is that they want to do but, the truth of it is we don't know.”*

(Consumer 6 - Academic commercialising, May 2017)

In the comment above consumer stakeholder 6, is talking about how invasive BCI technology is portrayed in the media and how this impact the perceived maturity of the technology. Overall consumer stakeholders commented that the technology is not very mature and that the industry is in a critical phase. One

## Reflections and analysis of stakeholder comments

stakeholder also mentioned that the fear of the industry not surviving takes priority over the ethical concerns the technology might impact.

### 4.4.2.4 BCI different from other brain technology

Several consumer stakeholders had comments on BCI being different from other brain technologies. These reflections will be analysed in this section. A comment that was mentioned by more than one consumer stakeholder was that using only EEG put the risk of the users at a minimum. This was seen by statements such as the following by consumer stakeholder 2:

*“So I think that, that concern about hacking and security applies to stimulators but not to sensors, to the same degree.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 makes a clear distinction between the risk of stimulators and sensors which is something other stakeholders does as well:

*“No, I mean, I am curious, where is the argument for that? See if you were using the argument for things like neurostimulation or transcranial magnetic stimulation, or electrical magnetic stimulation or whatever. See then I can understand, because then what you are doing, is you are essentially re-cunning your own abilities, by training your brain to become depended on this other stimuli.”*

(Consumer 1 - Founder/CEO, October 2016)

Additionally does consumer stakeholder 2 mentions that neurofeedback is not very powerful and therefore it is less potential to cause harm:

*“The worst thing you can do is compromise the data quality. Or change the feedback parameters, but biofeedback and neurofeedback are not so powerful, that they can harm people.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 also makes a statement to cement that the stakeholder is not working with the kind of technology where hacking and (implied physical) harm to the user is a serious concern:

*“if you are making something where, you know, hacking and harm to the user are serious concerns. Then you make a very different system than the kind of system we made.”*

(Consumer 2 - Chief Scientist, November 2016)

Asking consumer stakeholder 1 directly if he makes a clear distinction between the two technologies also resulted in verification that the stakeholder makes a clear distinction:

## Reflections and analysis of stakeholder comments

*“So, you make that distinction quite clearly between those who quote on quote simply read the EEG, contrasting. E: And those that manipulate yeah.”*

(Consumer 1 - Founder/CEO, October 2016)

This distinction goes beyond manipulating BCI devices and sensor devices though as seen by statements by consumer stakeholder 2:

*“It's not a concern for me as it applies to the [PRODUCT NAME], because, you know we are a long way from using sparse EEG for the same thing that we use high density EEG for. And there may be, to my mind some of the barriers to the use of sparse EEG in the same ways that very high density EEG are used, maybe technically insurmountable.”*

(Consumer 2 - Chief Scientist, November 2016)

The statement above suggests that there is also a distinction for the consumer stakeholder between different types of EEG used, a statement that is supported by consumer stakeholder 3 which also makes a distinction between invasive and non-invasive EEG and the level of data captured:

*“Because you would probably have to embed sensors to actually capture that level. We're just looking at very like, you know, limited patterns being like alpha wave, beta wave, and those don't typically reveal anything like that.”*

(Consumer 3 - Technical sales, November 2016)

Consumer stakeholder 4 even goes so far as to say that the data captured by the BCI device they are developing is more in line with current mobile apps:

*“There is, I mean it's, it's not specific to brain, brain wave data or applications related, you can ask the same questions for every mobile app you have. Is it specifically clear, do you have rules for ECG, snapping, whatever, I mean. I don't see the difference and I don't think there is a difference.”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 4 does, however, mention that a line must be identified where wellness apps turn into medical devices:

*“You need to define the line, and people need to define what they are giving, in the site whether they want to make it or you know leave it.”*

(Consumer 4 - CEO, April 2017)

## Reflections and analysis of stakeholder comments

Consumer stakeholder 4 also mentions that the FDA already looked at some of this when apps related to fitness trackers were developed and that the action then was not to block fitness apps which could indicate that a similar approach would be used for BCI devices:

*“They understood that the technology is there and they decided not to block it as long as you don't claim something like, heavy medical.”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 4 appears to be of the opinion that the data collected from BCI is no different than any other data. Overall the consumer stakeholders in this section believe the technology they work with is less troublesome than other technologies using brain data. BCI devices, however, does capture information that could provide information about the brain.

### 4.4.2.5 *Improvement of brain understanding*

As mentioned previously in the section about technology maturity there is a lot about the brain we are currently unsure about and that theme is also part of the following references. Consumer stakeholder 3 comments that it is unsure what kind of information a BCI can provide:

*“But yeah, I can see that. It can change the identity. But I don't know what would. We don't know what we can actually find out with the EEG so.”*

(Consumer 3 - Technical sales, November 2016)

In the statement above, according to consumer stakeholder 3, BCI technology can have an impact.

Consumer stakeholder 1 also believes that BCI technology can have an impact:

*And I think that is the only real fear, but then I think that there is another way to look at this, and that is. If people actually are using it for the original purpose of training their brain and becoming more emotionally aware and conscious and mindful. They are also less likely to get affected by those very standards because those standards are based on, understanding the way the brain works.*

(Consumer 1 - Founder/CEO, October 2016)

In the statement above consumer stakeholder 1 talks about how an improved understanding of the brain could be used by people to protect themselves from being affected by emotional impacts. Consumer stakeholder 1 also talks about how training is something athletes have been doing for a long time:

*“And something athletes have been training for, for years “*

(Consumer 1 - Founder/CEO, October 2016)

## Reflections and analysis of stakeholder comments

Consumer stakeholder 1 even goes so far as to argue that the accuracy of the BCI devices is not as much of a problem because it makes the consumer conscious about otherwise hidden aspects of their wellness:

*“It gives them insight into their brain even if it's not 100% accurate. It is like no ones bothered about or worried about the fact that the Fitbit was like 12% accurate to your heart. But we all took it as law because it actually still made us all conscious, and then as the technology improved it became more accurate because [INAUDIBLE] the money in the industry.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 is however not convinced that BCI technology should change how we view identity will change with BCI technology as consumer stakeholder 3 were:

*“Where as with the EEG, it's like saying, are you afraid that the hearth rate monitors are going to change the way we look at humans because we realize that we all got hearts. Like no, that's bollocks, that doesn't make sense.”*

(Consumer 1 - Founder/CEO, October 2016)

The comments above by consumer stakeholder 1 might not reflect his experience with peoples reaction to biofeedback from BCI devices as comments further below will show, other consumer stakeholders agree that improved knowledge about the brain could impact concepts such as identity:

*“Like philosophical I can agree with you but, you know, it's not something that I think about daily because it's not something that's related to what I am developing at the moment.”*

(Consumer 5 - Neuropsychologist, April 2017)

In the above comment consumer stakeholder 5, is talking about the impact on new knowledge potentially changing concepts such as free will. Consumer stakeholder 2 confirms what consumer stakeholder 1 mentions about the accuracy of BCI devices:

*“What we learned was that it wasn't particularly helpful, you know it didn't really reflect anything, in a real basis about brain performance or meditation performance.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 does, however, see this as a problem because people get attached to these metrics, which could have an impact on their self-perception:

## Reflections and analysis of stakeholder comments

*“But, that kind of thing works, special care when you are developing the technology and designing the software and the way that it's used by individuals. You know one of the things that you learn is that people get very attached to numbers, related to their brain.”*

(Consumer 2 - Chief Scientist, November 2016)

While consumer stakeholder 1 was not convinced that BCI devices should impact people's sense of identity, he does agree with consumer stakeholder 2 that people take importance in their brain data:

*“So it's really weird our expectations and everything else from our brain is very different. And I think that is a concern for me.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 also described an episode with a client that got very affected by his inability to operate one of consumer stakeholder 1's products at an event saying:

*“But the thing is, had I not known, the moral of the point is, had I not known that this had effected him so badly, I wouldn't have been able to fix it. And I would have had somebody going away feeling that they were somehow inadequate. But that is not nice, so, I guess the one thing is explaining to people that look.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 5 also suggest caution when applying BCI technology due to his experience with other biometric devices:

*“We know from other biofeedback or let's say psychologically interventions we know that for some people it's a. There is a contra indication to using, say using relaxation with psychotic people. It's something that is not recommended.”*

(Consumer 5 - Neuropsychologist, April 2017)

The reflection by consumer stakeholder 5 on the problematic design of experiments to determine the consequences of BCI device usage is something consumer stakeholder 3 also shows:

*“Yeah, I think that's one of the difficulties of actually. Designing experiments for these algorithms that we create.”*

(Consumer 3 - Technical sales, November 2016)

Consumer stakeholder 3 and 5 shows that they have reflected upon the problems with BCI experiment designs, and while the technology could be used to improve our understanding of the brain, the experiments done to do so could be problematic and needs to be thought out carefully. Consumer

## Reflections and analysis of stakeholder comments

stakeholder 2 also made a comment suggesting that he agrees with consumer stakeholder 1 that BCI devices could educate people about how their brain works:

*“That's one of the words we like to use, when it comes to BCIs, democratisation, you know, BCIs can come out of the lab now and anyone can, can theoretically have one and they can play with it, and they can learn about their brains and they can use it for whatever application they want. That they can, that it works for.”*

(Consumer 2 - Chief Scientist, November 2016)

The comment above shows that consumer stakeholder 2 is aware of the potential BCI technology has in providing information about the user. Overall this section shows that the potential of BCI is the case according to consumer stakeholders.

### 4.4.2.6 Privacy

All consumer stakeholders commented on reflections about privacy concerns, and most of them were not overly concerned about privacy issues, and various reasons were given for this based on their reflections. Consumer stakeholder 1 comments that the requirements for retrieving information limit the privacy concerns with BCI devices:

*“So in most situations, unless you are voluntary telling people what you are doing at that time, or you are connected to a device or an app. That was monitoring your behaviour at the same time. Then yes there is a concern, but that concern is more with the app, less with the technology.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 also mentions that the use of Bluetooth to connect the BCI devices with other hardware limits the ability for others to eavesdrop:

*The headset can only connect to one device, so the minute your device becomes inactive it's potentially been hijacked. But you would have to be around some kind of a Jedi within 10 meters of it in order for this occur. And they really desperately want your brainwaves, and unless he was also a neuroscientist that would be entirely useless to him.*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 2 also mentions that they specifically designed their devices to be “hackable” because they wanted people to break the devices and create different use cases:

*“So if we were building something for high security and we didn't want anyone to be able to break into it. We would design it differently. Yeah, that's basically it.”*

(Consumer 2 - Chief Scientist, November 2016)

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While consumer stakeholder 2 mentions the build approach in agreement with consumer stakeholder 1, stakeholder 3 mentions that the hardware limitations of only having a few sensors limit the privacy concerns:

*“And even if we, even if we can, you will have to be strapped into a very very huge EEG system to do that. So if anyone is looking at like a one single sensor or two or three, that's. It providing a very limited picture of your mind. So, people shouldn't be scared about that.”*

(Consumer 3 - Technical sales, November 2016)

Consumer stakeholder 2 also commented that engaging with your users can remove the privacy concerns users might have.

*“So if you engage actively, or pro-actively in ensuring that users feel comfortable about the privacy and ownership of their own data. That problem to a certain extent goes away.”*

(Consumer 2 - Chief Scientist, November 2016)

It is important here to note that engaging with the customers is not enough in itself, the engagement needs to be an ensuring of privacy and data ownership rights for users. Consumer stakeholder 4's reflection comments show that privacy concerns tie into a classification of data issue:

*“It depends to whom, you know. But yes I would put it with health, I would call it health information.”*

(Consumer 4 - CEO, April 2017)

While consumer stakeholder 4 is not of the opinion that brainwave data adds anything that should make it special compared to other health information, consumer stakeholder 5, however, does not agree with this:

*“Can you understand the argument that because it's data about our brain that this is in some sense more concerning? E: Yes, definitely. I do”*

(Consumer 5 - Neuropsychologist, April 2017)

Consumer stakeholder 6 also reflects on the classification of data, and adds that in his opinion, all data could eventually be classified as medical information:

*“frankly we feel that in the very near future every kind of data can be looked at as medical information okay.”*

(Consumer 6 - Academic commercialising, May 2017)

Finally consumer stakeholder 6 adds the argument that the advantage of the additional information outweighs the privacy concerns:



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*“It gives us real advantage in comparison with living without windows, then we are willing to take this risk.”*

(Consumer 6 - Academic commercialising, May 2017)

Overall the approach to the topic of privacy was quite similar for all the consumer stakeholders. Consumer stakeholders were mostly of the opinion that privacy concerns were not specific to BCI and in most cases were solved by informed consent and technical solutions that work for other technologies as well.

### *4.4.2.7 Potential solutions*

Various potential solutions to different problems were reflected upon by consumer stakeholders, some problems were caused by BCI technology and to some problems BCI technology was the solution. To round off the topic of privacy, some solutions were found to the BCI privacy concern. Consumer stakeholder 6 mentioned that engaging with users and informing them about their data ownership to some extent solved the privacy concern problem, another solution consumer stakeholder 6 mention is having mechanisms for users to control the access to BCI data:

*“You have to be careful not to leave that window open when they don't want to. But as long as they are given the opportunity to shut this window, and it is absolutely at their discursion then I feel that everything is possible.”*

(Consumer 6 - Academic commercialising, May 2017)

Consumer stakeholder 3 also points out that engaging with users is required to solve privacy concerns:

*“I: So it's really you engaging with people and letting them try. E: I think that engaging with people. Yeah correct.”*

(Consumer 3 - Technical sales, November 2016)

While the above comments do not provide any concrete solutions to concerns, consumer stakeholder 2 provides the solution of following proven standards in other technologies.

*“So they are concerns but you know, there are, in a sense, it's a bit of a solved problem because there are so many different approaches that have been tried in consumer technology and consumer information technology.”*

(Consumer 2 - Chief Scientist, November 2016)

The above comment is made when talking about using participant-centric consent and specifically the sage bio-networks version of this. In a similar way, consumer stakeholder 6 mentions that regulation from other technologies can show the direction that BCI regulations should take:

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*“No I mean, the regulation that says that a buss should be equipped with mechanisms to enable a person in a wheel chair to get on the buss is totally different regulation than what we would need to have for BCI, but the same concept is gonna hold.”*

(Consumer 6 - Academic commercialising, May 2017)

While the comments above suggest solutions for problems caused by BCI technology, the following comment suggests that BCI can solve part of the digital divide problem:

*“And I actually may be almost contradicting myself somewhat, is that I believe that most humans in terms of this type of control, have the same potential. Because it is not academic, and it's something that can be learned”*

(Consumer 1 - Founder/CEO, October 2016)

In addition to this, consumer stakeholder 1 mentions that introducing BCI in schools could be a solution to part of the digital divide, as well as improving the lives of future generations:

*“Schools, yes. The educational system needs to get involved. Because it starts early, and the earlier you can train the children to deal with life, the better.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 also comments on BCI being used in a solution to train prisoners to handle aggression and improve their ability to stay calm:

*“So the only way to complete the film, is to train yourself to become less responsive to deliberate aggression. And the results have been amazing”*

(Consumer 1 - Founder/CEO, October 2016)

Finally consumer stakeholder 4 mentions that their solution to potential bad impact from BCI devices on the public:

*“Because in this fact I could see a potential for people to get the data and which might affect them in a bad way. So we would rather wait with this either to develop it as a medical device or [deliver it] within the research field, than to take it out.”*

(Consumer 4 - CEO, April 2017)

The self-restriction above however is something that only appears to be used by consumer stakeholder 5. Overall consumer stakeholders have a wide variety of solutions to ethical concerns. These solutions range

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from policies to follow to technical solutions. One of the consumer stakeholders mentioned engaging with users to solve the problems with the technology.

### 4.4.2.8 Customer feedback

Consumer stakeholders had some statements that showed their reflections upon customer feedback.

Consumer stakeholder 1 mentions that user feedback can be very different due to personal preferences and that this is something consumer stakeholders have to manage:

*“Like we have had a few people say look I really don't like the colour black, but it's like yeah but you hug trees and I don't really like wearing flip flops to meetings, but hey, we are all different right.”*

(Consumer 1 - Founder/CEO, October 2016)

*“So that is a personal opinion, whereas when someone came back and said actually why don't you put your best selling apps first. And why don't you put recommended features and you know, you didn't have a telephone number on there, that would be really useful.”*

(Consumer 1 - Founder/CEO, October 2016)

Interestingly consumer stakeholder 1 appears quite dismissive of feedback that is personal, and very open to feedback regarding their website which could increase the usability and downloads. The above sentiment that some user feedback is useful, and that people will be of a different opinion is something further explained by consumer stakeholder 6:

*“Absolutely, you know, a medical doctor that has received a lot of medical education is very different than a consumer who just wants something very very simple to work with. Otherwise it's simply, you know no one reads manuals anymore. So you have to take that into account, you have to be [inaudible] explanatory and explain what to do. But at the same time we need to maintain the sophistication that you want to maintain there.”*

(Consumer 6 - Academic commercialising, May 2017)

Another interesting thing to note from the comment above is the statement that no one reads manuals anymore. This is a sentiment consumer stakeholder 2 mentions as well in the following comment:

*“Before they get frustrated, so you have to make something happen very quickly and that requires tremendous amount of user experience research and testing, and it limits to some extent the depths to which you can go initially.”*

(Consumer 2 - Chief Scientist, November 2016)

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The topic of user feedback is something consumer stakeholder 2 has reflected upon in terms of assessing technology as well. Consumer stakeholder 2 believes that user reviews are better at identifying the usability and ease of access for technology than media reviewers and scientists:

*“So you know, Amazon reviews are generally a better way of looking at something, rather than some tech reporter trying something for 5 minutes at the consumer electronics show.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 is pointing out that a broader user perspective of the technology might be more useful to accurately describe the technology. Consumer stakeholder 1 also mentions that focusing on individual users feedback can be problematic:

*“So, everyone's different I guess, so there is always going to be people who are going to be comfortable with it and there are going to be those that are going to be uncomfortable”*

(Consumer 1 - Founder/CEO, October 2016)

The comments in this section suggest that making changes based on user feedback can be difficult, due to the differences between people, consumer stakeholder 2 suggest that when they were trying to move away from biofeedback in terms of numbers, they had to approach the change gradually to avoid negative user feedback:

*“And this is, you know you have to make the change gradually, you can't make all the numbers all go away all of a sudden because people get upset.”*

(Consumer 2 - Chief Scientist, November 2016)

While consumer stakeholder 2 appears to have a controlled direction for making changes, consumer stakeholder 3 mentions that they were lucky they chose the material for their sensors that they did which suggest it was not based on user feedback:

*“And we, along the way, I guess, you know, [INAUDIBLE] came along, [INAUDIBLE] also started to create sensors, that are on the wrist and I think they had some issues with their sensors too so. I was like, I think we were lucky that we made that decision I think”*

(Consumer 3 - Technical sales, November 2016)

In this section, the topic of user feedback was described. The reflections on user feedback show that it is both seen as useful to improve their products and the ability to sell products when it is public reviews. But user feedback can also be problematic to deal with as some of the feedback can be personal.

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### 4.4.2.9 Company responsibility

Only consumer stakeholder 1 and 2 showed reflections on company responsibility. Both comment that the consumer industry should focus on making the technology more accessible and understandable:

*“I don't know if there is anything specific in that way, but I think that, one of the things, that my industry needs to do better for the consumer, is to hand hold them better, through the technology and through technologies like this”*

(Consumer 1 - Founder/CEO, October 2016)

In addition to the comment above, consumer stakeholder 1 mentions that having been in the industry for a long time, can be an impeding factor for keeping this in mind:

*“The real problem is the difference is we have been developing it for years, they haven't. So you kind of, when you are talking about it, you almost feel like you are repeating yourself for the 9th million time, but for them it is still the first time.”*

(Consumer 1 - Founder/CEO, October 2016)

While the comment above suggests that consumer stakeholder 1 believes the responsibility to inform the users is something companies should embrace, the following comment shows that consumer stakeholder 1 has reflected upon the impacts of the settings on when this responsibility transfers to the user:

*“No, because most of my stuff is entertainment or if it is training, your consent was you willing to be putting the thing on your head. But because we don't do it in a lab or a hospital or a controlled environment it's all about doing it yourself, and where it is done in a controlled environment or in a lab or used in that way, by a psychotherapist.”*

(Consumer 1 - Founder/CEO, October 2016)

The comment shows that once a user has agreed to use the device, the responsibility has moved from the company to the user. The comment also suggests that once a third-party stakeholder has taken on the task of using the device, the responsibility to inform the user is transferred to the third-party stakeholder. Consumer stakeholder 2 mentions that there is a risk of providing misinformation to users, but that even so, providing as much information as possible is the responsibility for the consumer industry:

*“So you know I supposed there is a bit of a risk of misinformation, I think ethically it is, manufactures of consumer BCIs should concern themselves what they are telling their consumers and their users. And they should try to impart as much information as is reasonable.”*

(Consumer 2 - Chief Scientist, November 2016)

## Reflections and analysis of stakeholder comments

The goal for consumer stakeholder 1 is, however, to keep their product cheap and customizable so that it is accessible:

*“So, our objective was I guess a little bit simpler. It is, keep it cheap, so accessible, make it affordable, make it customizable, so that way people don't need to buy different headsets”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 hereby shows that they reflected upon their responsibility and put accessibility as one of their main priorities. This could be directly related to the use case consumer stakeholder 1 has decided to focus on though as consumer stakeholder 4 decided to focus on a medical device first which could then be used in a consumer setting:

*“Yes, it's completely different. I mean, definitely the medical device it's very clear path that I have to follow and if I am going for a consumer device it's a different one and the informed consent is part of medical device and the term of use is part of consumer device so.”*

(Consumer 4 - CEO, April 2017)

This shows that consumer stakeholder 4 reflected upon the different possible use cases and concluded that it was the company's responsibility to make sure they followed medical device standards. It also shows that consumer stakeholder 4 also agrees that the responsibility the company has changed depending on the setting it is deployed in. Consumer stakeholder 6 also shows that reflections were made upon the impact of medical settings in terms of making sure information was provided to the users:

*“Of course in those cases it is extremely important that there will be no misinterpretation and that the information will be understood completely.”*

(Consumer 6 - Academic commercialising, May 2017)

Specifically, consumer stakeholder 6 is commenting on the use case for using BCI data in a setting with your personal doctor. This shows that consumer stakeholder 6 believes that the setting of a medical use case, makes it important that the company develops systems that allow very little misinterpretation. Overall consumer stakeholders are of the opinion that consumer developers have responsibility for informing their users of how the technology works. This responsibility can, however, be transferred to third-party providers such as therapists and doctors.

### 4.4.3 Researcher stakeholders

In the section above consumer stakeholders' comments were described and this section will describe the comments made by researchers that shows the reflections they have made upon ethical concerns. Overall

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themes for consumer stakeholders were identified to be, market projection, finding use cases, customer feedback, improvement in brain understanding, privacy, potential solutions and company responsibility, misinterpretation media coverage and consent, and BCI being different from other brain technologies. Overall seven of these themes were identified in the comments made by researchers talking about their reflections on BCI. These topics were, privacy, potential solutions, technology maturity, BCI being a different technology, consent, and while researchers did not talk about company responsibilities, they did talk about responsibilities various stakeholders should have or things stakeholders should do. Additionally, research stakeholders did not talk about market projections for BCI technology, however, some comments were made on the projection of the technology in general. In addition to these themes, research stakeholders also discussed the following themes: Accuracy, regulation, concerns about commercialisation. The following section will start by describing the comments made on themes unique to research stakeholders, followed by the comments made on themes shared with consumer stakeholders.

### 4.4.3.1 Accuracy

The accuracy reflections made by research stakeholders largely concern themselves with the consequences of incorrect data. Research stakeholder 1 in the comment below directly comments that the cost of mistakes should be directly weighed against the benefits a confident BCI reading would give:

*“Would a mistake of the BCI incur really high cost. Compare that, weighted by the confidence we have in the BCI results by the benefits if we actually used or get the correct output.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above is interesting as it shows a reflection from researcher 1 on what should be the primary ethical consideration for deciding upon using BCI data. In the following quote it is seen that research stakeholder 1 also made reflections on BCI comparing the accuracy of BCI data to that of other methods of interfaces:

*“But I mean, every gesture recognition, face interpretation voice analysis software. All these systems rely on statistics and machine learning and all of these allow misinterpretation by the machine or faulty classification results.”*

(Researcher 1 - Senior Researcher, November 2017)

While this does not give any indication whether research stakeholder 1 is satisfied with the accuracy of BCI and other interfaces, it shows us that reflections were made towards BCIs place within the interface market in terms of accuracy and ways to deal with it. Research stakeholder 2 comments that the nature of ways we deal with accuracy can be a problem as seen by the way false positives are treated in court:

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*"I think we have seen for example in court rooms how people misunderstand ideas like false positives and false negatives, we, I mean you can give, have a test that has very high false positive rate and people will still often convict on that basis without understanding the implications of having a very high false positive rate"*

(Researcher 2 - PhD, November 2017)

This statement seems to indicate a stronger stance from research stakeholder 2, than the statements from research stakeholder 1, on accuracy problem, as it clearly shows that researcher 2 has reflected on the problems accuracy issues can create. Research stakeholder 5 also commented on the issue of accuracy and showed having reflections on the cause for the accuracy problems. Unlike research stakeholder 1 and 2 that did not mention the reason for the accuracy problems, research stakeholder 5 mentions the hardware as the root of the problem:

*"I think the, the problem is on the hardware. I: Oh really. R: Yeah yeah yeah, the hardware. You have better algorithm, the algorithms is something that you always do better. The hardware I think is the problem."*

(Researcher 5 - Masters Student, February 2018)

Where research stakeholder 5 appears to suggest that while improving the algorithms is something that will always happen, the underlying problem appears to not be resolved by that solution. Unlike research stakeholder 5, research stakeholder 7 appears to suggest that improving the software and making it more redundant could be the solution:

*"But basically my main point is, most of such systems can be built with a lot of redundancy in mind. If the, if the interface we use to communicate is not, is not precise enough at the end of the day we can always say that we have to repeat each input 5-6 times so we understand that the input is right. It depends on basically what use case you have for such a system. Is that, I guess that would be all for now."*

(Researcher 7 - Masters Student, February 2018)

It is interesting to note here that the comment above could indicate that research stakeholder 7 is thinking of BCI devices in the use case the stakeholder is intending to use it, which could explain why their concerns for accuracy are less oriented towards the hardware than the software as it is possible to limit hardware errors due to a limited use case. Overall the reflections made by research stakeholders on the theme of accuracy appear to all be in line with there being a concern to deal with. The cause of the concern appears to be debatable as well as the solution to this problem. Based upon the statements it also appears that what intended use case you have for the device influence your level of concern as was seen by the reflections made by research stakeholder 7 and 1.



#### 4.4.3.2 Regulation

The reflections upon regulation by researcher stakeholders are largely speaking of increasing regulation and are in most cases related to a lack of regulation. Some of the comments are related to the concerns there are with creating regulation and all stakeholders except stakeholder 1 showed reflections upon regulations. Research stakeholder 2 shows that reflections have been made regarding brain-computer interfaces by the following statement:

*“At least here in [COUNTRY] I think there is much more of an effort to understand where scientists are a little bit more involved lately with politics. Maybe that is a good thing. But I have to assume that politicians will be mostly ignorant about how brain-computer interfaces [actually work] and what they can do.”*

(Researcher 2 - PhD, November 2017)

The statement above shows that research stakeholder 2 is of the opinion that regulators will in most cases be ignorant towards brain computer and that it means that scientists need to be involved in the lawmaking process to clear out wrong assumptions about the technology. The same reflection was made by research stakeholder 3 which suggest that researchers looking at the concerns of BCI are required to make the regulations made fit the technology and concerns it might bring:

*“Concerns are for the future, so yeah it is a concern but I feel that as we go forwards, usually the lawmakers try to make, to prevent this stuff. And research stuff. Like I imagine your work also is trying to, bring the concerns into the seat, to or to us. So we can see and we can learn how to do stuff. Prevent it.”*

(Researcher 3 - Bachelor Student, December 2017)

In the quote above it is also interesting to note, that research stakeholder 3 sees the regulation problem as a future concern, as it shows that research stakeholder 3 can identify an ethical concern while justifying his ability to work on the technology. Research stakeholder 4 made comments also showing that researchers working on the technology are a way for concerns to be discovered and dealt with:

*“And there are no regulations, it's just that it, the consumers all of a sudden or some researcher see is happen”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

In the statement above research stakeholder 4, was talking about how researchers and consumers hacking consumer devices (not BCI devices) showed that companies were collecting data they should not due to missing regulation. The lack of regulation in terms of data handling was something research stakeholder 5 also commented on which coupled with the privacy section later in this section shows that privacy and data handling is something research stakeholders reflected a lot upon:

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*“Maybe one solution for that is to, make new laws about a neuro data that is acquired. I think is a good solution. For people to follow the rules, follow the [numos], the law of biomedical ethics in general.”*

(Researcher 5 - Masters Student, February 2018)

In the quote above it shows that research stakeholder 5 had reflected on ways to deal with data handling regarding BCI and is specifically suggesting using the law of medical ethics to cover BCI devices. Research stakeholder 2 from the comment below appears to have reflected upon the future of BCI technology just like research stakeholder 3:

*“Requires us to say, certain things are a public good, like I believe the internet now should be considered a public good. And the infrastructure for internet should be available everywhere just like we have telephone lines and roads in most places.”*

(Researcher 2 - PhD, November 2017)

In the comment above research stakeholder 2, is talking about the digital divide that might be created by BCI technology and shows that research stakeholder 2 has reflected upon technologies role in society and how it might change over time. Research stakeholder 2 also mentions that political and social intervention is required to make sure the technology or knowledge gained by using the technology is not misused:

*“And obviously having that kind of knowledge and being able to disseminate it is only a first step, the rest of it, or a lot of it is then political and social.”*

(Researcher 2 - PhD, November 2017)

The comment above is interesting because it shows that based on previous comments by research stakeholder 2 that there is an obligation in the mind of research stakeholder 2 for “good” people to acquire knowledge about technologies so that they can inform the political and social change. Research stakeholder 4 also shows having reflected upon societal changes:

*“I: So some regulations to enforce transparency is something you would like to see. 1:04:20 R1: This is what is missing, so, in society, you know, at the moment. So, there is no transparency.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

What is interesting about the quote above is that it shows research stakeholder 4 is looking at some of the problems with BCI being problems with society rather than a problem with the technology. Overall the statements above show a desire for more regulation by research stakeholder, research stakeholder 7 has one requirement for the added regulation which is shown in the following comment:

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*“People should think more about this, but as long as it does not translate into. Into too much idiotic bureaucracy as it sometimes happen.”*

(Researcher 7 - Masters Student, February 2018)

The comment above suggests that research stakeholder 7 have reflected upon some of the consequences of more regulation and points out the problem of bureaucracy which can halt researchers' ability to work with technologies. Overall research stakeholders are of the opinion that more regulation is required. Some of the research stakeholders' comments appear to be closely related to BCI technology, however, equally some of the comments are related to technology and society in general.

### 4.4.3.3 *Concerns about commercialisation*

Research stakeholder 2 and 4 showed having reflected upon concerns about commercialising brain-computer interfaces. While research stakeholder 2 commented on this topic, it was largely commented on by research stakeholder 4 which appeared to have multiple concerns regarding this topic. Research stakeholder 4 mentioned multiple times the problem of obfuscation in consumer products as the comment below is an example of:

*“That when you want to, well, do your own kind of experiments with it, it's all like, well. Nicely coded so, you can't get to the raw data so that you need to have a license of, like an academic license for [INAUDIBLE] into, euros.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The above examples are interesting because this problem appears to be caused by technical difficulties with a specific product rather than the consumer industry as products such as openBCI provide all available data without obfuscation for free. Research stakeholder 2's problem with the commercialisation of BCI appears to be more of an overall problem with the purpose of using BCI:

*“I think, a big question that is part of that is whether this BCI, whether you are experimenting with a BCI because you want to then later use it for some commercial application or if this is meant to improve the lives of patients like these down the line.”*

(Researcher 2 - PhD, November 2017)

The comment above is interesting because it shows the emphasis research stakeholder 2 puts on the intent of the BCI usage and that BCI usage for improving the lives of patients are put in higher regard than commercial applications. In a similar fashion research stakeholder 4 comments on his disregard for BCI usage that is used to research the psychology of people to make them buy more:

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*“And it's not really research, it's more, you know, in a sense driven to understand more of the psychology, but also how to, basically influence the behaviour of people to buy more into the, into the capitalist consumer society. And I think that is a very bad way of doing business.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

These two comments by research stakeholder 2 and 4 are interesting because it might indicate the picture these stakeholders have of commercial BCI developers. Overall this topic is dominated by research stakeholder 2 and 4 and show concern for consumer stakeholders' impact on BCI technology. It also shows that specifically research stakeholder 4 is of the opinion that consumer stakeholders' intention for engaging with BCI technology is immoral and based on greed.

### 4.4.3.4 Projections

Just like consumer stakeholders made projections on the market of BCI products, research stakeholder showed to have made reflections upon the future of BCI devices. Overall the comments include an inherent uncertainty which shows in the comments that are less precise and confident compared to the comments made by consumer stakeholders. Some of this uncertainty can be seen in the comment below by research stakeholder 2:

*“that I think, by definition is something that we can't really understand because it would, right, the sum of human and AI is probably greater than either of those individually put together so, I don't think that we could really even speculate about what that would mean, if it gets to that point.”*

(Researcher 2 - PhD, November 2017)

The comment above shows that research stakeholder 2 has reflected upon the combination of AI technology (in this case using BCI technology to integrate AI into human entities) with other entities and how that creates uncertainty in our ability to predict what will happen. This comment was followed up by a comment about it being certain that this would change how we perceive ourselves. The combination of uncertainty in one aspect of ethical concern and certainty in another part of the topic can also be seen in the following comment:

*“And I don't see, I mean, clearly the potential for humans to have neuroenhancement can be enormously positive. Right, we could advance our society and ourselves, perhaps much more quickly than before. And in some sense maybe it's kind of inevitable.”*

(Researcher 2 - PhD, November 2017)

The comment above shows that research stakeholder 2 is certain about the potential that could be had with the use of neuroenhancement, but also the uncertainty in what this potential is. It is also seen by this

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statement that a sense of inevitability is expected in the advancement of technology. The uncertainty in projecting neuroenhancement is echoed by research stakeholder 1 with the following comment:

*“So I think, most, most thinking about that is probably, from my point of view, guess work.”*

(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 1 followed up the comment above with a denial of discussing the topic because it was (as per the point above) speculations. The fact that BCI technology could change how we perceive ourselves is something research stakeholder 7 agreed with indirectly by the following comment:

*“That is, at least some of the religion really shows epiphanies experiences, enlightments and stuff, they can be explained through neuroscience and some people still don't, are not sure about how to feel about this. I still am not sure how to feel about this.”*

(Researcher 7 - Masters Student, February 2018)

The comment above is also interesting because it shows that research stakeholder 7 have had reflections upon the stakeholder's own perception of humans due to the exposure of BCI technology and neuroscience. It is also interesting because it shows an ability to push away the concerns the stakeholder has about what it means for spirituality and keep working in the field of neuroscience. Research stakeholder 7 also mention the uncertainty in the development of technology usage as other stakeholders mentioned:

*“I'll be honest, I did not really think too much about this. So like any technology can be used in a different way. And also, one thing which history always does is that. It's not really easy to see how it will be used. So for example it was easy to see for the atomic bomb or maybe, it was clear that it could used differently. But it is not always obvious.”*

(Researcher 7 - Masters Student, February 2018)

The statement above is interesting as it appears to be that research stakeholder 7 is unsure about the stakeholders' stance on whether it could be predicted what technology could be used for, even though it appears that the stakeholders' intuition was that not everything can be predicted. This is then used as a justification for working with BCI as it is not possible to predict what the technology will be used for. Finally, research stakeholder 2 makes the projection that BCI technology will be used as cell phones are today:

*“I would suspect that, well, even us who were, who grew up maybe without cell phones for half of our lives, wouldn't really function too well without a cell phone now. Right?”*

(Researcher 2 - PhD, November 2017)

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The comment above is interesting because it shows that the concern there is regarding technology having a prominent role carries over to BCI devices. Research stakeholder 2 carries on with this comment saying that BCI devices might be a bigger problem in terms of reliance because they often have a therapeutic role which could make the loss of a BCI device more harmful than the loss of a recreational or work device such as a cell phone. Overall research stakeholders are of the opinion that projections of the future are uncertain, and one stakeholder even said that some of the projections were guesswork suggesting that it is not useful.

### 4.4.3.5 Solutions

Research stakeholders showed that they have made reflections on solutions to problems with BCI systems just like consumer stakeholders. As previously mentioned in the section regarding reflections upon regulation, one of the solutions suggested for privacy concerns are political solutions, research stakeholder 2:

*“The political solution I think is very similar to whatever the political solution is to regaining some sense of privacy on the internet and on your cell phone and things like that which seems like it has not been figured out yet.”*

(Researcher 2 - PhD, November 2017)

The comment above is interesting because it shows that research stakeholder 2 finds the current political movements (GDPR in the EU for example) to work with privacy concerns, are applicable to BCI devices as well. The comment below is also interesting in that regard as it shows that research stakeholder 2 has reflected upon different solutions to privacy concerns:

*“I would say both. I don't know enough about computer security to offer technical solution, but I would have, I would be interested in whether it would be possible to somehow prevent or encrypt the data in such a way that your brain activity couldn't be just sent off to some other server without you knowing, and analysed in ways that you weren't intending for it to be analysed.”*

(Researcher 2 - PhD, November 2017)

The comment above suggests that while research stakeholder 2 is not able to provide a technical solution, the stakeholder can identify it as a possible solution and appears to be suggesting that both solutions should be employed. When talking about BCI being more widely used research stakeholder 5 mentions that access and usability is a concern that can be solved by commercial developers making cheaper and easier to use products:

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*“that's, an answer that the companies should give. If you know what I mean. The big companies have to do. The BCIs simple enough for persons with disabilities access to it. For the rehabilitation. Problems. [...] Yeah, I think that would be a good solution. Easier access, cheaper access and easier to use BCIs.”*

(Researcher 5 - Masters Student, February 2018)

This comment is interesting as it shows an ability to identify the concern of a digital divide, but research stakeholder 5 puts the responsibility on the commercial BCI developers to come up with the technical solution. It is also interesting that stakeholder 5 is specifically concerned with commercial products used for therapeutic purposes which suggest that research stakeholder 5 puts special emphasis on access for people using it for this reason. Research stakeholder 1 also has this purpose in mind while making the following comment:

*“But that would still be better than for all the other treatments people get where they don't have any chance of back-channelling what they, or give feedback what they feel about that treatment.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above is interesting because it shows that research stakeholder 1 sees BCI as a solution for people that have been unable to communicate that they do not want certain treatments to communicate this to the people treating them. It is specifically interesting because it shows a willingness to perform treatment without consent if it provides the patients with a possibility to give consent or refuse treatment. Research stakeholder 2 also shows to have reflected upon the usage of BCI without the consent of people or directly against people:

*“It's a difficult question like a lot of things, the more people are aware about possibility and how it would work, can allow people to guard against it.”*

(Researcher 2 - PhD, November 2017)

The comment above is interesting in the sense that it shows that research stakeholder 2 is of the opinion that increased knowledge about BCI is the solution to the device being used in nefarious ways. It is interesting because it does not appear that research stakeholder 2 takes into consideration that the additional information itself could be used in nefarious ways. Overall this section shows that BCI researchers see both technical solutions, regulatory solutions, but also commercial solution as the way to deal with some of the concerns surrounding BCI technology.

### 4.4.3.6 BCI compared to other technologies

Research stakeholders commented on BCI and how it differs or are similar to other technologies. Overall these comments do not fall into either category and the consensus seems split for research stakeholders.

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Research stakeholder 1 mentions that the idea that we have familiarised ourselves with other modes of interfacing such as voice interfaces makes it easier for users to understand the technology:

*“most, basically nobody has exposure to BCIs on a regular basis. But many of us, at least have access to voice enabled devices. And I think that makes a huge difference.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above is interesting because it indicates that research stakeholder 1 sees the problem of BCI technology being a lack of exposure when it comes to solving issues of people misinterpreting or mispredictions what is possible with the technology. The following comment also shows that within the category of BCI devices there are also nuances which research stakeholder 1 is aware of:

*“Of course you could always use medical grade sensor technology etc, and that would not be required for, for something that would imagine could be a mass market BCI.”*

(Researcher 1 - Senior Researcher, November 2017)

This comment is interesting as it shows that research stakeholder 1's understanding of what a BCI is and what the technology can do, is to some degree coloured by which use case the BCI is for. While the statements from research stakeholder 1 do not directly answer the question as to whether BCI technology is different from other technology, the following statement from research stakeholder 1 makes that clear:

*“There are many other technologies which basically go the same route or could be misused in the same way.”*

(Researcher 1 - Senior Researcher, November 2017)

Similar clarity to the statement above from research stakeholder 1 is the following statement by research stakeholder 2:

*“I think brain-computer interfacing is in a way, fundamentally different in that. There is a real possibility that it will change us. Uhm, especially going back to the beginning talking about the long term possibility of integrating AI into our brain. I think that does fundamentally change us.”*

(Researcher 2 - PhD, November 2017)

The comment above is interesting as it directly provides BCI with features other technology does not have in the mind of research stakeholder 2. While research stakeholder 2 appears to have concerns about what BCI could potentially do in the future, research stakeholder 4 compares BCI devices with their experience with virtual reality devices:



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*"We had more complains with, when we used the oculus rift."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The statement above is interesting as it appears that research stakeholder 4 appears to be factoring in user feedback to his evaluation of how problematic the technology might be, and it appears that research stakeholder 4 based on a comparison with technology that is also commercially available justify the usage of BCI devices. The following statement could be a step in the opposite direction for research stakeholder 4:

*"Then if you allow BCIs in research, as we do right now, then at the same time we should also allow the entry of hallucinates in research. And in let's say research institutions. Because for me, it's the same thing."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

It is important to note here that research stakeholder 4 based on the complete interview it appears that this stakeholder would be for an ability to research hallucinates. This, however, is unclear as research stakeholder 4 was not directly asked if that was the case. Similar to research stakeholder 1 and 2 is research stakeholder 7 very clear about the opinion that BCI technology is not different from other technologies which are shown in the following two comments:

*"I think that most of what has been said about the topic would still apply to BCIs as household items."*

(Researcher 7 - Masters Student, February 2018)

*"But I cannot think, I cannot think of any, any BCI specific things about it."*

(Researcher 7 - Masters Student, February 2018)

The comments above are interesting because unlike research stakeholder 2's comments these comments put BCI technology in the same category as household items, which increases the scope of what type of technology BCI devices fit in for research stakeholders. Overall research stakeholders are of the opinion that BCI technology is not much different than other technologies. One stakeholder was not of this opinion, but this comment appeared to be different than most of the other stakeholders.

### 4.4.3.7 Privacy

The following reflections upon privacy show that research stakeholder 2 has spent some time reflecting upon the terms in societal ways. Research stakeholder 2 specifically mentions that both users and developers need to be aware of the lack of privacy technology can bring:

*"So, I think, when we are developing these technologies, both the developers and the users needs to be aware that someone is watching."*

(Researcher 2 - PhD, November 2017)

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The comment above is interesting because it shows that research stakeholder 2 is putting responsibility in both the developers and users to behave accordingly when dealing with BCI technology. Research stakeholder 2 also adds the following comment to the topic of privacy:

*“I think you just have to start with the assumption that, whether it's true or not, that someone is recording this brain activity and monitoring what I am doing with the system. Particularly if the system is connected to the internet in any way.”*

(Researcher 2 - PhD, November 2017)

The quote above is interesting because it shows that the trust that your privacy is by design implemented into systems should be abandoned according to research stakeholder 2. Similar research stakeholder 1 mentions that just like image analysis has developed and made what could be analysed on video more extensive, so would the development for BCI technology:

*“Maybe you would say the same thing, that you could analyse things in the future that you might not know now that you could. R: Yeah, that's probably the case, that's probably true. I mean for, no yeah I would agree with that.”*

(Researcher 1 - Senior Researcher, November 2017)

This comment is interesting as it not only projects the direction for BCI analysis but also puts BCI in the category as other monitoring technology which could indicate that they follow the same development projection and adoption. In general, the research stakeholders in this section were of the opinion that privacy concerns were a part of our world and everyone had to keep it in mind, which also includes BCI users and developers.

### 4.4.3.8 Technology maturity

In the same way, as consumer stakeholders mentioned their reflections upon the maturity of BCI technology did researchers mention the state of BCI as something they had reflected upon. Research stakeholder 1 was the research stakeholder that mentioned this the most and came with examples of how other technologies are more mature:

*“So for example voice analysis software has come a really long way. So now, every smart phone you buy has really nice working voice or speech recognition software for example.”*

(Researcher 1 - Senior Researcher, November 2017)

This comment is interesting as the usage of voice and speech recognition has fairly recently become something average consumers expect in their products which could give BCI developers a recent

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technology development to compare BCI technology to, which appears to be what research stakeholder 1. Research stakeholder 1, however, comments on the maturity of BCI technology as a problem in terms of comparing the technology with other technologies:

*“But, it's really hard to compare so of course I think expectations are different between the two, but that is probably due to the very different maturity level, of maturity and different levels of user experience.”*

(Researcher 1 - Senior Researcher, November 2017)

This comment above is interesting because it shows that a direct comparison between the two technologies is not possible according to research stakeholder 1, which does not hinder someone from comparing the state of BCI to voice and speech recognition in a similar maturity state. This was also seen in the comment by research stakeholder 1 about the possibility that future analysis could potentially reveal more information that is currently available, just like with video analysis. Research stakeholder 2 points out another problem with the maturity level of BCI technology which is the hype that can be created in popular media around the technology:

*“Which is frustrating and brain-computer interfacing, I, I mean there are examples of how it has been hyped in popular media when in reality what we can do with BCIs right now is extremely limited and rudimentary so.”*

(Researcher 2 - PhD, November 2017)

This comment is interesting because it confirms the statement by research stakeholder 1 that the usability and maturity level of BCI is very low. Finally, the maturity level is used by research stakeholder 1 as a reasoning for not discussing certain ethical concerns such as side effects:

*“but as long as we don't have a clearer picture of what is actually possible, and what are, what would be the side effects, I think it's not useful to really discuss that.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above is interesting as it tells us based on the quote above and other quotes by research stakeholder 1 that this is a reasoning for disregarding the ethical discussion that is reused in multiple scenarios. In this section research stakeholder 1 and 2, were of the opinion that BCI technology was not very mature and this could be a concern.

### 4.4.3.9 Consent

Research stakeholder showed reflections on the topic of consent as consumer stakeholders did. Mainly two concepts were explored in these comments which is the concern of consent when it is not possible for the

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user to give it and the problem of getting informed consent when the information and technology are hard to explain in a way for average users to understand. The following comment shows that research stakeholder 2 sees BCI as a solution for locked-in patients' problem of giving informed consent:

*"Which, you know, once they, if it's a non-invasive BCI hopefully in that case then they would be able to type out with their p300 speller, please take the system off of me. And then you would have your answer. It's a complicated issue though because, you know as you kind of allude to, often they can't give consent by themselves."*

(Researcher 2 - PhD, November 2017)

The comment above is interesting as it shows that research stakeholder 2 is interested in using the BCI device against the patients desire in order to verify that this is indeed the position of the patient. This is interesting as it shows that research stakeholder 2 values the accuracy of the patients' consent over the loss of autonomy of the patient experience. This idea is further supported by the following statement by research stakeholder 2:

*"Then perhaps it's worth taking the risk that they wouldn't want to be part of this experiment and that their caregiver has incorrectly identified them as someone who would consent."*

(Researcher 2 - PhD, November 2017)

In the comment above research stakeholder 2 also confirms the current way of getting consent and the problems this method of consent gathering. Research stakeholder 5 comments show that it is important for research stakeholder 5 to get consent from users before they use the BCI device:

*"Yeah. I think that the subjects MUST, with capitals, be informed properly. About the procedures, about the the performance of the headset, about what it will do. The techniques or whatever."*

(Researcher 5 - Masters Student, February 2018)

The interesting element about the comment above is the emphasis research stakeholder 5 puts on the idea that users need to be informed not only of procedures of the headset but also the performance of it. This importance is particularly interesting with the following comment by research stakeholder 4 in mind. Research stakeholder 4 is of the opinion that the nature of BCI data makes it hard for users to understand how information can be extracted from seemingly random lines of data:

*"And if it is, yeah getting their consent or yeah, you just want to, to let people play with it. Without them to fear, fear anything about, like, I didn't find any people that had like any issues with it, at all. Like this is looking into my brain or whatever, so that's already, sort of interesting to see I guess about, well how,*

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*adaptive, how people adapt it. Like, nobody sees, sees as their, if you can read their brainwaves, that, that is well. Strange. Because it's a random pattern and you can't see anything in it, but yeah. The idea is of course that you can see something in it."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comment above is particularly interesting with all of the comments above in mind as it shows that while patients or users might be able to use a BCI to give consent of consent cannot be given in another way, the consent gathered might not be informed consent as the technology could act as a black box for users making it unlikely that they understand what the device does. The research stakeholders in this section are of the opinion that consent needs to be achieved and one stakeholder even mentioned that BCI technology could be the only way to access the level of communication required to gather consent.

### 4.4.3.10 Community responsibility

Consumer stakeholders had reflections on what should be done, and the responsibilities companies had. Similarly, does research stakeholders reflect upon what researchers should do with BCI, however, research stakeholders also mention what other stakeholders should be doing and that shows their reflections upon that. The following comment by research stakeholder 1 shows how invasive BCI devices should be used:

*"So you would never use invasive BCIs if there is no pressuring medical implications to do so."*

(Researcher 1 - Senior Researcher, November 2017)

This comment is an interesting comment as research stakeholder 1 does not only say that in research stakeholder 1's mind is invasive BCI only applied when pressured by medical implications but it also indirectly shows that research stakeholder 1 does not think these should be used outside of medical settings. The following comment by research stakeholder 2 also shows that there are certain use cases BCI should not be used for according to research stakeholder 2:

*"Do we want to have systems that, where your BCI is also, used in terms of logging into your bank account.*

*Is that a safe thing to do? Is that a wise thing to do? 17:20 I am not so sure, although obviously it's a possibility."*

(Researcher 2 - PhD, November 2017)

The comment above is interesting because it shows that research stakeholder 2 is not confident in the security of BCI devices. It is however not clear from this comment why such use case could be problematic. It is not clear whether the security problems would be caused by BCI devices or whether the insecurity of bank technology is something research stakeholder 2 advice against integrating into BCI devices. Research stakeholder 5 also comments on what BCI devices should be used for with the following comment:

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*“I think that, the applications should focus on the persons with autism, or ALS and this problems. What I mean is that, we don't have the need, it's good, but we don't have the need for neuro games or BCI game developing or whatever. I think that the government and the researchers have to mainly focus on rehabilitation of cognitive or neurological relations. From my perspective.”*

(Researcher 5 - Masters Student, February 2018)

It shows that research stakeholder 5 values the need of improved tools for treatment of people over the value of improved entertainment and other consumer usages which could have potentially larger userbases than a treatment or communication tool for patients. Research stakeholder 1, however, values that the research tools developed gets used:

*“But if in the end you build a BCI which no one can use because there is always technology which solves the same problem in a better way then, all your research is basically. It doesn't go anywhere, so I think it is an important thing.”*

(Researcher 1 - Senior Researcher, November 2017)

It is important to note here that research stakeholder 1 does not necessarily disagree with research stakeholder 5 in the direction BCI devices should be developed, but that research stakeholder 1 acknowledges the importance of the device is being used. You could argue that research stakeholder 1's comment even supports research stakeholder 5's point as keyboard, mouse, and similar communication devices for consumers at the current time works better than BCI devices. While the above comments show reflection upon the direction of BCI devices the following comment shows that research stakeholder 1 has reflected upon the responsibility of BCI providers:

*“So this information must be available and if you would, if you are an reasonable supplier of a BCI would, you would give this information to your users.”*

(Researcher 1 - Senior Researcher, November 2017)

While the comment above does not show what kind of enforcement that should be applied to make sure BCI providers give the information required by users, it does show that research stakeholder 1 puts the responsibility of informing users on the BCI provider rather than the research community or the users themselves. The comment below shows that research stakeholder 4 puts some responsibility on the user (or in this case the researchers) of the BCI devices.

*“I think that is the best anyway to do with any kind of product that comes from industry, just take it apart and reassemble it they way you want it. And I hope that, basically, and this is a vision, that I have. That*

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*anybody in the world like, in any level of knowledge, or schooling, what do you have. That is able to make their own products.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Specifically, this comment shows that research stakeholder 4 is of the opinion that the users of any technology are responsible for modifying the devices to make them usable for that specific purpose. This opinion is interesting as this comment combined with other comments from research stakeholder 4 on the frustration obfuscation made by BCI providers implies that research stakeholder 4 is of the opinion that once a BCI device has been bought or acquired the ownership of the BCI device is completely the user. This removes the responsibility for the BCI developer but also increases the potential autonomy of the users as they are free to use and modify the device as they see fit. The final 3 comments are about the responsibility of researchers. Research stakeholder 3 points out that it is important that the side effects of BCI devices need to be researched:

*“I think it should be researched, and the side effects should be researched very well and like, it is always kind of a concern when you, when you start [picking] someone’s mind, be it psychology or be it like medical stuff.”*

(Researcher 3 - Bachelor Student, December 2017)

While the comment above might not be very interesting in regards to a researcher wanting more research to be done, it shows that research stakeholder 3 inherently values the mind and that the brain is of special importance to research stakeholder 3. Research stakeholder 2 also thinks that more research should be done on BCI devices and specifically the ethical concerns of the technology:

*“And so at some point we are going to need more than just BCI researchers thinking about these problems, which is why it's a good thing that you're thinking about these problems.”*

(Researcher 2 - PhD, November 2017)

This is interesting as it shows that researchers not directly connected to the ethical discussion surrounding BCI devices acknowledges the value of researching these concerns. It is also interesting as it shows that research stakeholder 2 is not of the opinion that the ethical concerns surrounding BCI devices are a hindrance to working with the devices. Similarly, research stakeholder 2 is of the opinion that political efforts have to be made to react to ethical concerns:

*“That's the best I can say on that. I think it's, it's a very political thing that needs to happen in that sense as well.”*

(Researcher 2 - PhD, November 2017)

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Once again the comment above is interesting because it shows that the lack of political efforts to address these concerns is not a hindrance to working on BCI devices. This section, in general, shows that research stakeholders can identify a large variety of responsibilities different stakeholders in society needs to take upon themselves. These responsibilities range from informing the users of the technology, to society not using invasive BCI technology when it is not absolutely required.

### 4.4.3.11 *Humans are the problem*

When reflecting upon the ethical concerns of BCI, some of the stakeholders would rather put the responsibility for these concerns on humans using the technology than on the technology itself. This could result in comments such as it being the shape of the human skull that was the reason for poor connectivity, or that technology developed for war was because of the military. In this section will these reflections be further explored. Research stakeholder 2 is of the mindset that the intent of the people developing is the problem that causes misuse rather than the technology:

*“The way I look at it is people with more like, I guess I can say nefarious goals, will develop these technologies with or without people who have more positive goals in mind. And so I think it will take people with, who care about the wellbeing of people, more than exploiting people to be able to understand the technologies well enough to point out how and when, and why and where they are being used. Misused.”*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 also uses this as a justification for continuing the development of BCI devices, by saying that people with good intentions will be required to fight back the people with nefarious intentions. Research stakeholder 2 also reflected upon the impact of war or the military on the development of BCI technology:

*“I don't see that, that is really a possibility. Aside from you know, even war on a global scale may not greatly slow it down because perhaps militaries will then take over in a greater sense the development of those technologies which would be terrifying.”*

(Researcher 2 - PhD, November 2017)

This reflection shows that research stakeholder 2 believes that the development of BCI technology will be based upon the people that work with it. This suggests that the technology itself does not inherently have use cases or future use cases that will be explored, but this development will be directed by the humans involved. Similarly does research stakeholder 2 think that the problems associated with AI or our ability to enhance our brains are a result of problems with humans:



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*“The problem is not the AI the problem is that we are people who collectively would allow those people to die on the streets without doing anything to stop it. That's the problem.”*

(Researcher 2 - PhD, November 2017)

*“So, I still see it as the problem is us, not the technology. Perhaps if we can enhance our brains with increased ability to empathize with other people. Maybe that would be a better start than improving cognition.”*

(Researcher 2 - PhD, November 2017)

In the last comment, research stakeholder 2 even assumes that the technology could be used to solve the problem of humans not being empathic enough. Research stakeholder 4 is also of the opinion that bad BCI devices are developed by bad designers:

*“Because it's not, it doesn't feel natural because it's designed by lousy engineers. And terrible designers, so it will never give you the full benefit of your regular physical embodiment, because it's an add-on.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

This shows that research stakeholder 4 is, upon reflection, concluding that while the potential for BCI devices allows them to become a physical embodiment and extension, the poor designers of BCI devices are the reasons they are not. Similarly, research stakeholder 4 believes that the nature of human behaviour will be the reason that these providers of BCI technology will continue to sell devices:

*“I think because, you cannot, you cannot stop it either. Because, there is just no way to stop it. I mean, we are people and we everything. You know, just throw them some food, and they will eat it, so.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The nature of humans is according to research stakeholder 4 unable to reject poor products. The nature of humans is also used as a justification for why computers are becoming more invasive in the lives of humans:

*“And that's the same with computers, but they are so dominant, technology has been made so dominant, that we think that is the ticket to ride. And I think we should curb that. We should really curb it and say no, it's just another rotten piece of furniture, you know, and at one point, don't consider it too much of importance.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 is largely blaming the designers of the BCI devices for poor performance and the users for accepting this development in BCI devices and technology in general. Research stakeholder 3 is

believing that the problem is people being too excited about using the devices which makes them perform badly:

*“If someone is trying way too hard it is going to be ba[d], it is not going to have a good results and if they are trying, if they are not trying hard enough the results wont be good either so.”*

(Researcher 3 - Bachelor Student, December 2017)

This belief is used as a justification for developing methods to deal with people’s expectations and making sure that they are able to use the devices properly. Interestingly it is not used as a justification for developing more robust technology that can be used by both very motivated users and those that are not. Research stakeholder 5 is also expressing opinions that suggest that the stakeholder believes the problem is with humans rather than the technology:

*“But the problem was that the connectors couldn’t have the proper connectivity. Most possibly I think due to the morphology of the subjects skull or something. That was the biggest problem. The graphical user interface was pretty easy to use. I think everyone, even an old person could use it.”*

(Researcher 5 - Masters Student, February 2018)

The individual differences between humans were a problem that was difficult for research stakeholder 5 to solve. Interestingly research stakeholder 5 did find technical solutions to the problem of humans being unable to understand the interface for the BCI devices. This suggests that some human problems could be solved by technical solutions. Overall the section shows that research stakeholders are of the opinion that in a variety of issues the problem is with humans rather than the technology. Either human intentions are not good, or humans are not good enough to develop technology that is useful.

#### 4.5 Anticipation

In the following section the comments showing anticipation from consumer and research stakeholders will be analysed. The comments include anticipated concerns, but also the lack of anticipated concerns. The section will also include comments that show anticipated developments or changes to the technology or society which are not clear concerns, but rather show the stakeholders ability to anticipate future developments. The section will start with the consumer stakeholders’ anticipation comments, followed by the research stakeholders’ comments. Some of the topics discussed will be, privacy, digital divide, side effects, accuracy and concerns about commercialization.

#### 4.5.1 Anticipation overview

This section describes the overall summary of the following sections. The themes identified in the sections below will be put into a table to improve the overview of the considerations about anticipation described by stakeholders. The further discussion of what these findings mean will be described in chapter 5.

Table 7: Anticipation overview

Consumer stakeholders	Research stakeholders
<p><b>Accuracy</b> Concerns with both data accuracy and depiction of data which could impact the usability of BCI devices.</p>	<p><b>Accuracy</b> Concerns with accuracy were anticipated and this would impact usability and the digital divide.</p>
<p><b>Privacy</b> Privacy concerns were anticipated, and some stakeholders made decisions based on these anticipations. Some stakeholders anticipated BCI technology providing new aspects to privacy concerns.</p>	<p><b>Privacy</b> Privacy concerns were anticipated but were based on privacy concerns related to technology in general rather than BCI devices.</p>
<p><b>Consent</b> No concerns were anticipated, and in cases such as ALS patients, internal policies were used to deal with the concerns.</p>	<p><b>Consent</b> Concerns with consent were anticipated to be resolved with good information prior to usage, and some stakeholders anticipated BCI devices to aid with the consent in ALS and similar cases.</p>
<p><b>Regulation</b> An external concern that they had to anticipate and keep an eye on. The regulation was used as pointers for company decisions.</p>	<p><b>Regulation</b> Stakeholders anticipate regulation to be required and an ongoing process that will develop. Trust in policymakers is not very high though.</p>
<p><b>Digital divide</b> Two versions of the digital divide were anticipated. One version is the availability of the devices, and the other being users ability to use the devices.</p>	<p><b>Digital divide</b> No major concerns were anticipated in terms of the digital divide, neither in accessibility or ability to use.</p>
<p><b>Other technologies</b> Mixed anticipation whether BCI is similar to other technologies or different, and how this impacts the concerns around the technology.</p>	<p><b>Other technologies</b> BCI technology is not causing any additional concerns comparing to other technologies.</p>
<p><b>Invasive vs non-invasive</b> Invasive technology is very different, this is used as a justification for not being concerned about non-invasive BCI.</p>	<p><b>Invasive</b> Research stakeholders anticipate invasive technology to be dangerous and only be used in medical settings. One stakeholder showed interest in using invasive technology himself without a medical usage.</p>
<p><b>Enhancement</b> Most stakeholders do not anticipate the enhancement capabilities of BCI devices to be effective or noticeable. Those that do, anticipate problems with accuracy, side effects and the digital divide.</p>	<p><b>Enhancement</b> Research stakeholders anticipate that enhancement will not be possible or similar to health trackers which are not considered an enhancement.</p>

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<p><b>Expectations</b> Stakeholders anticipate users to overestimate the ability of BCI devices leading to high expectations and disappointment.</p>	<p><b>Media and public opinion</b> Research stakeholders anticipate that people's opinion of BCI devices will be shaped by media which often overhype the technology leading to disappointment.</p>
<p><b>Potentials</b> BCI devices have a big potential to improve our lives.</p>	
	<p><b>Use cases</b> Most good use cases will be in the medical field and rehabilitation of people with disabilities. There is an anticipated use case for nefarious purposes though.</p>
	<p><b>Commercialization</b> Two stakeholders are critical of the commercialisation of BCI devices. Part of this critic is based upon experiences with specific commercial products and their inability to deliver accurate interactions between the user and computers.</p>
	<p><b>Side effects</b> Mostly societal side effects were anticipated, some stakeholders, however, mention that the technology will continue to develop which will reduce the concerns for side effects.</p>
	<p><b>Concept of identity</b> Research stakeholders anticipate topics such as religion to be impacted by BCI technology. While some anticipate BCI to remove the ability for people to be religious some anticipate that religion will survive.</p>

Overall both stakeholder groups agree when it comes to anticipations regarding ethical concerns and BCI devices. A few themes commented on by researchers were not commented on by consumer stakeholders. Both stakeholders were anticipating problems with the accuracy of BCI devices being a concern for the usability of the technology. The research stakeholders did however also mention the accuracy being a part of the digital divide concern as well. Both stakeholder groups also anticipated privacy concerns, however research stakeholders anticipated most of these concerns being tied to technology in general, and some consumer stakeholders anticipated that some of these concerns would be specific to BCI technology. The consumer stakeholders also mentioned having taken specific actions based upon this anticipated concern. On the topic of consent consumer stakeholders did not anticipate any concerns as they anticipated internal procedures to deal with any concerns that might arise when dealing with ALS patients. Similarly did research stakeholders anticipate concerns to be handled with good information prior to BCI usage, on the

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topic of ALS patients however, research stakeholders anticipated BCI technology to be a solution for the informed consent concern associated with locked in patients with no ability to give consent otherwise. Regarding regulation both stakeholder groups anticipated it to be an ongoing process, however the conclusions based on these anticipations were different. Research stakeholder groups mentioned regulation as something outside of their control and with lack of trust in regulators, whereas consumer stakeholders saw it as something they were required to react to and used it to direct the decisions taken for their company. Consumer stakeholders were also anticipating differently than research stakeholders on the topic of digital divide. The consumer stakeholders were anticipating that both availability and usability concerns would be problems to overcome regarding the digital divide. Research stakeholders on the other hand did not anticipate digital divide concerns. Similarly does research stakeholders not anticipate BCI technology to be different from other technologies in terms of ethical concerns, whereas the consumer stakeholders were more split in their anticipated concerns regarding BCI compared to other technologies. These types of anticipations were also mirrored in the anticipation for invasive technology compared to non-invasive technology and the usage of BCI technology as enhancement technology. Either BCI technology were considered like other technologies such as health trackers, or invasive technologies were considered a different technology that was worse than non-invasive BCI technology. Consumer stakeholders specifically used invasive technology to justify their non-invasive technology to be less problematic and therefore less of a concern. Both stakeholders also anticipated that users not familiar with BCI technology would approach them with over hype and too many expectations to the technology. Research stakeholders mentioned the public media to be the reason for this. While both stakeholder groups believed the technology were over hyped at this point, consumer stakeholders believed the technology had great potential for improving our lives. Research stakeholders on the other hand were critical of the consumer stakeholders current use cases for their products and some research stakeholders based on personal experiences with a specific consumer product were very critical of the commercialisation of BCI products. The anticipation for research stakeholders were therefore that nefarious use cases of BCI technology would appear and that societal side effects would occur. Some research stakeholders even anticipated that BCI technology could impact religion. One researcher anticipated that the concept of religion would be hard to keep up, whereas another stakeholder anticipated that religion would survive BCI technology. The following sections will describe the analysis of consumer and research stakeholder comments further.

#### 4.5.2 Consumer stakeholders

Overall the following themes were identified for the comments anticipating or not anticipating concerns or problems with BCI: Privacy, enhancement, consent, digital divide, regulations, accuracy, expectations, invasive vs non-invasive, comparison to other technologies, and potentials. The following section will show that the degree and reasonings behind consumer stakeholders anticipated risks or lack thereof can range from extremely concerned to the extent that it forced actions, to not concerned at all. In some cases, the consumer stakeholders were upset that a particular topic was even considered a concern. One stakeholder was in particularly consistent with not being concerned which resulted in short yes and no answers when asked if this was a concern they had thought about.

##### 4.5.2.1 Privacy

Overall consumer stakeholders were not concerned with privacy besides a few cases, which will be described further in this section. Various reasons were given for either not being concerned about privacy concerns, one of which were the lack of BCI devices being connected directly to the internet:

*“If something is not connected, and doesn't have the potential to be connected. There is no potential to be hacked.”*

(Consumer 1 - Founder/CEO, October 2016)

The comment above is one example of the consumer stakeholder directly denying that there could be a potential concern. This could be problematic because while the device is not directly connected to the internet, the information that is captured by a BCI device can easily be stored locally and later accessed remotely which would nullify the stakeholders' reason for not being worried about privacy concerns. Consumer stakeholder 2 comments that the potential data that could be collected from BCI devices could be potential data about health information:

*“And the possibility of developing a behavioural or a brain bio marker for disease, so we have a lot of research partnerships aimed simply at that. Looking at, what are the kind of things that we can detect with brain signals.”*

(Consumer 2 - Chief Scientist, November 2016)

This distinction is significant for privacy concerns as health information in most cases are considered data that needs extra care in terms of privacy. Which is something consumer stakeholder 5 shows he is aware of and anticipate could be a privacy concern for BCI as well:

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*“Privacy is important because you can also understand from heartrate variability you can understand medical condition of a person.”*

(Consumer 5 - Neuropsychologist, April 2017)

*“You know things about him that he wouldn't reveal himself. So yes, in that aspect, you can get a lot of information about people by hacking a device that is on them, and if the recording stress levels and this I can see maybe problematic.”*

(Consumer 5 - Neuropsychologist, April 2017)

The two comments in combination show that consumer stakeholder 5 is not only aware and anticipate a privacy concern with bio-data provided by BCI technology, but also that unauthorized access could allow analysis of this data that was not intended by the user of the BCI device. Consumer stakeholder 5 also pointed out that the anticipated risk caused them to take actions to limit the risk:

*“And we already in the development you know, to keep the data as discrete as possible.”*

(Consumer 5 - Neuropsychologist, April 2017)

Consumer stakeholder 3 disagrees with the idea that unintended data provided via BCI devices is a potential problem at the moment:

*“I think the biggest thing is people think that we can soon be reading peoples mind and get credit card infos and I think those are things that are like out of what, like right now I don't think it's possible at all.”*

(Consumer 3 - Technical sales, November 2016)

The reasoning for consumer stakeholder 3 not being concerned as the comment above show, is that consumer stakeholder 3 considers the information collected to be extremely limited:

*“Uhm, so one thing is EEG is probably providing very limited information so. I don't think it's going to be too much, and you also, secure information by saying that it's. We are just [INAUDIBLE] maybe certain metrics like age, height, and sex or gender.”*

(Consumer 3 - Technical sales, November 2016)

While consumer stakeholder 3 does not think that the information collected is very rich, it is noteworthy that consumer stakeholder 3 still mentions that the information is being secured, which indicate that despite the lack of data collected (in the mind of stakeholder 3), the risk of privacy being breached was considered big enough to take measurements against it. The topic of BCI data being medical data is something consumer stakeholder 6 also mentions:

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*“When it is converted to medical information and medical conclusions [INAUDIBLE] then suddenly this consumer data becomes to be falling, or maybe not now, but we believe that it should be changed, to be falling under the medical regulations of data privacy etc etc and”*

(Consumer 6 - Academic commercialising, May 2017)

The comment above shows an interesting aspect of the perception of the data collected which is that while the data in itself is not medical data, but the data collected can be converted into medical data. The comment also shows that consumer stakeholder 6 anticipates the BCI data to eventually fall under medical regulations and privacy regulations. Consumer stakeholder 2 also mentions that BCI data as health data was so anticipated that they formed an organization to try and handle this concern:

*“The one of the ways we have worked around this. We have anticipated as a challenge, so we created something called the [NAME OF INITIATIVE], which is a non-profit entity, with a bunch of members of the industry.”*

(Consumer 2 - Chief Scientist, November 2016)

While consumer stakeholder 2 mentions the forming of a non-profit entity to handle this concern, consumer stakeholder 6s' solution is more in line with consumer stakeholder 3 by concealing the information from people we do not want to see it:

*“But just like the way we [solved it] in our home, we either have a curtain, or we can shut the window we can make it opaque, etc and we are, we have to be aware not to, [I don't know] undress or take a shower in front of the window in the case that someone else is moving, walking in the streets.”*

(Consumer 6 - Academic commercialising, May 2017)

Consumer stakeholder 6 however also anticipates that this might have implications which the following comment shows:

*“But the price that we pay is that we have the big company, one of the biggest actually read all our emails and they make a lot of conclusions from those emails.”*

(Consumer 6 - Academic commercialising, May 2017)

The topic of privacy for consumer stakeholders appeared to relate largely to anticipated privacy concerns in general and how someone might use that information to either know things about you that they would not otherwise (as seen in the comment above by stakeholder 6) or being able to manipulate you using this data as seen by the comment by consumer stakeholder 3:



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*"I mean, if it goes, for kind of a mind control, I think I would be kind of a scary aspect."*

(Consumer 3 - Technical sales, November 2016)

This was a concern anticipated by consumer stakeholder 2 in a previous comment as well, however, consumer stakeholder 3 only anticipate it to be possible, not that it will eventually happen:

*"That might be difficult, uh, be interesting but I don't think it's going to go that far."*

(Consumer 3 - Technical sales, November 2016)

The comment above is the way consumer stakeholder 3 is able to justify the collection of the data, as it provides consumer stakeholder 3 with a worst-case scenario that makes the collection of data they do seem innocent and very deprived of value. Consumer stakeholder 2 comments below another potential problem with BCI and privacy which is the collection of concealed information:

*"Uhm, I mean there is always, you know when it comes to BCI the one that always comes to mind is the lie detector or the brain lie detector. Or the, applications like covert information concealment, and the detection thereof."*

(Consumer 2 - Chief Scientist, November 2016)

This comment is interesting as it shows that consumer stakeholder 2 considers thoughts or the information held in the brain as concealed, which the BCI technology would then be a violation of this privacy. This statement is further supported by the following comment:

*"There are ethical concerns around lie detectors and the concealment of information and information, I guess you would call it sanctity and security in the individual"*

(Consumer 2 - Chief Scientist, November 2016)

This anticipated problem is particularly interesting because it is a problem that is inherited by BCI devices functionality. Because it is a technology that provides an insight into a previously inaccessible part of the body, it inherently breaks the privacy that was previously had.

This section has described the comments made by consumer stakeholders on the topic of privacy. It was shown that consumer stakeholders were aware of privacy as a concern and some anticipated this to an extent where they took actions to tackle this anticipation. It was also shown that the anticipated concern with privacy was met with various reasons for how it could be justified such as the information being low in richness and accuracy as well as being similar to the privacy concerns met in other technologies. Lastly, some comments were dealing with the usage of BCI technology to reveal covert information which shows that BCI technology could inherently have privacy concerns due to dealing with brain data. One comment

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touched upon the fact that we are okay giving up privacy when we are aware of giving up that privacy and what benefits we gain from it, as is the case with windows in our houses.

### 4.5.2.2 Consent

In general, the consumer stakeholders were not anticipating major issues in regards to gathering consent of their users. Consumer stakeholder 1 does, however, anticipate that consent is something that is important with the following statement:

*“So this kind of technology has really cool potential, in terms of where data collection can be made possible.*

*But that entirely relies on the individual being a willing participant, in that, at that time.”*

(Consumer 1 - Founder/CEO, October 2016)

This comment is important as it acknowledges that consumer stakeholder 1 finds it important to gather consent from participants when gathering data, it does not tell us much about what is required to gather consent though. In the following comment consumer stakeholder 1 also mentions that they expect other stakeholders to make efforts into making sure consent was gathered:

*“Then we expect the expert to administer their own controls.”*

(Consumer 1 - Founder/CEO, October 2016)

This comment is important as it shifts the responsibility onto a third party. This could also explain why the stakeholder does not give more details on why he anticipates the gathering of consent to be a topic of interest and how he plans to manage this as the responsibility for managing this concern has been put onto the third party. Consumer stakeholder 3 is a bit more specific about the process of gathering consent when it comes to ALS patients:

*“I guess we would have to take a consent right before they lose all their communication levels.”*

(Consumer 3 - Technical sales, November 2016)

What it shows is that a policy is being used to avoid the issue of gathering consent from ALS patients which is that such consent must be given before the patient loses the ability to do so. This will inherently limit the BCI developers from working with people that are in the later stages of ALS. When asked about whether this applied at all to their average consumer the answer was a clear no:

*“I: Okay, but I guess then, for your average consumer this is not something you worry about. E: No. “*

(Consumer 3 - Technical sales, November 2016)

This statement is perhaps not surprising as ALS is a niche case for BCI and the concern of getting consent from users however this was followed by the following comment:

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*“I mean, they definitely have the choice, I mean to put the EEG, the headset on or not, so I think they, that's the consent that they gave.”*

(Consumer 3 - Technical sales, November 2016)

The comment shows that the act of putting on the device is for consumer stakeholder 3 enough to warrant consent from the user. This shows that consumer stakeholder 3 does not anticipate any consent issues when it comes to the average consumer using a BCI device. Consumer stakeholder 3 was then presented with the question of whether things would change if a user did not feel like they had the possibility to say no such as in a lie detector test which consumer stakeholder 3 responded to by explaining that they do not directly administer such tests:

*“I mean whenever we are doing the, the [INAUDIBLE] department would definitely have to get consent so, I, I guess we don't experience such things at a day to day.”*

(Consumer 3 - Technical sales, November 2016)

While this could be used as a justification in the sense that the company itself is not performing lie detection tests, the fact that they provide the technology for those that do could be a potential problem consumer stakeholder 3 did not anticipate.

This section describes comments on the topic of gathering consent. Overall no consumer stakeholder anticipated the problem of gathering consent and where problems were identified, such as the case of ALS patients, policies were used as a tool to avoid the potential problem.

### 4.5.2.3 Regulations

Overall most consumer stakeholders anticipate regulations to be put in place. Most consumer stakeholders also anticipate this regulation to impact their BCI development either through impact upon material usage or safety precautions. Privacy is an area where consumer stakeholder 1 anticipate regulation to be put in place:

*“No, because, I don't understand where the risk potentially lies. I think regulation could be something along the lines of, you are not allowed to conceal it. So for example you go and you wear a cap and all of a sudden you don't realise but now your brain has been monitored without your knowledge. To me, that is wrong. Not because of what they could do with the data. But because it's an invasion of your privacy, so that to me comes under more kind of human privacy and natural law, rather than a specific technology based law. But I think it has to come under the same category.”*

(Consumer 1 - Founder/CEO, October 2016)

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While consumer stakeholder 1 anticipates regulation to be put in place to ensure privacy, a significant note to make is the comment that the regulation will be towards technology in general rather than BCI specific. This means that consumer stakeholder 1 could anticipate the methods other technologies employ to deal with new regulation could potentially be used by BCI developers as well. Consumer stakeholder 1 also mentions that the technology could become a device people would rely on:

*“But then the danger is, if you start doing this thing, where people becomes reliant on this technology. Now that doesn't make the technology evil. It just means that it must be controlled.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 anticipates that regulation will be employed to keep technology in check. An additional insight the comment above gives is that consumer stakeholder 1 does not add an ethical value to the technology but puts the responsibility upon human stakeholders to ensure that technology is kept in check. Consumer stakeholder 2 also anticipate that the development of BCI technology will be kept in check and corrected by regulations in the form of consumer and health standards:

*“You know, the material design and selection, and to some extent that is controlled by consumer and health standards. You know, there are certain materials you can use and you can't use. There are always going to be some, challenges and trade-offs between quality of signal coming from the signals that you chose and the, the risk of say an allergic reaction or a skin reaction or something to that effect.”*

(Consumer 2 - Chief Scientist, November 2016)

Once again it enforces the idea that technology or the materials are not of ethical value, but that humans are supposed to direct the technology to good usage. The comment above is also an indication that it is the responsibility of regulators to ensure that development is taken in the right direction in the mind of consumer stakeholder 2. A couple of consumer stakeholders mention the requirement for FDA approval and how they anticipate that in their development:

*“When you have to go run a clinical trial and get it approved by the FDA and then it takes years.”*

(Consumer 2 - Chief Scientist, November 2016)

It is clear from the comment above that the requirement for FDA approval is something they anticipate will delay their development if clinical trials are required. Consumer stakeholder 3 also mentions the requirement for FDA approval:

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*“I think, there is a lot of legal concerns, well not legal, I get certification like the FDA levels, in terms of EEG technology.”*

(Consumer 3 - Technical sales, November 2016)

The two comments above show that the usage of BCI in medical settings introduces an anticipated requirement for certification and regulation. This increased regulatory requirement is also described by consumer stakeholder 4:

*“So it's not, it depends. The line between medical and wellness, so you will start to for every pedometer you would start to [require] medical device, you wouldn't have anything.”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 4's comment is interesting because it shows that the stakeholder is not interested in regulation on devices used for wellness purposes. This is a similar distinction made by consumer stakeholder 3 which mentioned that using EEG for diagnosing would be the usage that would require them to get FDA approval. This shows that regulation is anticipated by consumer stakeholders but also directs the development of BCI devices in a consumer setting (as mentioned by consumer stakeholder 3). When asked whether consumer stakeholder 3 thought BCI technology had introduced new policy gaps that needed to be addressed the following was said:

*“I: Okay, do you see any policy gaps, where BCI might have changed something, that might not be covered anymore? E: Not that I know of.”*

(Consumer 3 - Technical sales, November 2016)

This shows that consumer stakeholder 3 does not anticipate BCI technology to introduce new policy requirements, but it also shows that consumer stakeholder 3 agrees with stakeholder 2 on the point that regulation on other technology could cover BCI technology. While consumer stakeholder 3 and 4 appeared to be avoiding the medical usage of BCI devices, consumer stakeholder 6 anticipate this classification to be relevant at some point:

*“So we assume that the regulation on this new technology will arrive at some point and will be very strict. And we are now trying, already to think about what specifically that regulation is going to be and we are already thinking of [alto-traffic] specifically there is what is called HIPAA compliance which is the regulation for storing medical information on the cloud or outside of you know the local disk that you used to give to the patient and still do.”*

(Consumer 6 - Academic commercialising, May 2017)

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This shows anticipation, not only towards new regulation, but also new use cases of BCI devices. In general consumer stakeholder 6, appears to be anticipating regulation to play a big role in the development of BCI devices as multiple comments were made on the anticipated introduction of regulation such as:

*“And of course regulation has to be there to reduce the risk, to reduce the abuse of that channelling opening, that we just did.”*

(Consumer 6 - Academic commercialising, May 2017)

While the other stakeholders have been anticipating BCI to be affected by regulation of technology in general, the comment above shows that consumer stakeholder 6 anticipate BCI devices to open up a new type of information that might require specific regulation. Consumer stakeholder 6 specifically anticipates this for technology that affects the persons' brain:

*“Well, you know, if we are getting closer to persons brain, and actually affecting that persons brain. Clearly there may be legal issues involved.”*

(Consumer 6 - Academic commercialising, May 2017)

When it comes to affecting peoples brains it could indicate implants for medical reasons, which would introduce a security risk as well, and consumer stakeholder 6 anticipate a technical solution to that, as well as a regulatory solution:

*“And that is a challenge, and the regulation will go with that, but eventually yes, because we like the vice president of the united states, the previous one may decide to disconnect their pacemaker from the internet and sacrifice something in that direction. But for the sake of maintaining their safety.”*

(Consumer 6 - Academic commercialising, May 2017)

It is interesting to note that consumer stakeholder 6 anticipate the technical and regulatory solutions to force a sacrifice in terms of convenience and usage of the devices, for the sake of safety for the consumers. While this use case is smaller than an average consumer being affected by regulation, consumer stakeholder 6 also anticipate regulation to impact the average consumer:

*“And of course it will be up to the state, the legislator to regulate it because of course I will always be able to download an app, but those stores that provides me with those apps will have to adhere to those regulations.”*

(Consumer 6 - Academic commercialising, May 2017)

It is interesting though that consumer stakeholder 6 puts some regulatory responsibility onto third party stakeholders such as app store developers. This also shows that consumer stakeholder 6 anticipate

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regulation to impact the BCI development on multiple fronts as both the health and security properties of the hardware is anticipated to be impacted as well as the software development. Additionally, consumer stakeholder 6 also anticipate the accessibility of devices to be regulated:

*“And there will be just like we have ways to access the [phone] for disabled people there will have to be regulation that will enable ways to access the [phone] for various types of disabilities.”*

(Consumer 6 - Academic commercialising, May 2017)

The comment above is interesting as it shows that consumer stakeholder 6 anticipate regulation to not directly impact the accessibility in terms of price and availability, but rather the usability of devices.

Consumer stakeholder 6 also anticipate that regulation might extend further than just BCI devices:

*“I really feel that we are getting to that stage where all the information that is being collected on us from the GPS from the location of where we are, and from the emails that we send and from the voice messages and from Alexa that we speak to etc will eventually be used, can be used and therefore will be used for various source of medical application, so we actually consider the medical regulation and informed consent that requires the patient, not the patient the subject to fully understand what it is that is going to happen etc, actually this is really [feel its] going to be the only guideline.”*

(Consumer 6 - Academic commercialising, May 2017)

The comment above is interesting because it shows that consumer stakeholder 6 believes other data to be of personal and medical importance, but this belief is also used as a justification for BCI data not being more compromising and requiring additional regulation. Overall the stakeholders anticipated regulation of the technology to be created in the future and this anticipation lead to decisions being made around their company. Most of the stakeholders viewed regulation as an external concern they had to anticipate and be aware of. It is also interesting that consumer stakeholder 6 is of the mind that users should not be required to understand what is going on.

### 4.5.2.4 Digital divide

Overall most consumer stakeholders anticipate digital divide to be a topic of interest for BCI developers. Most of the comments on the topic of digit divide mention that the problem of the digital divide will relate to the ability to use the device and not a monetary divide. Consumer stakeholder 1 goes so far as to say that he anticipates BCI devices to become an equalizer to digital divides currently present:

*“But the great thing is, this becomes an equalizer, where for example if you are privileged, your life experiences will train your brain in a certain way.”*

(Consumer 1 - Founder/CEO, October 2016)

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While the comment suggests that the BCI device could be a solution, this does not solve the issues of the digital divide with BCI devices such as affordability and usability. Consumer stakeholder 1 is not convinced though that the digital divide problem is a question of those that have and those that do not:

*“I don't think there will ever be an A and a B team, because in the real world, it isn't like that. It's like A to Z and then infinite amount of numbers. You know you got the 1% down to the 99% type of people, and everything in between. So, but I see the potential for this”*

(Consumer 1 - Founder/CEO, October 2016)

This statement is interesting as it is a way for consumer stakeholder 1 to solve the problem of the digital divide in terms of usability and even accessibility. This is because consumer stakeholder 1 can consider people with limited access to the devices as part of a subgroup of people rather than part of the group that does not have access. Consumer stakeholder 1 does, however, mention that the usability and accessibility of their devices are a concern of theirs with limitations:

*“Well it's always hard to please everyone all the time.”*

(Consumer 1 - Founder/CEO, October 2016)

This shows that consumer stakeholder 1 anticipate that there will be consumers not pleased with their devices. This could potentially be used to dismiss criticism and concerns made by consumers. Consumer stakeholder 2 mentions that the accessibility of BCI devices could equalize access to health care:

*“So, we are still not at a point where everyone can get an MRI every year, but you know, we are not that far from where everyone can get an EEG every year.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2's comment suggests that the stakeholder anticipate the availability of BCI devices at least in a medical setting would be less of a problem. Consumer stakeholder 2 also mentions that the problem of the digital divide for BCI devices will not be a question of availability but technical expertise:

*“So I think that the divide will not be along the lines of economic opportunity, so much as technical expertise.”*

(Consumer 2 - Chief Scientist, November 2016)

This comment is interesting as it allows consumer stakeholder 2 to justify a focus on making BCI devices usability better rather than trying to reduce the cost of their devices. Consumer stakeholder 2 anticipate the development of cheaper BCI devices to be a natural development due to the capitalist imperative:



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*“So in a sense the capitalist imperative is, like, make this as accessible as possible to as many people as possible so you can make more of them and you can make more money at it. And that is at odds with this inequality concern.”*

(Consumer 2 - Chief Scientist, November 2016)

The comment above is interesting because it shows that the availability problem is a self-resolving problem due to the nature of the consumer market according to consumer stakeholder 2. This idea is a justification that can be used for consumer stakeholder 2 to remove the responsibility consumer stakeholder 2 has in resolving this concern. Consumer stakeholder 4, however, does not anticipate the problem of the digital divide to be a problem:

*“No it's not so much about whether you can contribute to anything or solve the problem, but just whether that's something you thought about at all or is it just? E: No”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 4 shows the capability of not anticipating the availability of its products as a concern. While this shows the range of anticipations by consumer stakeholder, does not provide many insights into the reasoning why consumer stakeholder 4 have not thought about the problem of the digital divide. Consumer stakeholder 5 have thought about the problem of the digital divide and anticipate that some people will be unable to integrate BCI devices into their lives:

*“They grow into and they understand it, so I am sure that what you are saying is right, that some people will not catch up or will not have the money to go, to integrate it into their life and they will be able to do less things.”*

(Consumer 5 - Neuropsychologist, April 2017)

Consumer stakeholder 5's comment shows that he anticipates both the ability to use BCI devices and the ability to purchase them to be a concern regarding the problem of the digital divide. Consumer stakeholder 5 anticipate that this is a similar problem as seen with elders adopting other new technology:

*“So they encounter much more problems in catching up with very basic daily activities, and they have to get help or assistance so we can see it in every when things are being computerized and developed.”*

(Consumer 5 - Neuropsychologist, April 2017)

The comment above suggests that the problem of usability for BCI devices is a similar digital divide problem as other technology that has been introduced in our lives. This suggests that consumer stakeholder 5 could look too similar solutions to solve the digital divide problem for BCI devices as has been employed for other

technologies. Consumer stakeholder 6 specifically anticipate the digital divide problem to be targeted “low-level jobs”:

*“I agree, this is actually a huge risk, because really what is happening is that slowly but surely some people say too fast, we are seeing that the more low kind of level jobs.”*

(Consumer 6 - Academic commercialising, May 2017)

Consumer stakeholder 6 suggest that the digital divide will not only be a question of availability and usability but also what kind of jobs that will be affected by technology. Specifically, consumer stakeholder 6 anticipate jobs in agriculture to be a target of concern:

*“So the whole world is going into a place where agriculture is going to be mechanised you know. Everything is going to be mechanised and it is not clear how the world will cope with this social problem.”*

(Consumer 6 - Academic commercialising, May 2017)

The comment above specifies that the digital divide problem for consumer stakeholder 6 will be a social problem rather than a technological one. This also suggests that consumer stakeholder 6 might look at solving social problems rather than technological problems in order to solve the problem of the digital divide.

Overall the consumer stakeholders anticipated that the digital divide was a topic of interest however the level of anticipated concern were not consistent. Some were anticipating the problem to be an availability concern whereas others found the concerns to be a matter of people being able to use and understand the devices.

#### 4.5.2.5 Accuracy

Overall the comments relate to the concern of increasing accuracy and limiting mistakes as well as concerns anticipated by a lack of accuracy. Consumer stakeholder 2 specifically mentions that the stakeholder anticipates critic for the accuracy by the academic community:

*“And I think this is part of where the criticism comes from, from the academic community about consumer BCIs. That they say, well it's hopelessly simplistic. And well you know, the answer is of course it is, it can't be a 128 channel system.”*

(Consumer 2 - Chief Scientist, November 2016)

The comment above shows that the accuracy requirements and the anticipated concerns are different in the two settings explored in this analysis. According to consumer stakeholder 2, the requirement for

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accuracy is higher in the academic setting compared to the consumer market. The following comment also shows that the requirement is different in part because of the intended user of the device:

*“That being said, you know, there is a careful balance between the level of accuracy that a neuroscientist would desire and the level of accuracy of information that a lay person would desire. And you can quickly overwhelm a lay person with neuroscientist level of information.”*

(Consumer 2 - Chief Scientist, November 2016)

This shows that the intended user changes the requirement for accuracy and the availability of data according to consumer stakeholder 2. While consumer stakeholder 2 anticipates the layperson to be less concerned about the accuracy of the data provided, consumer stakeholder 6 anticipates differently:

*“In fact, even in the consumer market if I am playing a certain game where my brain is being read as part of the game, of course you know, as a person who wants to succeed in the game, I would like that system that is actually looking into my brain to be as accurate as possible.”*

(Consumer 6 - Academic commercialising, May 2017)

While consumer stakeholder 6 comments that accuracy is still important for consumers using BCI for games, it shows that there is different kind of accuracy concerns to be discussed. The two accuracy problem described in the problems above is the problem of accurate readings and accurate depiction of data. Consumer stakeholder 2 in this statement is anticipating concerns about both problems, whereas consumer stakeholder 6 is mostly concerned with the data accuracy in the comment above. The concern of accurate data depiction is further explained by consumer stakeholder 2:

*“The challenge in the consumer space is that, we got a few minutes to help the user get some idea how this brain-computer interface works and how they are supposed to use it.”*

(Consumer 2 - Chief Scientist, November 2016)

This comment suggests that while consumer stakeholder 2 understands the critic from the academic setting, the consumer setting is used as a justification for making the data depiction less detailed in order to not overwhelm the average consumer. Consumer stakeholder 2 (as well as multiple other stakeholders) anticipate accuracy problems in terms of lack of information as well though:

*“So there may be a signal to noise issue, or you know you can't do source localisation in sparse EEG. There is just not enough information to do it, despite some manufacturers claim that you can, and they make interfaces that make it look like you can.”*

(Consumer 2 - Chief Scientist, November 2016)

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Interestingly the comment by consumer stakeholder 2 suggests that the accuracy problem and capabilities of non-invasive BCI are something the stakeholder claims other developers are not describing correctly. This is specifically interesting as most other stakeholders mention the accuracy problems as inherent and something they need to work around:

*“Sure, there is the skull that is masking the information coming from inside the brain and with this masking you have to have very good analytics and statistics to get correct [INAUDIBLE] and to get clean signals and I think that there are a lot of artefacts that many times are not being accounted for.”*

(Consumer 5 - Neuropsychologist, April 2017)

*“EEG is very different from person to person so we probably have to adjust. And if we want to increase our accuracy we have to probably personalise our algorithms to each person.”*

(Consumer 3 - Technical sales, November 2016)

The comments above show that consumer stakeholder 3 and 5 both anticipate using algorithms and analysis to improve the accuracy of an inherent problem caused by the skull limiting the access to the source of the data being captured. Consumer stakeholder 3 also suggest that the data captured is very personalized which increase the difficulty in getting accurate readings:

*“Yeah, it's very difficult to create, capture that accuracy because everyone, these are all subjectively when you are like staying happy or sad, or when you are like concentrated.”*

(Consumer 3 - Technical sales, November 2016)

Overall these comments by consumer stakeholder 3 and 5 suggest that the stakeholders anticipate a problem with accuracy that could prove difficult to solve as they are personalized and inherent problems. The accuracy problems of EEG were so anticipated by consumer stakeholder 5 that the stakeholder decided to not use the devices initially due to methods performing better:

*“No it's unrelated, we also, we're familiar with EEG biofeedback or neurofeedback, but it's harder to implement at the moment and it's also controversial in some aspects so it was easier to start with the peripheral physiology, maybe in the future there are good accurate system, we can also add some neurofeedback.”*

(Consumer 5 - Neuropsychologist, April 2017)

Consumer stakeholder 3 also specify an applicational problem of the anticipated accuracy concern which relates to the usage of BCI as a control device:

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*“It's like how you know that the person is saying go right, when you are driving. Or you might just be saying, oh can you, can you get something on the right side. It's like, in your car, and it might just turn right on you.”*

(Consumer 3 - Technical sales, November 2016)

This comment is interesting as many consumer devices suggest that BCI devices can be used for control devices, so a concern for the accuracy of BCI devices as control devices could impact a large group of consumer users. While control devices is a popular topic for consumer devices, some comments also suggest that the usability of BCI in wellness could have accuracy concerns:

*“So this is regarding over sensitivity, if you train someone, it can be also sensitive them instead of desensitise where you want. So you don't really know very accurately yet, what such a general training outside the skull what it does to people.”*

(Consumer 5 - Neuropsychologist, April 2017)

This concern is also one of the reasons consumer stakeholder 4 decided not to provide consumer devices:

*“No it's the feedback, for people, specific psychiatric applications, the feedback may effect the indication, the state of the person.”*

(Consumer 4 - CEO, April 2017)

These anticipated concerns with the accuracy in wellness applications are interesting as this combined with the anticipated accuracy concern could severely limit the actual usability of BCI devices in a consumer setting. Consumer stakeholder 5 also talks about the accuracy concern as a problem related to the setting the devices are used in:

*“And if you do the evaluation in a safe place, it doesn't mean that their brain works in the same way when they are outside. So, this is a big problem.”*

(Consumer 5 - Neuropsychologist, April 2017)

The comment above show that consumer stakeholder 5 anticipate that solving the accuracy problem and getting accurate data of the effect can be difficult because it is harder to reduce variables when not done in a clinical setting. This ties into the problem of getting large enough data sets to make accurate analysis described by consumer stakeholder 6:

*“there is a big chance of what is called in statistics over fitting, mainly that we draw wrong conclusions from the small data set that we are looking at.”*

(Consumer 6 - Academic commercialising, May 2017)

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The comment above are specifically interesting because they describe the problem with accuracy for BCI devices in multiple ways. The problem of overfitting is both applicable to the concern of individual BCI devices accuracy and the analysis provided by these, and the accuracy concern of general analysis of BCI data.

Overall the comments on the topic of accuracy show an anticipated concern with the accuracy of BCI technology. The major types of concerns for accuracy appear to be a concern with accurate data as well as accurate depictions of this data. The consumer stakeholders anticipate these problems to impact the usability of the devices and could potentially affect how the technology is perceived compared to the expectations for the technology.

### 4.5.2.6 Expectations

In general, the consumer stakeholders mention that they anticipate user expectations to be high for the products developed. Mainly the concern for consumer stakeholders regarding expectations appears to be a fear of not being able to live up to these expectations. The following comment by consumer stakeholder 2 describes how the usage of BCI as a control device might always leave people disappointed:

*“So if you are talking about [paraphilics], then it's a great technology that has real potential to change someones life. But that's like 50 thousand people a year globally, so it's very small number. So when it comes to, you know, brain-computer interfaces as a control device, I think that people will always be disappointed.”*

(Consumer 2 - Chief Scientist, November 2016)

This statement is interesting as this shows that consumer stakeholder 2 is expecting a major usage consideration to be disappointing for the consumers. Consumer stakeholder 2 also anticipate that the usage in specific medical settings is usable by a minimal user group. Finally, consumer stakeholder 2 also anticipate that BCI technology as a control device will never reach a state where people's expectations will be met. This could be used as a justification by consumer stakeholder 2 to avoid working with the technology as a control device or to improve the usability for those that need the device as a control technology. Consumer stakeholder 2 is very concerned about the anticipated expectations of consumers as the following comments show:

*“To my mind I think that the, the biggest concern is over promising and under delivering with BCIs.”*

(Consumer 2 - Chief Scientist, November 2016)

*“They can get frustrated and walk out, but they frequently don't. But a consumer will, if you make something that is hard to use and didn't test it and that doesn't really work. The consumer will, walk away*

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*from it.”*

(Consumer 2 - Chief Scientist, November 2016)

While the first comment by consumer stakeholder 2 suggested that the lack of usability as a control device could be used as a justification for consumer stakeholder 2 to not improve the usability in this use case, the comments above suggest that it is used as a justification for spending additional time on improving the usability. Additionally, the comments above show that consumer stakeholder 2 see this as a major difference between BCI in other settings as a consumer will walk away from a product that does not live up to the expectations. This could also be the reason why consumer stakeholder 2 anticipate the problem of living up to expectations as the biggest concern of BCI devices. Consumer stakeholder 2 compares this situation with the situation other technologies have gone through where expectations were high and the technology underdelivered:

*“Where BCI is you know, the thing that never was, and that couldn't deliver on the promises that it made and, and that really dampens enthusiasm for among consumers, among investors, among you know, sort of the whole industry, and killed it for ten years.”*

(Consumer 2 - Chief Scientist, November 2016)

The comment above is an indication that consumer stakeholder 2 is perceiving BCI technology as other new technologies that will have the same problems breaking through as a consumer product as other new technologies. Consumer stakeholder 3 also mentions that public awareness of BCI devices can be dangerous for the industry in another way:

*“I mean, EEG already has you know, you pulled up that public awareness of like people think it's dangerous and everything. So we have to take extra steps on being careful, so that's why I think we chose the medical route.”*

(Consumer 3 - Technical sales, November 2016)

This suggests that the positive stories about BCI are not the only anticipated concern by consumer stakeholders as the negative stories can be of a concern as well. Consumer stakeholder 3, however, mentions that the anticipation of such negative stories has impacted the development direction taken trying to minimize the risk of their devices being part of the negative public awareness. Consumer stakeholder 2 also anticipate that non-invasive BCI will not have a significant effect as an enhancement tool in the next 10-20 years:

*“I can't see non-invasive BCIs having a significant effect in the next 10 years. Maybe even in the next 20.”*

(Consumer 2 - Chief Scientist, November 2016)

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This significantly limits the use cases of a BCI device in the mind of consumer stakeholder 2 as it working as an enhancement tool as well as being limited as a control device appears to be rather restrictive for the current use case examples of BCI devices. This limitation is something consumer stakeholder 2 also mentions which means that BCI devices will not be widely adopted within the next 5 years according to consumer stakeholder 2. Consumer stakeholder 2 also comments where the expectations might come from:

*“And I certainly think that, while there is, sure there are things that non-invasive BCIs can do, and some of them are powerful and potentially helpful, they don't cross the boundaries with the implanted BCIs or with the kind of things that we see in science fiction the [inaudible] kinds of BCI.”*

(Consumer 2 - Chief Scientist, November 2016)

While consumer stakeholder 2 does not directly say that the expectations from users come from science fiction, the comment above suggests that this is in part the anticipated reason for high expectations by consumer stakeholder 2. Consumer stakeholder 6 statement below suggests that the use case for BCI devices is also limited by the ability to make the data available in an understandable form:

*“It has to really trade off between ease of use and at the same time make sure that the lay person is going to understand what is going on.”*

(Consumer 6 - Academic commercialising, May 2017)

This could be caused by a difference between the usability seen in science fiction and the actual usability and readability of BCI devices. This anticipated difference in usability is also described by consumer stakeholder 4:

*“So you get index and it is designed for research in a way that you can define areas of interest and the way that you can extract the data, it doesn't have any features like you would expect for consumer applications regarding recommendations or things like that that.”*

(Consumer 4 - CEO, April 2017)

This shows that consumer stakeholder 4 anticipate consumer applications to have a higher requirement for usability before a BCI can be used in this setting. This expected usability from consumer users is something that consumer stakeholder 2 also mentioned in previous comments and suggest that this is anticipated by most consumer stakeholders. Finally, consumer stakeholder 2 anticipate that consumers expectations their brain data might impact their thoughts on BCI devices:



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*"I think there is a minor concern in the same way there are concerns about the experimentation on first year undergraduate psychology students. That someone's feelings might get hurt because they might get attached to a particular idea about their brain that they related to by the technology."*

(Consumer 2 - Chief Scientist, November 2016)

The interesting part of the comment above is that consumer stakeholder 2 considers this concern to be minor compared to other concerns. Overall in this section consumer stakeholders have shown anticipation for user expectations being too high. This overestimation of the technology means that consumer stakeholders anticipate that users will be disappointed in the technology.

### 4.5.2.7 Potentials

Not surprisingly consumer stakeholders anticipate potential developments with BCI technology. Most potentials are positive developments such as better diagnosis from doctors, however, some also anticipate problems such as neuromarketing using BCI devices to perfect manipulation. Some stakeholders also do not anticipate any negative use cases of the specific technology they are developing such as consumer stakeholder 4:

*"I: No I am just wondering if there is any use cases that you can see your devices being used for that you wouldn't be so happy about? E: [...] Not really."*

(Consumer 4 - CEO, April 2017)

This seems fairly naïve as most consumer stakeholders either in anticipation or in other comments have indicated that there could be problematic use cases of BCI technology. Most consumer stakeholders do, however, have anticipated positive potentials of the technology. Consumer stakeholder 3 mentions the potential of increasing the information available for doctors:

*"You can actually get your blood pressure, you can get your glucose level, you can get your EEG, you can get ECG, you can send all that, to your doctor, and say, you actually have this. Or not even a doctor at that point, you can actually send it to a server, and it will diagnose you to a certain thing and say, you might want to take these pills. Or you might want to take these vegetables or like meat, it might actually do some recommendations like that so."*

(Consumer 3 - Technical sales, November 2016)

This could easily be used as a justification for developing BCI technology as it could potentially improve the overall health of people or reduce the amount of misdiagnosis. This comment also suggests that consumer stakeholder 3 considers the data derived from BCI devices to be medical data or at least capable of being used in such a setting.

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*"I mean, computer is equipment of many different sensors, speakers, you know, cameras and everything, I think there will be another device that's for medical."*

(Consumer 3 - Technical sales, November 2016)

The statement above further verifies that consumer stakeholder 3 views the potential of BCI devices to be in the medical setting. Consumer stakeholder 3 even goes so far as anticipating a science fiction like development where a BCI is worked into a tricorder (a device often thought of as a tool in the star trek universe used by medical staff):

*"So, the BCI, I guess it's not BCI but I think there will be EEG technology embedded into that, tricorder to diagnose you to, during symptoms."*

(Consumer 3 - Technical sales, November 2016)

The comparison to a science fiction tool shows that consumer stakeholder 3 is capable of imagining BCI development in the future which shows that consumer stakeholder 3 anticipate the development of BCI technology to continue and to be implemented in other tools. Consumer stakeholder 3 also anticipate BCI to have potential in slowing the decline of the mind:

*"I think BCI would because, and in terms of the mind, I think a lot of people don't know how powerful the mind is. And I think we need to provide that feedback to each one. And maybe, if we can actually slow the decline of the mind because of the certain behaviours that's also a benefit for certain people too."*

(Consumer 3 - Technical sales, November 2016)

This comment is another example of consumer stakeholder 3 anticipating BCI to be used in a medical setting. It also shows that consumer stakeholder 3 anticipate BCI devices to change the perception of the mind. This could potentially cause issues with people's perception of personality which consumer stakeholder 2 also comments on:

*"So sure, you know, if you are looking decades out, there may be some ethical issues there, related to identity, related to transhumanism, I feel like some of those have been addressed a lot by the transhumanist writers."*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 anticipate this to be a potential for the future, however, consumer stakeholder 2 also negates this risk with the help of transhumanism writers. This gives consumer stakeholder 2 two potential ways of mitigating the risk. Both the idea that the risk is decades away, and that another

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community have dealt with the issue removes the responsibility for consumer stakeholder 2. Consumer stakeholder 4 anticipate BCI to have potentials in educational settings:

*“What we are doing for example when measure attention, which can be very useful in e-learning in order to evaluate how much your engaged in learning activity. And you can tune basically the level of the material, the study material.”*

(Consumer 4 - CEO, April 2017)

While consumer stakeholder 4 anticipate that BCI can be used to identify the engagement of students to the study material, consumer stakeholder 4 does not anticipate the negative potentials of monitoring engagement such as consumer stakeholder 1:

*“And now I think one of the scarier things is, the potential for neuromarketing to hone down the science of essential manipulation.”*

(Consumer 1 - Founder/CEO, October 2016)

The anticipated concern of BCI being used in neuromarketing is particularly interesting because it is in line with the literature found on the topic of BCI devices, showing that the concerns of the research setting can translate into concern in the consumer setting.

Consumer stakeholder 6 anticipate that BCIs potential as a control device could impact our motor skills in the same way keyboards have impacted our general ability to write with pen and paper:

*“I mean some side effects to me is not an issue, so [INAUDIBLE] our fine motor skills are being affected from typing on the computer instead of writing with hand writing, and maybe in a generation or two, people will not be doing any handwriting at all, but still people will be drawing, people will be playing musical instruments, so there will be a lot of other ways to kind of maintain this skill.”*

(Consumer 6 - Academic commercialising, May 2017)

Interestingly, consumer stakeholder 6 anticipate that the loss of practising motor skills would be other means of maintaining these skills. Consumer stakeholder 6 does however not anticipate the impact this change might have for those that do not have other means of maintaining those skills through music, drawing and other recreational methods. Consumer stakeholder 6 does, however, anticipate that this change is like changes seen before:

*“So you know, that's part of the change in skills, you know in the past we had to walk for many kilometres, now a days we have to know how to drive a car, and very soon we will only need to know how to run the*

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*application to get a car to pick us.”*

(Consumer 6 - Academic commercialising, May 2017)

Throughout these statements from consumer stakeholders, it has been seen that overall the potential of BCI devices are perceived to be positive, and the concerns identified are largely considered to not be novel at this point by consumer stakeholders. Most of the stakeholders anticipate the potential of BCI devices to be an improvement to our lives and a development similar to the overall development of human progress so far.

### 4.5.2.8 Other technologies

As seen in the section above, it is often used as a justification for not being too concerned about ethical problems that BCI technology is either similar to other technologies or can employ solutions used in other technologies. This section will describe comments showing such sentiment further. Almost all consumer stakeholders are represented in this section, however, consumer stakeholder 4 was the most adamant of this justification that BCI is no different than other technologies such as Facebook:

*“I don't think that your brain waves are more private than your pictures on the Facebook”*

(Consumer 4 - CEO, April 2017)

This comment is particularly interesting paired with the following comment by consumer stakeholder 4:

*“I mean what could you do it? [INAUDIBLE] Brainwaves you have a possibly you have, can be connected to specific disease but then, it's the same with heart, it's the same with mobile app which doesn't measure your brainwaves, but only you give information regarding specific disease.”*

(Consumer 4 - CEO, April 2017)

While Facebook does not record medical information directly, it is interesting that consumer stakeholder 4 sees the privacy concerns for both technologies on the same level. The comments, however, does not directly show how critical consumer stakeholder 4 views the privacy concerns of BCI except that the word only is used to suggest that it could be worse. Consumer stakeholder 2 is also not anticipating many concerns regarding BCI devices that record information:

*“I think that, there is not a lot that concerns me as far as non-invasive passive or you know, BCI that records information”*

(Consumer 2 - Chief Scientist, November 2016)

This lack of concern is partially caused by consumer stakeholder 2 being of the mindset that the concerns with BCI technology have already been dealt with by other devices in the medical device industry:

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*“I think that, you know, I think that those are unavoidable, challenges that. But there is a clear path to how you do them. And the path has been laid out by other dev, medical device and partly by the medical device industry.”*

(Consumer 2 - Chief Scientist, November 2016)

These justifications allow consumer stakeholder 2 to continue the development of BCI devices as solutions can be found in other technologies and industries. Consumer stakeholder 4 was also asked whether BCI data caused for any anticipated concerns regarding the coverage of policies and legal situations or whether BCI data were covered by policies derived for other technologies:

*“You think that it falls under any other technology out there? E: Yes.”*

(Consumer 4 - CEO, April 2017)

This once again justifies the consumer stakeholders in continuing their development as the ethical concerns regarding BCI data is handled by other technologies. Consumer stakeholder 4 mentions that the concern of skin irritation and having sensors directly on the skin was also anticipated to not be a concern due to other technologies such as headphones having a similar use case:

*“Yeah so if you like with surgery insert a reader. E: It's non-invasive EEG, it's passive so, it's [INAUDIBLE] it's no constant, and they don't see any irritation like the sensors are compatible, bio compatibles every consumer sensor. So it's the same issue as headphones. I: Okay, so you don't see that one as a big one. E: No, I don't see it at all.”*

(Consumer 4 - CEO, April 2017)

Consumer stakeholder 3, however, did anticipate skin irritation to be a concern and took actions to counter this:

*“I think it was implemented from the start, I mean, when we think about something that goes to your skin, definitely we definitely have to look into like sensitivity to skin, skin allergies and everything”*

(Consumer 3 - Technical sales, November 2016)

This shows a difference in approach between the two stakeholders. It is important to note here that consumer stakeholder 4 was not developing BCI hardware but using and modifying BCI hardware developed by others, which could be the reason why consumer stakeholder 3 were concerned with this and consumer stakeholder 4 was not. Consumer stakeholder 6 has an interesting point that other technologies also run into the problem of users handling technology in an unsafe way:

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*“It's obvious that there will still be people that will be unplugging their freon from their ventilator from their air-condition [then they] kind of inhaling this. So you know, there will be a lot of ways to overcome as there are now for various things.”*

(Consumer 6 - Academic commercialising, May 2017)

The comment is showing that while consumer stakeholder 6 anticipate users to do this, consumer stakeholder 6 does not use this as a way to remove responsibility for themselves. Instead, the fact that other technologies have had such issues, is instead used as a guideline for consumer stakeholder 6 to follow in regard to BCI technology. Consumer stakeholder 6 also anticipating BCI technology to be another step in the development of people being connected to the web at all times:

*“I believe that BCI is just going to be another step in that direction of connecting us to the web at all times and [vanishing] is also filling sometimes the other direction of not benefitting the fact that we are connected all the time.”*

(Consumer 6 - Academic commercialising, May 2017)

This means that BCI technology in the mind of consumer stakeholder 6 is not only following the development of other technologies and therefore affected by the same concerns but is also a factor in progressing this development further. This puts BCI developers into a position of responsibility for whether they develop BCI technology that furthers this development or tries to limit this development.

This section has shown that BCI is considered similar to other technologies by some consumer developer and other stakeholders see them as different. This means that the anticipated concerns regarding BCI have very different responses depending on whether you view them as one or the other.

### 4.5.2.9 *Invasive vs non-invasive*

Overall consumer stakeholders are of the opinion that the two technologies have different concerns. One example of this opinion is the comment by consumer stakeholder 2:

*“Sure, for a deep brain stimulator that absolutely an issue, that has real health implications. For a non-invasive feedback based BCI it's a very different question.”*

(Consumer 2 - Chief Scientist, November 2016)

While you might argue that a deep brain stimulator is a third technology, the combination of deep brain stimulator and the term BCI has been seen in research articles as well. This in itself could prove to be a problem as it is not always clear what type of technology people are talking about. Consumer stakeholder 1 is also of the opinion that non-invasive is plainly better than implanting chips:

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*“And if it does get to that stage with some kind of a helmet, brilliant, it's better than putting some chip in someone's brain.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 also anticipate that the accuracy of non-invasive BCI will improve and that this is better than improving the accuracy by implanting devices. Consumer stakeholder 1 also mentions the risk of stimulation devices like consumer stakeholder 2 did:

*“Yeah, but not just within my sector, I mean in any sector where it comes to manipulating the human mind or the human body in a way that it's unnatural, I think has a risk. Especially when the body is trainable.”*

(Consumer 1 - Founder/CEO, October 2016)

The choice of words by consumer stakeholder 1 is especially interesting as the word unnatural is used. The use of unnatural is often an argument used in the discussion of enhancement. Consumer stakeholder 1 does, however, offer more arguments against invasive BCIs, which is that it has a risk and that an effect could be had by training instead of implanting. Once again these are often arguments used against enhancement, which suggest that consumer stakeholder 1 anticipate invasive BCI to be used as enhancement devices. Consumer stakeholder 1 further anticipate that the risks with invasive BCI are uncertain:

*“That is scary, because product malfunction, amplitudes change, resistors burn out, you do not want to be pumping electricity into somebodies brain because we do not know how the brain will cope with that.”*

(Consumer 1 - Founder/CEO, October 2016)

Consumer stakeholder 1 is anticipating a physical risk of invasive BCIs, however, consumer stakeholder 2 is anticipating more of existential risk:

*“invasive BCIs and really really effective BCIs that allow us to interface with machines, in a really effective and engaging way. That does change, you know that changes our concept of who we are, changes our concepts of ego.”*

(Consumer 2 - Chief Scientist, November 2016)

It is key to this comment though that this risk is also transferred to non-invasive BCIs in the mind of consumer stakeholder 2 when non-invasive BCIs becomes very effective as an interface with machines. This suggests that the difference between non-invasive and invasive BCIs in terms of anticipated risks are connected to the effectiveness of the devices. This difference is something consumer stakeholder 2 also touch upon with the following comment:

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*“That’s a concern, you know, what really could you do if you hack an EEG system. What really could you do if you hack an [INAUDIBLE] system?”*

(Consumer 2 - Chief Scientist, November 2016)

This comment shows that while consumer stakeholder 2 is concerned with both the health implications of invasive BCIs and very effective BCIs, consumer stakeholder 2 is not concerned with the risk of current systems. This allows consumer stakeholder 2 to acknowledge and anticipate risks for the future but allows to continue developing the devices. This continuation is justified in the mind of consumer stakeholder 2 because the anticipated concerns are for the future, and for invasive devices. Consumer stakeholder 6 also anticipate that non-invasive BCIs will not be deployed for consumers:

*“I do not see in the near future to say the least, anyone going to an implantable device without a reason. Without a medical reason.”*

(Consumer 6 - Academic commercialising, May 2017)

The reasoning for not implanting devices for non-medical reasons is something consumer stakeholder 2 also talks about:

*“We are sure that we can implant electrodes in individuals now, even chronically to some extent, but we still haven’t solved some very basic problems that may not have a solution.”*

(Consumer 2 - Chief Scientist, November 2016)

Some of the basic problems that have not been solved consumer stakeholder 6 clarifies with the following statement:

*“But of course it is a huge challenge, because in the bank, those computers are connected to an enormous amount of electricity. The pace maker runs on a battery that is supposed to last for five years, and you can imagine the difficulty in replacing the battery.”*

(Consumer 6 - Academic commercialising, May 2017)

Overall it shows that consumer stakeholder 2 and 6 anticipate these problems to persist which gives them a justification for not dealing with those concerns. Interesting additional information shown in the comment by consumer stakeholder 2 is that not only does consumer stakeholder 2 anticipate these problems, the stakeholder also anticipate that these problems are unsolvable, which further increases the justification for not spending energy and resources on finding solutions. Similarly consumer stakeholder 4 completely disregards any concerns that is connected to invasive BCIs because the stakeholder is not using them:



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*"I assume since you're only using non-invasive EEG, this is not something you are concerned about? E: No"*

(Consumer 4 - CEO, April 2017)

This makes sense to do if the perception of invasive and non-invasive BCIs are that they are two different technologies not affecting each other, as it would be a waste of resources.

Overall all stakeholders talking about invasive and non-invasive BCIs have been of the mindset that the technologies are different and therefore require different concerns to be anticipated but technologies being different is also used as a justification for not worrying about the concerns related to invasive BCIs.

### 4.5.2.10 Enhancement

This section will be analysing the topic of enhancement and will include comments from all consumer stakeholders except consumer stakeholder 6. Overall a lot of consumer stakeholders view enhancement in the term of BCI as training. This specific use case is something anticipated by consumer stakeholder 1:

*"One day everybody will have the same access to their brain data and their ability to train their brain the way they say train every other muscle."*

(Consumer 1 - Founder/CEO, October 2016)

While it is not very clear from the comment above, consumer stakeholder 1 is very positive about the idea of enhancing your brain by training it with BCI devices. This becomes clearer in the comment below:

*"The real benefit of this technology is your brain. Knowing that you can control, so if you can control your attention, you can control your thought process. If you can control your calm, your alpha frequency, you can control your emotions, which means. You not only control what comes in and out of your mind, but you also control how that thought is processed, emotionally. And that to me is a power, that is Jedi in it's kind of ability."*

(Consumer 1 - Founder/CEO, October 2016)

The comment above clearly shows that consumer stakeholder 1 sees the enhancement as a positive. Consumer stakeholder 1 also anticipate that BCI devices will give the users a sense of empowerment and control over things that could be perceived as uncontrollable or hard to grasp. Additionally, consumer stakeholder 1 anticipate this to impact crime and gang culture:

*"Can you imagine how much of an effect, it would have on crime, gang culture. Gangs are all about weak minds, it's a few strong men leading the weak, emotionally. You train that out of people, you solve problems of anti-terrorism, you solve problems of crime, knife crime."*

(Consumer 1 - Founder/CEO, October 2016)

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The reasons above could easily be used as a justification for working on BCI devices, which consumer stakeholder 1 also does, however, consumer stakeholder 1 also anticipate that BCI devices are limited and perhaps, therefore, should not be considered enhancement devices in the traditional sense:

*“But with EEG, because it's a monitoring device, all it's doing is giving you access and saying: See if you can change it. And make yourself better at controlling it. So, I don't see.”*

(Consumer 1 - Founder/CEO, October 2016)

This comment implies that while the device can enhance the ability to control emotions and our brain in general, consumer stakeholder 1 makes the user the responsible entity for the enhancement. This allows consumer stakeholder 1 to take away responsibility for the enhancement from the developer and give it to the user. This shift in responsibility shift consumer stakeholder 1 even mentions:

*“So it's the deliverer of the training, who is responsible and if that happens to be you that's on you. And if it happens to be your therapist it's on your therapist.”*

(Consumer 1 - Founder/CEO, October 2016)

Interestingly, none of these comments by consumer stakeholder 1 mentions any concerns with the enhancement provided by BCI devices. This is unlike consumer stakeholder 2:

*“You know I think that, the potential definitely exists for enhancement, obviously associated with that there is the question of access and inequality as there is with every new technology.”*

(Consumer 2 - Chief Scientist, November 2016)

Consumer stakeholder 2 shows an anticipated concern regarding the digital divide with enhancement. However, consumer stakeholder 2 manages to reduce this concern by mentioning that this concern is present with all new technology. This suggests that the risk of the digital divide is present as soon as you develop new technology. This removes the concern of a digital divide for consumer stakeholder 2 because not developing this new technology is not an option. Consumer stakeholder 2 also reduces the impact of enhancement by saying that the current technology is not a reliable enhancer:

*“I think that, we're still, [INAUDIBLE] away from, from using BCI reliably to augment cognition or to augment healthy individuals, beyond just some of the basic benefits like "hey you can learn how to meditate and that will benefit you". “*

(Consumer 2 - Chief Scientist, November 2016)

The comment suggests that the enhancement possible is rather limited, which is further explained in the following comment:

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*"I don't see them being things that really significantly augment human life, beyond the way that they can do in in active or in passive and inactive BCI where, you know, you might get subtle benefits from having a thing that teaches you how to control cognition a little bit better or that responds to, responds to your cognitive state to, to change the way that stimuli or information is presented to you."*

(Consumer 2 - Chief Scientist, November 2016)

This comment is particularly interesting because consumer stakeholder 1 perceives this kind of enhancement as a big enhancement that can even reduce crime. This difference in understanding of enhancement could be very problematic when trying to analyse the concerns related to enhancement. This difference is particularly a problem because the two consumer stakeholders agree on the abilities of the device but disagree on the effect this might have. Consumer stakeholder 3 also uses the justification that BCI is like other technologies to justify an anticipated usage of enhancement:

*"No, I don't think so. I think I mean, people have different ways of enhancing themselves, and I think EEG is one of them. So I don't think it would create any different groups."*

(Consumer 3 - Technical sales, November 2016)

The comment above also show that consumer stakeholder 3 does not anticipate the digital divide to be a concern with BCI enhancement as other technologies and methods could be used for similar results. Consumer stakeholder 3 is similar to consumer stakeholder 1 of the mindset that enhancement is a good thing for society:

*"I don't think so, I mean, I think we need more enhancement so that we can actually advance society in terms of well for, and I think in having more of people being enhanced could help the local community to move forward."*

(Consumer 3 - Technical sales, November 2016)

It is not clear what consumer stakeholder 3 means by the local community in this comment. However, it could be similar to how consumer stakeholder 1 believes that BCI enhancement could be used to reduce the prevalence of gangs in certain communities. Unlike the previous consumer stakeholders, consumer stakeholder 5 is anticipating some concerns with BCI enhancement in terms of a training tool:

*"I'm not sure, if side effects of neurofeedback has been properly investigated because if you are intervening and if it works, and you are strengthening one muscle, one brain muscle, you have to check what it does to other brain areas."*

(Consumer 5 - Neuropsychologist, April 2017)

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In the comment above it is clear that consumer stakeholder 5 is concerned with the side effects of training specific parts of the brain. This is partly a concern caused by the uncertainty of the effects, but this uncertainty does not carry on to his overall confidence that this could be a problem:

*“Sure, any skill that you practice a lot not only at the physician’s office, but daily will become automatic and will become better learned, so this is something that is definitely going to change the ability of people to learn new skills and to use them.”*

(Consumer 5 - Neuropsychologist, April 2017)

So, while consumer stakeholder 5 is concerned about side effects and unknown factors of the training, consumer stakeholder 5 is not uncertain about the fact that such training could provide results. While the previous consumer stakeholders used the training comparison to reduce the anticipated risk, consumer stakeholder 5 uses it as an argument for why such side effects are actually a concern for BCI usage:

*“because the body compensates, so it may lead to some damage if you are not doing the training in the right way or the right intensity and I think its the same problem that happens in the gym, can happen with the mind.”*

(Consumer 5 - Neuropsychologist, April 2017)

What is interesting is that the same argument could be used for training at a gym. There are competing training philosophies in gyms, however, for gyms, there is a large body of research trying to determine how different methods of training can impact your body. A similar body of work could be required for the BCI training to reach a point where it could be considered as safe as regular training. Consumer stakeholder 5 also comments on the concern that there is a lack of policy and protocol regarding training with BCI:

*“I still feel that there is a lot of confusion, different protocols, different hardware and software that give different results and there is still not enough agreement in the field in many aspects of training so.”*

(Consumer 5 - Neuropsychologist, April 2017)

The lack of protocol is something that appears to be a reference to the field consumer stakeholder 5 is in of neuro-psychology which uses a protocol to establish treatments and procedures to help people. These protocols are used to get an agreed upon standard for what should be done, and what is good practice. The lack of these protocols was one factor that made consumer stakeholder 5 drop the usage of BCI devices:

*“I am also not a very big expert on neurofeedback because I have been focusing mainly on peripheral physiology but I know that when I was using neurofeedback those questions were concerning. I was*

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*concerned with those questions.”*

(Consumer 5 - Neuropsychologist, April 2017)

This comment is particularly interesting because consumer stakeholder 1 put the responsibility of training problems on the user or the representative applying the BCI training such as your therapist, and it appears that consumer stakeholder 5 suggest that a responsible therapist or developer of therapeutic solutions would not be using BCIs until proper protocol had been developed. Finally, consumer stakeholder 4 was asked whether the stakeholder had any thoughts or comments to enhancement with BCI devices:

*“I was wondering if that is something you think about at all or, do you have any stance on that at all? E: No”*

(Consumer 4 - CEO, April 2017)

Following the previous comments by consumer stakeholder 4, the lack of reflections is perhaps not too surprising as this stakeholder specifically in most cases appeared to be very limited in the scope of concerns they anticipated. Overall consumer stakeholders anticipate that the enhancement capability of BCI devices are either overestimated, questionable or should not be considered an enhancement. This means that many of the concerns about enhancement are downplayed by the stakeholders. Those that do see enhancement as an anticipated concern for BCI devices anticipate the problems to relate to the digital divide, and enhancement accuracy and side effects.

### 4.5.3 Research Stakeholders

In the following section the anticipation comments by research stakeholders will be analysed. The topics mentioned by research stakeholders are topics such as regulation, a concern for commercialization, invasive technology, media and the public opinion and enhancement.

#### 4.5.3.1 Use cases

All researchers anticipated various use cases for BCI systems and some anticipated concerns due to these usages. In this section comments on different use cases by research stakeholders will be analysed. Research stakeholder 1 anticipates BCI to be used as a complement to current interaction devices:

*“so I am less interested in building a pure BCI system which or force BCI into everything where it could potentially be a sub-optimal replacement for established interaction components but more as a complement to measure user states and user situations to which we with other means don't have. Don't have access to.”*

(Researcher 1 - Senior Researcher, November 2017)

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While this would mean that current interaction devices are not challenged by the use case anticipated by research stakeholder 1, as BCI is used as a complement, it suggests improved use cases for current interaction technology. The improvement, for example, could be from more accurate interactions or different interactions depending on feedback from BCI devices. It is interesting though that research stakeholder 1 also believes that BCI devices could be used as a stand-alone interaction technology, in situations where no other interaction media would provide better experiences:

*“I think if, if anything the BCI increases user autonomy, in these very very difficult cases where user autonomy is basically at the lowest point possible.”*

(Researcher 1 - Senior Researcher, November 2017)

The justification for using BCI devices in this use case is an anticipated increased user autonomy for people that normally have a small degree of autonomy. While this sounds promising, research stakeholder 1 also anticipate that this increase in user autonomy is only possible if the BCI device works properly:

*“I mean, the BCI at least in theory would, that would increase user autonomy if it works correctly right.”*

(Researcher 1 - Senior Researcher, November 2017)

This suggests that research stakeholder 1 anticipate the accuracy or usability of the current devices to not be able to provide low autonomy users with an interaction device that works well enough to provide them with an increase in autonomy. The usage of BCI devices to increase user autonomy for people locked in or otherwise with low autonomy is something research stakeholder 2 also mentions:

*“Brain-computer interfacing can take that a step further and say. And perhaps in someone who is in a coma, but actually conscious. If you can perhaps give them the ability to tell us what they want, and what they need, and how they feel and how to understand people in that situation a little bit better. So that we can make better decisions about how to treat them. How to provide for them. Things like that.”*

(Researcher 2 - PhD, November 2017)

The comment above shows that research stakeholder 2 anticipate BCI to be used for such purposes, which can be used as a justification for developing BCI devices. Research stakeholder 2 however also agrees with research stakeholder 1 that the current state of BCI devices is not good enough to provide useful use cases:

*“Yeah potentially. It really depends on how, how the technology develops. [I mean] right now we are not at the point like, where it's a useful tool in the workplace. I do hope that one day it will be. Because I think that, you know, making, allowing us to work more efficiently to solve maybe more complicated problems that we*

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*wouldn't be able to solve, or wouldn't be able to solve as quickly is ultimately a good thing."*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 anticipate that BCI devices will be used in office environments to improve efficiency or as a tool to solve complicated problems. This development is, however, dependant on the future development of BCI devices according to research stakeholder 2. Research stakeholder 2 also anticipate that BCI devices could be used for more nefarious purposes such as governments for surveillance:

*"Then, and if they are using a brain-computer interface for maybe, maybe for some other reason, but then their brain activity is recorded, analysed by some machine-learning algorithm on I don't know, some government server, and then it says this person, has say a negative reaction to our, military efforts in this other place."*

(Researcher 2 - PhD, November 2017)

While the comment above does not definitively show whether research stakeholder 2 use this as a justification for not developing BCI devices or for not developing BCI devices, the following comment suggests that such purposes are something research stakeholder 2 is against:

*"in the future being able to directly stimulate networks in the brain to kind of kill that emotion right away for example so. 06:03 There is a lot of ways that brain-computer interfacing can and I think will be used against people."*

(Researcher 2 - PhD, November 2017)

While the comment above is not directly related to the previous comment, the statement from research stakeholder 2 about BCI being used against people suggest that the stakeholder anticipate multiple use cases that could be problematic. Consumer stakeholder 3 is also anticipating that BCI could be used for unethical purposes:

*"No, I guess yeah, you can always use good stuff for bad stuff so. I don't think there should be much concern about that to be honest with you."*

(Researcher 3 - Bachelor Student, December 2017)

The statement above shows that while research stakeholder 3 anticipate these use cases to appear, that the justification for continuing the development is that all technology has good and bad use cases. This suggests a utilitarian approach to the ethical question and that the good use cases outweigh the bad use cases. Some of the good cases research stakeholder 3 anticipate is BCI as a control device for artificial limbs:

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*“Ideally like, everyday life. I mean, it would be tremendously [INAUDIBLE] if artificial limbs could be, can be controlled totally by mind, but that's years ahead so. Yeah, but ideally you want the technology to be used all the time.”*

(Researcher 3 - Bachelor Student, December 2017)

In the same way as research stakeholder 1 and 2 do research stakeholder 3, however, anticipate these use cases to be far in the future. Research stakeholder 3 also anticipate BCI to be used in commercial settings:

*“Definitely, there is, there is commercial, there is always, if it turns out to be engaging towards the audience it's gonna have plenty of commercial uses I imagine, entertainment and stuff. But I mean, to, as a, to progress as a human race I see that, that medical uses will be the most important.”*

(Researcher 3 - Bachelor Student, December 2017)

The two last comments by research stakeholder 3 are used as a justification for the development of BCI devices despite the anticipated bad usages of BCI devices. Firstly, the current BCI devices are anticipated to not be used until later. Secondly, the main usage anticipated by research stakeholder 3 is in medical usage, which in the mind of will progress the human race. All of the above stakeholders anticipate that the current state of BCI limits the use cases of BCI devices, which is echoed by research stakeholder 4:

*“You know, before, before you, you actually can do something you have to, you have to strap on all kinds of contraptions and, like an exoskeleton or, or a BCI headset or google glasses or a MIYO or whatever you have and that. Right away has major implications on the naturalness of your interaction.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 does, however, mention that this perception and anticipation might be based on the devices they had access to:

*“Now this is stupid right? I mean this is a big drawback. You just don't want that, now of course that is my, maybe the type of BCI we had at that particular time. But most, most research, at that particular moment was done the way that I just explained. Always with cline, kind of fluid, in order to make the contacts, to the sensor, the best.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Despite these anticipated restrictions in use cases for BCI devices, research stakeholder 4 still anticipate they will be used as a control device:

*“But, what is the real use of it, you know? Like, do I interact better or what do we? And it's all because we want to go into robotics and we want to have like robots that will be assistive in future, and this is another*



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*dire situation that we are creating. That need to assist us in our lives. But we don't even get our own physical life in order yet."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 argues that these use cases are not desired because more pressing things should be the focus of research. This is then used as a justification for research stakeholder 4 to not wanting to work with BCI devices. Research stakeholder 4 also anticipates that BCI devices will be used in prisons:

*"And there are millions of them incarcerated because that's complete new economy, you probably know about that, but like, you know, I can see that, these Americans will fit them up with BCIs and you know, start mind control all these people, you know. It's scary, and I know for sure they already probably do it. So. Just shows you like, why are we doing this? Is it mass control? Is it? What is it?"*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

This use case is interesting as it is similar to the use cases anticipated by research stakeholder 3, which is BCI as a device to control people and for surveillance. Unlike research stakeholder 4, research stakeholder 5 is anticipating more positive use cases for BCI devices:

*"That you can use, with your mind, with a little bit training a person will have some disabilities. He could use everyday things as brushing the [teeth] or holding a cap or something like that. That's the main goal of my research."*

(Researcher 5 - Masters Student, February 2018)

The usage of BCI devices to increase user autonomy for disabled users is used as a justification for research stakeholder 5 to do the research. In a similar way as other research stakeholders are research stakeholder 5 anticipating this development and use case to be in the future though:

*"Yeah, I believe in that. What I mean. I think the BCI in the future, it will help for rehabilitation of cognitive or neurological problems. That aims [wait] people with motor [INAUDIBLE] such as ALS paralysis or stuff like that."*

(Researcher 5 - Masters Student, February 2018)

Unlike the other research stakeholders though, this comment suggests that the use case of BCI devices as rehabilitation is not only a justification for BCI research but also the goal for research stakeholder 5. While research stakeholder 5 is actively developing BCI for a specific purpose, the stakeholder is also anticipating that there might be potential unintended use cases for BCI devices. Research stakeholder 5, however, anticipate that by employing biomedical standards for ethics, these concerns will be reduced:

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*“From the research part I think, as long as the research follows the biomedical standards for ethics I am okay with it.”*

(Researcher 5 - Masters Student, February 2018)

Research stakeholder 6 potentially has a more direct approach to anticipating unintended use cases which are shown by the following comment:

*“No, for the moment no. We have only used it for that.”*

(Researcher 6 - Bachelor Student, February 2018)

The comment above shows that research stakeholder 6 only anticipated the use case in the setting they were using it in their research. Since the technology in that setting were only used for one thing, there were no unintended use cases. Research stakeholder 6, however, does acknowledge that this justification is restricted to that specific setting:

*“No. No because I think, if people use with good purpose everything is fine. And it depends to. My, the machine is as good as the creator. So. We have to be careful, just in, with [hands] it is, but not for now. I think we are so far away from that [INAUDIBLE] to watch literally in our brains so. For now, no I am not concerned.”*

(Researcher 6 - Bachelor Student, February 2018)

While research stakeholder 6 anticipate that the technology could be cause for concern when in other hands than themselves it also shows that research stakeholder 6 is of the opinion that ethical values can be embedded into the technology by the developers. Research stakeholder 6 also anticipated that the technology could be used for controlling other applications:

*“No, no absolutely. I don't think it will be a problem, in fact. I tried to make an application with [INAUDIBLE] to try to control the [INAUDIBLE] applications. And obviously you, a person has to be, has to be careful with, when it, is using or wear.”*

(Researcher 6 - Bachelor Student, February 2018)

Interestingly research stakeholder 6 also anticipated that while the developer has an influence on the ethical values embedded in the technology, the user of the device needs to be careful when using it. This could potentially make it complicated when it comes to a situation where responsibility for something happening has to be determined. Research stakeholder 7 also mentions that it is not always possible to predict how technology can be used:

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*“So like, I cannot say that, so personally I have not thought in too much about it when during my research. But, and right now on my two feet I cannot think of too many, too many variance how it can be used probably. But this doesn't mean that it cannot be so.”*

(Researcher 7 - Masters Student, February 2018)

This shows that research stakeholder 7 did not anticipate this as a concern, which suggests that research stakeholder 7 anticipates the technology to be used in the ways intended by the developer. Overall research stakeholders anticipate that some use cases will be bad for humanity and that most of the good use cases for BCI devices will be in the area of medical use or to improve the lives of people with disabilities.

### 4.5.3.2 Regulation

Overall the research stakeholders anticipate that regulations will come for BCI devices. Some research stakeholders also anticipate that the regulators do not know much about BCI devices, and some worry that the added regulation will create undesired bureaucracy preventing them from doing their work. In this section these anticipated concerns will be analysed. Research stakeholder 1 anticipates that regulators need to get a better understanding of other sensor technologies to make a regulation that will also affect BCI devices:

*“that would require a better, a better understanding or abstraction of what all these intelligent sensors are capable of, of doing. How they process data and all these things. I think that would actually be important and I would of course cover the BCIs as well.”*

(Researcher 1 - Senior Researcher, November 2017)

The important thing to note about this comment is that research stakeholder 1 considers BCI devices as a sensor device, and regulating sensors, in general, will cover the concerns that might be associated with BCI devices. This shows that research stakeholder 1 does not anticipate BCI to be a novel technology compared to other sensory devices. Additionally, research stakeholder 1 anticipate that the solution to policy gaps is making more general regulation instead of targeting specific technologies:

*“I think, what would be needed would be a more general understanding of all these components work and not to, to really start from scratch again and again, and to always be behind in a next, in the next innovation which comes up and is not covered again by, by your current laws.”*

(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 1 anticipates that making the correct regulation requires an overall understanding of how sensor technology works, which is something research stakeholder 2 anticipate as well:

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*“So the kinds of political decisions they make about them I think will be poorly informed. And I am not sure what the solution to that is. 36:15 Because I don't think there is much of an interest on the part of politicians to become well informed.”*

(Researcher 2 - PhD, November 2017)

While research stakeholder 1 was anticipating an overall understanding to be a requirement for making the correct regulation, research stakeholder 2 is less optimistic politicians having that knowledge. Research stakeholder 2 anticipate when working with regulators that their knowledge of the technology will be limited. This is further seen in the following comment:

*“Well, I, I assume that politicians for the most part, will not be well informed about what brain-computer interfaces are, and what they can do. And that is going to be a barrier at all times. It's really going to depend on the country as well, I mean, as you might have guessed I don't have much hope for the US these days. The degree to which they seem to be ignoring science lately I think worries me quite a bit.”*

(Researcher 2 - PhD, November 2017)

Overall this means that research stakeholder 2 anticipates that regulators are not capable of providing good regulation for BCI devices because of a lack of knowledge and understanding of the technology. This could potentially be used as a justification for not wanting regulation to be implemented, or as a justification for further engaging in the regulatory process to ensure that politicians are well informed about the technology. Research stakeholder 3 is unlike research stakeholder 1 and 2 anticipating new regulation, expects current regulation to be modified to either be tougher or weaker in regard to BCI technology:

*“But, yeah like, obviously there is, there is some rules that's gonna have to either be, more, rough in some areas and some that should be softened a little bit.”*

(Researcher 3 - Bachelor Student, December 2017)

This process is something research stakeholder 3 also anticipate will come naturally:

*“Yeah, I, we, I think it's a, yeah as we go forward we should always update our legislation. We do not, like, we do not burn women for adultery anymore so.”*

(Researcher 3 - Bachelor Student, December 2017)

This argument could be used as a justification for not participating in the change in regulation, as the progress would happen naturally no matter what. This is further supposed to be the case by the following statement:

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*“To allow people with these things to, to [apply their selves] as well. Yeah, I, it will probably be changing, obviously, how much I am not a law maker to be able to say that. But yeah it's. I think it's going to happen.”*

(Researcher 3 - Bachelor Student, December 2017)

In the comment above research stakeholder 3, justifies not participating in the anticipated process by the idea that they are not regulators themselves. A similar justification is used by research stakeholder 4:

*“You know, because there is nothing to regulate because there are no rules for that. And, and at one day if we need them, like, I hope like what happened to google glass that, the same will happen to BCI that it will just be a defunct project and product.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The justification used by research stakeholder 4 is the development of another technology, particularly google glasses. This justification is based on research stakeholders 4 anticipations to the development of BCI technology leading to the technology to be unsuccessful in getting mass adoption, which reduces the need for specific regulation for the technology. Research stakeholder 5 is similar to research stakeholder 2 and 3 not convinced that regulators will do a good job:

*“I think that governments do whatever bring, brings them money. As to, here in [COUNTRY] I can't tell for other countries.”*

(Researcher 5 - Masters Student, February 2018)

Unlike previous stakeholders though, research stakeholder 5 is anticipating that governments will be looking at the profits rather than what would be the best regulation for BCI technology. Research stakeholder 5 is, however, anticipating that if BCI technology follows bioethical standards, that it will be okay:

*“yeah, I think I answered that before, I think the little concerns, it, as long as the BCI technology follow the bioethical standards world wide. I think this is not. There would be no problems.”*

(Researcher 5 - Masters Student, February 2018)

This suggests that research stakeholder 5 is anticipating self-regulation within the industry/research setting to be better at dealing with ethical concerns than government regulation. This could be used as a justification for prioritizing work in these areas rather than regulation. Research stakeholder 6 is also of the mindset that self-regulation is enough:

*“yeah I think this is a career of what you want to do. So. But for the time it's just, it's just research so. I, we are doing, is helping straightly help. So, it's something that, is not, affect affecting people now, so. I think,*

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*for the moment we police it, they are so. Are, are okay.”*

(Researcher 6 - Bachelor Student, February 2018)

Research stakeholder 6 has the condition that self-regulation only works in a research setting. When the technology moves to the public, regulation has to be introduced to keep the use cases in check according to research stakeholder 6:

*“Yes, I think, if, if it will be public, it has to be. Because. Because for example we, we try to do, something with people who are brain disorders for example. But this person we are going to, to try the product on. Hasn't the, the conscious to think what they want to do so. They are not conscious of what they are doing so. Something is insured about them, they have to. Someone has to control what they are doing with the product.”*

(Researcher 6 - Bachelor Student, February 2018)

Specifically, research stakeholder 6 is concerned about the use case when BCI technology is used by people who have brain disorders. It is unclear whether research stakeholder 6 believes the regulation should be put on the technology, or the people delivering the product though, which could implicate what kind of regulation research stakeholder 6 expects to be put in place. Research stakeholder 7 is of the opinion that regulation creates barriers for research:

*“Let's say I work in a mental hospital, or a hospital in general, I have this really nice idea about doing a study. I have the people I need, who agrees with it, I have some person in the hospital which can, which knows a bit about the policy stuff. It is, there is this really big barrier about actually going ahead and doing this.”*

(Researcher 7 - Masters Student, February 2018)

While research stakeholder 7 above anticipate regulation to create a bureaucracy for BCI research, research stakeholder 7 also anticipate that such regulation is currently not in place and this gives researchers the ability to do research:

*“Which makes it much harder to do research sometimes than it should be. So, how it is right now. The situation we have right now where I would not say that it is a bit of wild west, but it's not. But policy, bureaucracy etc, there is not too much of it as, which is specific to this field and actually thank god for this, because if you are, if you are a normal nice person, who actually wants to help and who has the ability to do so. It is, right now, it is possible.”*

(Researcher 7 - Masters Student, February 2018)

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Research stakeholder 7 uses the argument that good people who are willing to do research with BCI devices are able to do so due to the lack of regulation currently existing. Research stakeholder 7 is thereby anticipating that people involved in BCI research are inherently trying to do good. The acknowledgement that it requires “normal nice” persons for this to be the case, however, also shows that research stakeholder 7 anticipates that not everyone is “normal nice” persons, which should be a cause for concern. Research stakeholders have made similar comments about anticipating the commercialization of BCI devices to be a concern. Overall research stakeholders anticipate regulation to be something that needs to be developed, however, the trust in policymakers are not very high.

### 4.5.3.3 Commercialization

This section will analyse the comments made by research stakeholder 2 and 4 about anticipating the commercialization of BCI devices to be a concern. Overall the two research stakeholders anticipate that the BCI developers setting will impact BCI development in a negative way. These settings are corporate settings, as well as military settings. Specifically, research stakeholder 4 is concerned about how corporate entities might impact research and how capital interests might influence research settings. Research stakeholder 2 is specifically worried about consumer stakeholders exploiting people for capital gain:

*“Uh, yeah a lot of things. I think, I think brain-computer interfacing has a lot of potential to improve peoples life, but developing brain-computer interfacing in the type of society we have, which is very keen to exploit for capital gain worries me a lot.”*

(Researcher 2 - PhD, November 2017)

This comment is interesting as it shows research stakeholder 2 is anticipating exploiting behaviour from consumer stakeholders. Research stakeholder 2 anticipates that the exploitation of users will be consumer stakeholders taking advantage of people addicted to self-diagnosis:

*“so I can see that down the line being an issue in brain-computer interfacing, for example, you'll probably, you'll have, I am sure you will have companies kind of going after this self-diagnosis market, of people who are addicted to websites like WebMD and diagnose themselves with different form of cancer every week.”*

(Researcher 2 - PhD, November 2017)

This sort of exploitation is however not the only form of exploitation that research stakeholder 2 anticipate for BCI devices. The usage of BCI devices in corporate settings is making research stakeholder 2 anticipate concerns, however, it is also extended to the usage in military settings:

*“It's more corporate entities I think that I am worried about the most. 05:04 And the military of course, so the possibility of us, of people. Reading for example when a soldier behaves, is behaving empathetically*

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*towards someone who the military doesn't care about and then, using that as a way to retrain in some psychologically sense that soldier."*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 mentions that the military could use BCI devices to monitor soldiers and use this data to retrain soldiers to be less empathic towards people. While this does not further explain the problems with the commercialisation of BCI devices, it shows that research stakeholder 2 is concerned with the settings that BCI devices are used in. Both examples also show that research stakeholder 2 anticipate BCI devices to be used to manipulate users. While research stakeholder 2 is concerned with the commercialisation of BCI resulting in direct manipulation of the users, research stakeholder 4 is worried about the unintended changes to people's behaviour:

*"I find very interesting, but also, industry doesn't have any morals. And I always say that design and, especially industrial design and designers. They have no ethics, what they do. And that is one of the biggest problems we have, I find, currently, also already for, for the large decades but especially right now because of all the technology push that's been going on lately. And, on and on, because we don't, understand it anymore. What it really does to us."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 is questioning the morals of the BCI industry. Research stakeholder 4 is specifically anticipating that the push for the technology before the consequences has been thoroughly researched will result in concerns. The questioning is also based on the practices in the industry that promotes research that requires the usage of the products they are developing. This suggests that research stakeholder 4 is convinced that the motivation for the industry to promote the technology and further research is for capital gain.

*"We have to understand how the brain works, how all the synapses function, and have, all the, let's say the interactions in the brain are working, so we can make an artificial brain. That's basically what we need to know, that's why contraptions like the BCI shit is being made by industry. So to put it forward in order to get more researchers to go into the research because it will fill their bank account, but it's you know, we have."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The concern with the capitalisation of BCI development research stakeholder 4 has is further explained in the following comment:

*"Well, the researchers like to receive these presents of course, and well then they let all the students play around with it and well, eventually they produce some new nice research, which you can, well go back of*



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*course to the original company so. That's with the, yeah, that's a bit of maybe an issue there."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Specifically, research stakeholder 4 is concerned with the influence consumer stakeholders has on research. It appears that research stakeholder 4 is of the opinion that the consumer stakeholders take advantage of the research industry by paying them indirectly to perform certain research they can later use to promote their devices. Research stakeholder 4 is also anticipating that the products developed by consumer stakeholders have too many side effects to be worth the use case:

*"So, there is, there is just no correlation between how the interaction was facilitated by the company and what is really needed for us to become, that so that the tool becomes a very useful entity. So you know. There is something of a, a constraint there, but there are also many trade-offs because, the developers don't think of these things."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 anticipate that commercial developers are unable to develop products that are useful. This anticipation is based upon research stakeholder 4s experience with a particular product, and it is unsure whether the stakeholder would be of the same opinion if more devices had been used. Research stakeholder 4 is however quite sure in the idea that the industry is deceiving and overselling their devices:

*"Not like, because yeah, of course the sensors have the limitation of yeah, in this case, only a [picture], mesh of brainwaves and, well so there is not a clear. There is not a lot of clear thoughts visible but for direct interaction, so. So that's I guess where it comes from. Okay, we have a sensor and well, let's just put in our heads. Let's fake some kind of interactions, and hype it in some ways that, well you can use it in games or whatever, but, I guess nobody, or a lot of people who bought that stuff, yeah, will not still use it because yeah it's. R1: Redundant R2: Yeah it's, it's more okay you are, able to do some interactions, but yeah."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comment above is used by research stakeholder 4 to justify their critique of the commercialisation of BCI devices, and research stakeholder 4 attributes this to the nature of a commercial industry:

*"That's how industry work, because it's all, it's all for the good of consumerism so, yeah, and that's a highly ethical problem."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

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Overall research stakeholder 2 and 4 are critical to the commercialisation of BCI devices. Part of this criticism from research stakeholder 4 is based upon experiences with specific commercial products and their inability to deliver accurate interactions between the user and computers.

### 4.5.3.4 Accuracy

Overall all research stakeholders except research stakeholder 7 mentioned anticipated concerns with the accuracy of BCI devices. Particularly were research stakeholders concerned with the accuracy of BCI devices due to the high level of the signal to noise ratio caused by the way non-invasive BCI devices work outside the skull. Some researchers anticipated the accuracy problem to be related to usability problems because of the increased need for calibration to each individual user. Research stakeholder 1 anticipates that the accuracy concerns identified are impossible to solve:

*“Well you always have to care about that your, the BCI will never be very accurate. I think that is impossible”*

(Researcher 1 - Senior Researcher, November 2017)

While this could be used as a justification for not working on the accuracy of BCI devices, it could also be used as a justification for limiting the use cases BCI can be used for. The current accuracy problems and getting rid of these problems being impossible could push BCI in a direction of use cases that do not require high accuracy. This appears to be the direction research stakeholder 1 is looking at:

*“And I think there is a lot of potential for more improvement, but you always have to deal with that the BCI works on a very noisy channel.”*

(Researcher 1 - Senior Researcher, November 2017)

It is clear that while research stakeholder 1 is anticipating accuracy to be a concern for BCI devices, the concern is not stopping research stakeholder 1 from working with BCI devices. The anticipated accuracy concerns are rather informing research stakeholder 1 on the direction BCI research needs to take. Research stakeholder 2 further adds to the topic discussed in the previous section of commercialisation with the following comment:

*“So in the literature there is a lot about misinterpretation and the accuracy of data, is that something you concern yourself with as well? 07:48 R: Uhm, yeah, I think especially when brain-computer interfacing enters commercial use.”*

(Researcher 2 - PhD, November 2017)

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It is, however, important to mention on the topic of accuracy that research stakeholder 2 is anticipating the accuracy of the devices to be a concern. More specifically research stakeholder 2 is anticipating a concern with the false positives being interpreted from the BCI data:

*“but then they don't tell you that there is a 60% false positive rate, that's part of that, and even if they tell you that in the fine print I think, my sense is that a majority of people are not aware of how to incorporate that into their interpretation of the results. So that's potentially troubling I think.”*

(Researcher 2 - PhD, November 2017)

Unlike research stakeholder 1, research stakeholder 2 is anticipating that these problems can be solved if the developers are aware of the lack of understanding from users, and actively deal with the concern. Research stakeholder 3 believes the problem of misinterpreted data is not a problem for BCI technology only:

*“But that's like, that's the reason why MI based BCI takes usually multiple training sessions and such. I mean, everything can be, [INAUDIBLE] misunderstood or misconstrued”*

(Researcher 3 - Bachelor Student, December 2017)

Research stakeholder 3 statement above also shows that there is a justification for the stakeholder to work with BCI devices, as the solution to the accuracy problem is multiple training sessions according to research stakeholder 3. Using multiple training sessions was also anticipated by research stakeholder 6 to be the solution to this accuracy problem:

*“Yeah we have some issues because, the [signal] we are using, was changed according to people so, I, at the first place I have to use it, but when I test it in another person I have to change everything. Because everything change, so it was a issue we had.”*

(Researcher 6 - Bachelor Student, February 2018)

The anticipated problem with accuracy by research stakeholder 3 and 6 is also depending on the state of the mind of the user according to research stakeholder 3:

*“oh I think that, that, like the data itself is kind of hard to balance because some people, it depends a lot on the state of mind of the person.”*

(Researcher 3 - Bachelor Student, December 2017)

It provides interesting insight that research stakeholder 3 thinks that the state of mind of the user is important, as this could mean that developers need to be aware of the state of mind of users to ensure the

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accuracy of their devices. Unlike research stakeholder 3 research stakeholder 5 anticipated the problem of accuracy to be related to the hardware of the devices rather than the users:

*“Yeah, in my research, with an emotive EPOC. I faced this difficulties. The sensors couldn't have good connectivity. It's [INAUDIBLE]. There is, much of the time, the signal had to. How to say that. It's a little sensitive to noise and to [INAUDIBLE] so the. The outcome has to be done by filters.”*

(Researcher 5 - Masters Student, February 2018)

The justification for research stakeholder 5 to continue working with BCI is that the difficulties with accuracy would be solved with filters. While research stakeholder 5 anticipate some of the accuracy problems to be solved this way, research stakeholder 5 also anticipate that training sessions would be another way to handle accuracy problems:

*“The second difficulties that you have to do, much much, you have to, to dedicate much time in training. So the, acquired data is not about precision than is more about the skill rating of the subject.”*

(Researcher 5 - Masters Student, February 2018)

Interestingly, research stakeholder 5's comment also shows that the stakeholder anticipates that the accuracy problem could be a contributor to another ethical concern which is the problem of the digital divide. Overall the research stakeholders anticipate accuracy of the BCI devices to be a concern and this could relate to not only the digital divide concern but also concerns about usability.

### 4.5.3.5 Digital divide

Almost all research stakeholders commented on anticipated concerns regarding the digital divide. Overall research stakeholders were of the opinion that the digital divide would be a concern for BCI devices. Some of the reasons for this anticipated concern were differences in financial opportunities, technical abilities, and dehumanising. These comments will be further explored in this section. Research stakeholder 1 is anticipating that BCI devices do not have the potential to create a financial digital divide:

*“And there are people who can afford it and people who don't but, I think, I don't think BCI opens an, opens an area where only the richest 5% could afford it.”*

(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 1 shows in the comment above, that the understanding of the digital financial divide is understood as a divide between the very rich and the average consumer. This, however, does not address the financial digital divide, which could occur between average consumers and those less wealthy. This is a concern research stakeholder 2 however anticipates:

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*“One issue is that someone who can afford BCIs outside of work, will also have an advantage at work. Because they might be more effective at using BCIs, but it's a similar issue that we have now. People who, who spend more time on computers, and can afford more modern computer technology are just better at using computers I guess on average.”*

(Researcher 2 - PhD, November 2017)

While research stakeholder 2 anticipates this concern to be based on a financial divide, the stakeholder anticipates that the divide will result in a divide in technical ability as well. While this could be used as a justification for developing on BCI devices to make them more financially accessible, research stakeholder 2 also points out that some of the financial divides are partly resolved in corporate settings:

*“One of the nice things about the workplace is that your work place provides you with your computer, I would hope. And so the workplace should provide you with the BCI”*

(Researcher 2 - PhD, November 2017)

Most of these anticipated concerns rely on BCI devices becoming more useful and providing an advantage to its user, which is something identified and anticipated by research stakeholder 2 as well:

*“For me the big one is the digital divide as you mentioned. I do think, [although] of course that could be wrong, that at some point we will have brain-computer interfaces which give, a real and clear advantage to people who are able to use them and afford them.”*

(Researcher 2 - PhD, November 2017)

The comment above shows that research stakeholder 2 does not view BCI technology as providing a clear advantage to users as it is, but that they have the potential to do so. The anticipated problem for BCI technology is one of the largest concerns research stakeholder 2 has:

*“Particularly if we have sort of, invasive technologies become mainstream in some way. Having a divide there where some people and some people can't I think, would be disastrous for a society. All sense of equality to the extent that it still exists I think is lost at that point. That I think is the biggest, in my mind that's the biggest concern that requires a political answer.”*

(Researcher 2 - PhD, November 2017)

Interestingly, the anticipated concern of BCI devices is increased if the devices become invasive. This increase is most likely connected to the accuracy concerns described previously, which limits the use cases for BCI devices. Research stakeholder 2, however, is also anticipating that BCI technology could provide

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enhancement opportunities for its users which could further increase the concerns regarding a digital divide:

*“The problem I see, is that we apparently as a group lack the empathy to not allow people to become destitute to go without, that we don't see them. That we will stop seeing them as people. 26:52 Because they don't have the enhancements that other people have.”*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 also anticipates that the digital divide might be of increased concern because enhancement could remove empathy for those that are not enhanced, thereby changing the concept of who we consider human. This topic is further described in a later section on the BCI and the concept of identity (section 4.5.3.13). Research stakeholder 2 was anticipating that people's ability to use BCI devices could be the effect of a financial digital divide. Research stakeholder 3 believes that the digital divide is a natural difference between people:

*“I think, I think that people can learn and if not, the technology can be better. And like, I mean it's also kind of natural like, you can have musical instruments in your house and there are people who can't play it and there are people who will never be able to play.”*

(Researcher 3 - Bachelor Student, December 2017)

This comment is interesting as it shows that research stakeholder 3 is agreeing that the access to technology will create a digital divide, however research stakeholder 3 is not anticipating this to be a problem or a concern. That research stakeholder 3 is in agreement that access to technology can change your ability to use the device is further supported in the following statement:

*“Not really, I think that, like, it's a way of thinking and it can be kind of [INAUDIBLE], in my opinion you can program a person to think in a way. That's what the upbringing is, I didn't. In the nature vs nurture argument I am on the nurture side so.”*

(Researcher 3 - Bachelor Student, December 2017)

This statement shows that research stakeholder 3 puts emphasis on people's ability to train and thereby increase their skill at a technical device or instrument. The statement that it is natural for people to have different abilities according to research stakeholder 3 is then used to justify a lack of concern regarding the digital divide:

*“And, I don't know, that's, I don't see it as much of a concern myself. Like, it's gonna happen probably, but like I don't, I wouldn't worry about it too much. I think, [the picture] will change if that comes to, to happen*

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*[pretty soon]."*

(Researcher 3 - Bachelor Student, December 2017)

In this statement research stakeholder 3 confirms that a digital divide will most likely happen, but that it is not a concern for the stakeholder. Research stakeholder 5 is just like research stakeholder 2 concerned about a financial digital divide:

*"Imagine a subject that have a disability and don't have the money to buy or don't have the technological knowledge to use a computer or a BCI or something like that. I think the side effect it will be psychological if you know what I mean, feel left out. Yeah."*

(Researcher 5 - Masters Student, February 2018)

Research stakeholder 5 is specifically worried about people with disabilities not having access to technology. Research stakeholder 5 is, therefore, anticipating the use case for BCI devices to be in either a medical setting or as a supportive tool for those in need of such a communication device. Research stakeholder 5 further specifies how a generational gap might exist between those that are capable of using the devices and those who are not:

*"An old person don't have the knowledge to use a, properly. A computer system. So if the graphical user interface or the menu or something is easier to use, if you know what I mean."*

(Researcher 5 - Masters Student, February 2018)

This anticipated generational gap is something that could be used by research stakeholder 5 to justify working on improving the usability of BCI devices, to limit the generational gap between those users who are capable of using BCI devices and those who are not. Having heard consumer stakeholders mentioning that some users were incapable of using BCI devices research stakeholder 6 was also asked whether this was something he anticipated as well:

*"I've heard that some have, had issues where they didn't register on BCIs as well as other people. Is that something you've encountered as well? 16:55 R: No, no I don't."*

(Researcher 6 - Bachelor Student, February 2018)

While this does not mean that research stakeholder 6 did not acknowledge the problem, the stakeholder had not experienced it. This suggests that the concern was at least not anticipated. This further limits the anticipated amount of users that are unable to use the devices either due to poor graphical interfaces or technical difficulties. Research stakeholder 7 is unlike the other stakeholders on this topic very specific in the anticipated developments in BCI and the concern of a digital divide:

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*“Sometime, maybe I think in the next 10,15,20 years it will become much more widely adopted but, I would not say lifechanging.”*

(Researcher 7 - Masters Student, February 2018)

The comment shows that research stakeholder 7 believes that BCI usability and impact on society is rather small, and the development will take time to be put in effect. This could be used by research stakeholder 7 as a justification for not being concerned about a digital divide. If the impact is rather small, and slowly implemented, there is less reason for concerns compared to a technology that has wide implications and is fast to be developed and implemented. Research stakeholder 7 is however concerned that a financial gap will be present for BCI devices:

*“And if we think about a future society when your ability to do this will influence how much money you earn, how many others BCIs can you get? Then it will be [INAUDIBLE] the situational. The rich getting richer and the poor staying poor.”*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 anticipates that BCI could increase the gap that already exists between different levels of wealth. However, it is unclear how much of a concern is anticipated as research stakeholder 7 is not anticipating BCI devices to be revolutionary:

*“different possibilities. I really do not think that BCIs will become something on a whole new level.”*

(Researcher 7 - Masters Student, February 2018)

While research stakeholder 7 is not of the opinion that the concerns are going to take it to a whole new level, research stakeholders overall on the topic of digital divide appear to be anticipating the digital divide to be a concern of varying degree. Research stakeholder 7 is of the opinion that the limits of BCI are the redeeming factor for the digital divide. Overall research stakeholders are not anticipating the digital divide concerns to be of major importance. Which is true both for availability concerns as well as the ability to use the devices. Research stakeholder 2 mentioned that this would change if the technology becomes invasive.

### 4.5.3.6 Invasive

The research stakeholders commenting on the topic of invasive BCI in general mention that invasive BCIs has inherent risks and concerns. A point being made in this section is that research stakeholders believe that invasive BCIs will be restricted to research settings or medical settings. Research stakeholder 1 is of the opinion that invasive BCI inherently has a risk:



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*“So of course for invasive BCIs there will always be. Risks. I mean it's a highly, highly invasive technology. And the risk will always be there, and will always be substantial.”*

(Researcher 1 - Senior Researcher, November 2017)

The stakeholder also specifies that the risk associated with invasive technology is a risk that cannot be removed. The permanent risk associated with invasive technology is also used for creating certain restrictions for BCI technology:

*“And invasive BCI that will always be administered by a medical doctor, so these will of course never be systems which you would buy or get at the store or BCI service or whatever.”*

(Researcher 1 - Senior Researcher, November 2017)

Due to the permanent risk associated with the technology, research stakeholder 1 predicts that such technology will never be used in consumer settings. One of the concerns research stakeholder 1 is anticipating is the risk of devices being hacked:

*“Or control prostheses sure, I mean, these could in principle be hacked and attacked, and that's probably in the same, in the same security level ballpark as pace makers for example are.”*

(Researcher 1 - Senior Researcher, November 2017)

The anticipated risk is expected to be similar to other invasive technologies according to research stakeholder 1. The comparison of BCI technology with other technologies is a topic that will be further explored in section 4.4.3.8. Research stakeholder 2 are anticipating other risks with invasive technology:

*“Uh, yes, I guess I would say the only difference between an invasive and a non-invasive BCI in that sense is that you can take off the non-invasive BCI. So if the user has some kind of off switch that can't be overwritten, for an invasive BCI, that might be a technical solution to that. Although I don't know again to what extent it's possible to, to prevent someone else from turning it on.”*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 is anticipating that invasive technology will be of increased concerns because the users lose their autonomy. The stakeholder is anticipating that the permanent nature of an invasive technology will reduce users' ability to restrict access to the BCI data. Research stakeholder 2 is not sure to what extent the concern will be relevant, as the stakeholder is unsure to what extent it is possible to mitigate the risk. These risks can be used by research stakeholder 2 to justify not engaging with invasive technology and restricting the availability of invasive technology. The availability of invasive technology is something research stakeholder 5 is also commenting on:

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*“As far as I know, the commercial BCIs is strictly non-invasive so if someone has an implant in his head for BCI research, it's for research, it's non-commercial. So. As far as, my concern in the commercial BCIs. This is not a problem.”*

(Researcher 5 - Masters Student, February 2018)

It is clear that research stakeholder 5 similar to research stakeholder 1 is using the availability and restricted use case of invasive BCI technology as a mitigating factor for the concerns related to invasive BCI technology. Research stakeholder 7 also comments on the availability, however with a different concern in mind:

*“Uhm. I do not have a, I do not have much to say about this, but most things which are like invasive pacemakers still have to be tested. And such technologies in general. I think a really interesting [INAUDIBLE] in regards to ethics would be how do we actually find people to test them on because it is much, I think it can be more dangerous than for example medicines and stuff, but again this is not my field.”*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 is anticipating that the risk associated with invasive BCI devices will limit the uses, but that the risk will also make it a bigger ethical concern to find research participants. This would limit the ability for researchers to make progress and mitigate the concerns currently known for invasive BCIs. This could be used as a justification for increased regulation of invasive BCI devices, however, it could also be used as a justification for creating guidelines on how to recruit research participants and thereby increasing the access for researchers to participants. Research stakeholder 4 is also commenting that some people will be excited to try invasive technology:

*“And I kind of like that, so if you can have an implant, I'll do it.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 is not only anticipating that some people will be willing to take on the risk of invasive technology, but the stakeholder is also anticipating that one of the users will be themselves.

Research stakeholder 2 is anticipating that there will also be side effects of invasive technology:

*“So, first of course in terms of an invasive BCI there are potentially some biological side effects of having some, piece of technology directly interfacing with the brain in some way.”*

(Researcher 2 - PhD, November 2017)

In the comment above research stakeholder 2, anticipate that invasive technology will have side effects.

Overall research stakeholders anticipate that invasive BCI technology will be dangerous and will mostly be if

not only be used in medical situations. Only research stakeholder 4 said specifically that they would use invasive technology if possible.

#### 4.5.3.7 Side effects

All research stakeholders except research stakeholder 7 commented on the topic of side effects. Unlike on the topic of invasive BCI, most research stakeholders are not anticipating any major side effects. Most research stakeholders are of the opinion that the side effects associated with BCI devices are minor, or even being removed as the technology progresses. Research stakeholder 1 points out that the trend of moving away from gels used in BCI technology reduces the risk of skin irritation:

*“so for healthy users, I say that the side effects from a medical perspective they are really minuscule so I mean. So many new devices are available or come up. You don't have to use [embrasive] gel anymore, I mean there are devices which works completely without any gel which could irritate skin for example.”*

(Researcher 1 - Senior Researcher, November 2017)

The side effect of gels in terms of skin irritation is something also mentioned by research stakeholder 4:

*“So I don't really see that there are a lot of concerns actually about well this, just capturing kind of way. Yeah just, just that, well, you have this kind of gel of course that you need to use, or well, not anymore but what people dislike. But it's [INAUDIBLE]. feel dirty, but.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 1 and 4 are both anticipating that the medical side effects are reduced over time. Specifically, the problem of skin irritation is considered to be the side effect being reduced over time, which is a deviation from the side effects of invasive BCI mentioned in the previous section. Research stakeholder 1 is also anticipating that BCI technology will have side effects on society:

*“but the technology is moving so fast, yeah so I would say that this is really minor. And should be improving over time. And yeah, of course regarding the societal aspects, there probably is potential for side effects there, as again, I think for a [heavy] systems which on a regular basis monitor our behaviour.”*

(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 1 anticipates that monitoring of people's behaviour will have side effects on society. The anticipated risk is however uncertain and could be used as justification for either avoiding working on BCI devices, or increased work to uncover these uncertainties. Research stakeholder 3 is also anticipating that a side effect of BCI usage could be societal or how our way of thinking operates:

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*“You no longer need to think like after I go right, I will go left, because the moment you think I will go left, you think in the future, but the game like represents it or the technology represents it right away. So you kind of have to think, in the moment. And that kind of thinking, like it kind of changes the way you think.”*

(Researcher 3 - Bachelor Student, December 2017)

Research stakeholder 3 is clear in the idea that the stakeholder is using the uncertainty as a justification for further exploring the technology:

*“And it is a concern but in the end like, as long as it benefits, the human kind. Sure why not? But the side effects should be, like we should all, there are areas where people should always proceed with caution.”*

(Researcher 3 - Bachelor Student, December 2017)

The restriction research stakeholder 3 is putting on the exploration of BCI technology is that the consequences are benefiting the humankind. Research stakeholder 4 and 5 have both experienced the side effect of dizziness and feeling nauseous when using their BCI devices:

*“well, I, thought maybe I had some side effects myself because, well, because I hacked all of this stuff, so sometimes when I was wearing, well my hacked version a bit too long. I was, well feeling kind of nauseous sometimes. So, but that's, that's my own fault I guess. But. I am not sure.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

*“For non-invasive technology I think there is no side effects. From the users of a BCI headset. The side effect that I could have in my mind right now is after a few hours of [research] the subject as is, normally, will feel some dizziness or something. As if you are in front of a computer screen for 5 hours.”*

(Researcher 5 - Masters Student, February 2018)

Both stakeholders are anticipating that these side effects are related to a similar side effect of extended computer usage or sedentary work. Which is used as a justification for not investigating these side effects further and continuing to use the technology. This is a justification used by research stakeholder 6 as well:

*“ah, yeah. Yeah I. No, I think this is not a problem because, for the moment there, weren't problems about it so. There is the [INAUDIBLE] in those [INAUDIBLE] so I think it's better use that. Because if there is problem, it's with the [inpassive] techniques so, it was, there are more complicated [INAUDIBLE]. Just my answer around this [thing]. So I think it's not a problem.”*

(Researcher 6 - Bachelor Student, February 2018)

Research stakeholder 4 also mentioned that the use of virtual reality had shown more severe side effects. In general research, stakeholders are not anticipating a lot of concerns regarding side effects. The most

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anticipated concern is societal side effects, however, most of the researchers anticipating is uncertain on the specific side effects. It was also mentioned that it was anticipated that the technology would develop further as other technologies have, which would reduce the number of side effects.

### 4.5.3.8 Other technologies

The research stakeholders engaging in the topic of other technologies in their interviews mostly use other technology or society in general as a justification for BCI not being a great concern, or BCI technology adding anything new to the already existing concern. Only research stakeholder 2 specifically mentions BCI technology as being something that could create more dramatic changes than other technologies.

*“We become reliant on these things. The difference for the BCI I guess, I think it were, [it] depend on the type of BCI and the application, but potentially more dramatically effects the way we think. And the way we interact with the world.”*

(Researcher 2 - PhD, November 2017)

Unlike research stakeholder 2, which is anticipating that certain BCI applications will impact people more than other technologies, research stakeholder 1 believes that for concerns such as privacy and monitoring, other technologies can be used in the same way:

*“For example once your, when your boss forces you to use a BCI to monitor your workload or whatever but I mean there are plenty of other technologies which could be misused in that way.”*

(Researcher 1 - Senior Researcher, November 2017)

Research stakeholder 1 is anticipating that the type of monitoring done by BCI devices will be no more invasive in privacy than other technologies. This shows that research stakeholder 1 values brain data the same as other technical data about our behaviour and mindsets. Research stakeholder 1 is also anticipating that the methods used in other technologies to limit the inaccuracy of monitoring and recognition devices will solve some of the problems for BCI devices:

*“You have to come up with a scheme for HCI which erases this, and I think if you do that. You can cope with that.”*

(Researcher 1 - Senior Researcher, November 2017)

While research stakeholder 1 is not anticipating BCI to add anything novel to the concerns, research stakeholder 1 does anticipate the problems, and that the problems will affect BCI technology as well:

*“Again, not to an extent which is super BCI specific. So I mean of course there is, what you say, the digital divide or is that how it's called? And that's, that's potentially a really huge issue for society I mean, if you*

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*really would go mass [mar..] had a BCI application which would appeal to the mass market."*

(Researcher 1 - Senior Researcher, November 2017)

The point of view that the concerns are not anticipated to be specific to BCI devices, could be used as a justification for not investing themselves in finding solutions to the problems. Research stakeholder 2 did anticipate BCI technology to potentially be more dramatic in the way it affected concerns, however on the topic of the digital divide, the stakeholder views BCI the same way the stakeholder views other technologies:

*"Yeah, well the way, the way I kind of view technology in general is that, having. I do see that as a positive application of brain-computer interfacing, the issue is the divide between people who can afford it and people who can't afford it. This is kind of a way I view most technologies."*

(Researcher 2 - PhD, November 2017)

The attitude above that technology has positive applications could be used as a justification for continuing the development of the technology. This comment is further supported by the following statement that there is little that can be done to stop this development:

*"The way things have gone traditionally is that progress has kind of made despite the concerns of people, and society has to, is forced to adapt. I don't think there is a stopping or slowing down the development of these technologies in a real sense."*

(Researcher 2 - PhD, November 2017)

Research stakeholder 2 is also moving the responsibility for the problems with technology from technology or the developers, to society in general:

*"It's not, to me it's not, the problem is not the technology the problem is us. Because we would allow people to go without. It's sort of, it's the same with my response to when people bring up the concern that robots or AI will take over a lot of peoples jobs. And people will be homeless."*

(Researcher 2 - PhD, November 2017)

This allows research stakeholder 2 to remove responsibility from the stakeholder and the technology and continue the development of the technology. Research stakeholder 3 is in agreement with research stakeholder 1 and 2 that BCI technology can be misused like other technologies:

*"sure, I mean but it kind of is, every tool can be, can be used to harm, someone else. That is true for probably everything, so I don't think the concern should be, that [hard]. You can do plenty of stuff with it but for now, the technology is so imperfect that the, I think the worrying needs to come, like it doesn't need to*

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*come right away.”*

(Researcher 3 - Bachelor Student, December 2017)

While research stakeholder 1 and 2 justified the risks of misuse with the argument that other technologies could be misused as well, research stakeholder 3 justifies the continued development with the argument that the BCI technology is currently imperfect. Which is an interesting justification because it suggests that research stakeholder 3 anticipate the imperfect nature of BCI devices to be a problem that will persist in the near future. This idea is further explained by research stakeholder 3 in the following comment:

*“I think that's a concern that's, uhm, that can be true for most of the future. Like, the more into the future we get the more like the computers they go huge, like bigger parts of our lives so. Of course it would apply to BCI as well but again, right now sure yeah.”*

(Researcher 3 - Bachelor Student, December 2017)

In the comment above it is seen that the concerns of computers, in general, are drawn on to apply to BCI devices as well. However, instead of using it as a justification for taking actions towards this concerns for BCI, it is used as a justification for BCI not playing a particular role in the concern anticipated. Similar to research stakeholder 2, research stakeholder 3 sees this development as a natural one:

*“It feels to me kind of natural for it to happen. Because this has been happening for the past like you know, however long we are here and have been developing ourselves so.”*

(Researcher 3 - Bachelor Student, December 2017)

The argument of the development being natural for technology is thereby used as a justification for not actively engaging in the anticipated concern. The anticipated development for technology that is deemed dangerous is for the technology to change according to research stakeholder 3:

*“So that's, that's just technology like, I wouldn't worry too much about it because, if the concerns comes up, and it's like, it is dangerous, then technology will just change like. That's just natural, I mean, sure if there is something that, that could damage people, then yeah but it should be regulated, it should be changed and stuff.”*

(Researcher 3 - Bachelor Student, December 2017)

Where research stakeholder 3 apparently anticipate actions to be taken, is if the technology is dangerous in the sense that it could damage people. The anticipated response to such risks is increased regulation. Research stakeholder 3, however, was more worried about the imperfect nature of the devices than the anticipated risks:

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*“My biggest concern were just the, well the how bad is this going to be, and will it actually work, at the time and stuff like that. But nothing too extreme, I am, I fancy myself an optimist so I believe that as the technology will go on, so will the mindsets of people and legislation, regulation, and all that stuff so, as long as there is a rational mind behind it, that drives it and we don't do anything too extreme then I think we are Gucci.”*

(Researcher 3 - Bachelor Student, December 2017)

Part of the reduced concern from research stakeholder 3 was a belief that technology and society will continue to develop for the better. Research stakeholder 3 does, however, anticipate that extreme actions could lead to problems. Anything rational and not too extreme was not anticipated to cause any major concerns. Research stakeholder 4 is anticipating that society, in general, will be less sceptical about technology in the future:

*“That we are like, I guess as society just, well getting kind of horny of all the well new developments and just embracing it. Spot on, and without this kind of scepticism about what used to be I guess.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comment above shows an anticipated fast adoption of BCI technology, which is further explained by comparison to the virtual reality technology:

*“Yeah, it will come, like, when the oculus rift came out there were instantly companies that sells smartphones that. And they came included with a goggle. Just to fill, fill the market, fill them up with goggles. There was no content whatsoever, useful content. So BCIs will flood the market as well, once there is some kind of easy PC setup and that.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 shows an anticipated problem with BCI devices being adopted before the market is ready for it with useful content. The comment above shows a scepticism towards the motivation of the industry as it suggests the industry is more interested in earning money than providing useful technology and content to the users. Research stakeholder 7 is similar to research stakeholder 2 anticipating that the imperfect state of BCI devices will be influencing the consequences of BCI adoption:

*“And one really interesting topic is that this is a first generation who has this, and we still have no idea how it influences the brain, if it influences the brain. I think that something similar could be also relevant to BCIs, when they actual become seamless and easy enough.”*

(Researcher 7 - Masters Student, February 2018)



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Research stakeholder 7 is transferring an anticipated concern with other technologies to BCI technology. The concern is however restricted to the future when BCI devices are more seamless and easier to use. This makes it possible for research stakeholder 7 to shift the concern into the future and not worry about it as the BCI is in its current state. Research stakeholder 7 uses the same justification when it comes to the anticipated concern of the digital divide:

*“And I think that actually it will be like this, even for the next 50 years or so. So maybe later BCIs will become a real indispensable part of, of living in our society like, like it happened for example with computer. But before this I don't, I do not think that anything too bad or too different will happen.”*

(Researcher 7 - Masters Student, February 2018)

While the comment above moves the concern 50 years into the future, research stakeholder 7 still anticipates some bad things in regard to BCI technology. Research stakeholder 7 is also using a utilitarian approach by quantifying the consequences of BCI technology. Research stakeholder 7 even goes so far to explaining his ethical position by pointing out his disagreement with people who are more focused on ethical values:

*“Okay you know, I can, I could imagine that after some time, it would become even a religious thing. I can imagine that there could be people who thinks that this is somehow intrinsically wrong or something. No idea, no idea, but it is not something which I would worry about, at the moment. There were always unfair advantages, I don't see why BCIs should be treated as a particular case of them.”*

(Researcher 7 - Masters Student, February 2018)

The comment that BCI devices should not be treated in a particular way is something research stakeholder 7 also comments on the topic of privacy and security:

*“Like we have more information but the rules about how do we, how do we keep this information safe are still the same. Be it emails or be it someone's pacemaker or be it someone's [INAUDIBLE]. So the ideas would still be the same.”*

(Researcher 7 - Masters Student, February 2018)

According to research stakeholder 7, the solution to BCI privacy are the solutions also seen in other technologies. The comparison to other technologies is something the stakeholder also uses to explain the belief the stakeholder has on enhancement:

*“Five years ago I had a really long summer, and I decided to learn touch typing, and that [work] keyboard layout. I have learned it, now I type a bit faster than usually, the question is if this gives me an advantage. I*

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*could say the same about, about various [nootropic] drugs for example. I am thinking in the direction of [INAUDIBLE] Ritalin, [what I think] if it is an unfair, if it is an unfair advantage or not.”*

(Researcher 7 - Masters Student, February 2018)

Similar to one of the comments before, research stakeholder 7 compares BCI technology to other forms of enhancement in order to measure the level of unfairness a BCI device would create in the question of the digital divide. This shows that research stakeholder 7 does anticipate BCI devices to give an advantage and by measuring the unfairness introduced by the digital divide, the introduction of BCI devices is justified. This unfairness research stakeholder 7 measures up against the advantages or disadvantages positions society, in general, puts people in:

*“Ah yes, thank you, you said it better than I have. We are living, and have always lived in a society with a lot of unfair and fair advantages. We are living in a society where the family you are born into determines 90% of, usually statistically what you do, of whom you communicate with, with, we have different money, we have different families, on, of a different level of [brokenness] and abusiveness.”*

(Researcher 7 - Masters Student, February 2018)

By doing so, research stakeholder 7 is capable of justifying the introducing of BCI devices as the impact of BCI devices is small in comparison to how society, in general, is not fair in the distribution of advantages and disadvantages. In general research stakeholders, did not anticipate BCI technology to be much different than other technologies, and most concerns around BCI devices could be related to concerns for other technologies or society in general. Some of the stakeholders on the topic of other technology were of mentioning the society in general as the problem for the digital divide and other concerns.

### 4.5.3.9 Media and public opinion

On the topic of media and public opinion, most of the research stakeholders are anticipating media to have an effect on public opinions on BCI devices. Most researchers are also critical of the way BCI devices are portrayed in the media and anticipating that the media coverage will increase the expectations of users. Research stakeholder 1 is anticipating that the difference between people’s expectations and what the BCI technology can do will exist for some time:

*“BCI is probably a long way to go to get to that point. Or to get to a point where there is a convergence of what people think that systems can do. And what systems can actually do.”*

(Researcher 1 - Senior Researcher, November 2017)

This comment is further explained by the following comment by research stakeholder 1:

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*“where everyone understands that okay we wont always have an EEG cap on our head when we use our computers for example, but these are outlooks into the quite possible future and I think there is a more positive, more positive and yeah curiosity driven coverage regarding these aspects.”*

(Researcher 1 - Senior Researcher, November 2017)

The comment above suggests that research stakeholder 1 is anticipating the media to cover BCI technology as being more useful than it is at the moment. Research stakeholder 1 is also anticipating that the development of BCI technology will be slower than the media coverage, and this could be the reason for the difference between media coverage and what the technology can actually be. Research stakeholder 1 is also anticipating the media coverage to bring up concerns that are currently not the case:

*“what always is difficult is when BCI is framed in something like a mind reading context. Because that is usually never the case.”*

(Researcher 1 - Senior Researcher, November 2017)

While research stakeholder 1 is not mentioning whether this anticipated concern is directed at a specific area of the media, research stakeholder 2 is anticipating the pop culture and extreme tech media to be the main reason for concern:

*“Well, if we are talking about sort of like, pop culture, and websites like I don't know, the wired or extreme tech or those kind of websites, yeah I think it's not so uncommon that you'll see really sensationalised article which in the first paragraph directly contradicts the abstract of the article they are citing.”*

(Researcher 2 - PhD, November 2017)

The comment above suggests that research stakeholder 2 is evaluating the media against the value of media being truthful and valuing correct and accurate reporting. Which conflicts with the other motivation of media to earn money according to research stakeholder 2:

*“I think that trend will continue. I don't really have an answer to that. To how we can address that, because it's all about click bait and money at the end.”*

(Researcher 2 - PhD, November 2017)

The stakeholder is unable to come up with a solution to this problem, but it suggests that the problem research stakeholder 2 has with the media is not isolated to be a problem with BCI coverage alone. Research stakeholder 3 is anticipating being confronted with users that expect the BCI devices to do more than they are capable of:

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*“Because like, you know, if people expect too much and it doesn't go their way, it can be discouraging.”*

(Researcher 3 - Bachelor Student, December 2017)

Research stakeholder 3 is anticipating that the difference between expectations and reality will be discouraging for the users. This could be used as a justification to either develop BCI technology faster or to engage in behaviour that could make the expectations more accurate. Research stakeholder 4 is also anticipating that expectations will be too high:

*“Or an expectation are always higher than the real benefits of it. So we always come across real big interaction problems that, that is, first of the encumberedness in the setup, it takes forever, the calibration, and it's with any kind of product that comes out, you know. And these companies are just churn it out too fast, because they don't want to wait because they invest lot of money.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Unlike research stakeholder 3 though, the stakeholder is focused on the companies developing BCI devices rather than the impact on the user. Research stakeholder 4 is anticipating that commercial developers will be motivated by money and abuse the high expectations to sell their products. This anticipation is further explained in the following comment:

*“Because you know, we are very gullible, we look at all the commercials and everything that is spammed on a daily basis and, on your phone. I mean it's, it's ridiculous really. Right, it's really come to a point and just say, well what are we doing as a society?”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

This suggests that research stakeholder 4 is anticipating that the media will be used by commercial developers to promote their devices and that users will not be able to balance their expectations with the reality of the devices. The problem, however, is not limited to consumer stakeholder's usage of the media according to the stakeholder:

*“Like, especially not when it becomes a consumer product like the BCIs for example, because they can be hacked and I know that all the toys that come out there are hidden agendas, there is lots of obfuscation in the. In what the actual, let's say internet of thing artefact can do. You know, and that is not being stressed, and that is not being conveyed to the public at large, and the thing that is a big problem.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

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The comment above shows research stakeholder 4 anticipating the media in general do not convey the information required to inform the public about technology. The other researcher in research stakeholder 4 is suggesting that the way media portrays technology is influenced by the use case:

*“R2: I guess in general, I don't know, [INAUDIBLE] was talking about it, but, if just a technology is, well portrayed in a area where it's beneficial so in healthcare or this kind of things. Then that's also the public statement, that this helps us. While when you see robotics from Boston dynamics created for, for defence, everybody is like whoa that shit is fucking dangerous so.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comment from research stakeholder 4 is anticipating that the public opinion is possible to manipulate by promoting the use cases most people can get behind (better healthcare in this example) and creating fear for the technology by promoting questionable use cases (military robotics in this example). The topic of the public opinion being controlled partly by fear is something research stakeholder 5 mentions as well:

*“The concerns about the BCI developing, I think is more on, from my respect. I think the general public has a, a technophobia bias, if you know what I mean. Person that doesn't have much knowledge could be afraid or something like that. So that, [INAUDIBLE] all the stakeholders in general they have to, to make a trust building marketing of the BCI from commercial use”*

(Researcher 5 - Masters Student, February 2018)

Unlike research stakeholder 4, research stakeholder 5 talks about the current state of public opinion. According to research stakeholder 5, the public opinion on technology is leaning towards technophobia. Research stakeholder 5 is anticipating the solution for this to be consumer stakeholder using marketing to build trust with the consumers. Research stakeholder 6 is looking more positive towards the anticipated consequences of working with media and the public:

*“No, I do not worry about because, when you share the knowledge you can, you find your boundaries so. I can't. For example I can, I cannot, I fix in some way my issue. But if someone who will practice or have experience with the [that]. Maybe he can, he can find another solution for the problems so. It was a, a collaboration.”*

(Researcher 6 - Bachelor Student, February 2018)

Research stakeholder 6 is anticipating that sharing knowledge about BCI devices and the problems the technology is facing could provide solutions. A public with technophobia could, however, be difficult to work with as they might not be interested in finding solutions as research stakeholder 6 is anticipating. The

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positive attitude towards the media and how it might change people's perception could be based on the idea that research stakeholder 6 did not meet some of these perceptions:

*"And have you, had contact with anyone who had been worried about putting on a BCI or? Thought you were reading their mind or anything? 06:15 R: No. Not yet."*

(Researcher 6 - Bachelor Student, February 2018)

While research stakeholder 6 above is saying they did not meet this public opinion, the comment above suggests that research stakeholder 6 is anticipating that they might meet it in the future, which could be because the technology is not currently at a state close to mind reading. Research stakeholder 7 is anticipating that the fear in the public will be worse than is warranted by the technology:

*"Sometimes it happens but I don't, at least in my experience it was never bad, so there is always this when there is any new technology there is always this couple of person the people who say it is much worse than it is, or could not understand it and therefore fear it. But it was, it has always been like this and it almost never stopped anyone. It is not something which I personally ever worried about."*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 is not considering the experiences the stakeholder has had with the public to be specifically bad for BCI technology and misinterpretations were not so bad that the stakeholder was anticipating it to be a danger for BCI development:

*"I, personally, [INAUDIBLE] last couple of years, I did not see any. Is there. Sometimes misinterpretations but they were never something which worried me, or at least not. Never something which I found wrong enough to be dangerous for the future of BCIs for example."*

(Researcher 7 - Masters Student, February 2018)

Unlike the other stakeholders, research stakeholder 7 is, however, anticipating that people with mental illness might experience a fear of mind control, which has been seen with other technologies as well:

*"And maybe the last point about this, this is probably not what you are looking for, but there is also the topic about mental illnesses there is this, segment of the population especially in regards to schizophrenia and [INAUDIBLE] who had this point about, [in the states] this was, it was radio controlling their minds, if remember the [INAUDIBLE] generation how accusing [the radio] of hypnotism."*

(Researcher 7 - Masters Student, February 2018)

What research stakeholder 7 is anticipating could be used as a justification for BCI developers to focus on improving the general public knowledge about BCI devices and their capabilities. This could be done with

the justification that an increased general public knowledge would make it easier for the public to identify people with an irrational fear towards BCI devices. Making sure the public is able to identify people with irrational fears would be justified by the idea that the future of BCI devices would be less challenged. Overall research stakeholders are anticipating that the media will shape public opinion of BCI technology and they anticipate that users will have too high expectations of the technology based on the media. The topic of mind reading is related to the topic of privacy.

#### 4.5.3.10 Privacy

The research stakeholders are not anticipating many privacy concerns. The overall justification for this lack of anticipated concerns is mostly the setting they are using BCI devices in, which forces certain privacy enhancements to be put in place. Another justification used is similar to the reasons explored in the section about other technologies. Either privacy is considered already lost due to societal considerations or other technologies are more privacy-invasive or harder to avoid than BCI devices. Research stakeholder 1 anticipates privacy to be important, but is of the opinion that the concern is not specific to BCI devices at all:

*“Of course privacy is an important issue. But I think it is not BCI specific at all.*

(Researcher 1 - Senior Researcher, November 2017)

This allows research stakeholder 1 to acknowledge the concern of privacy, without acknowledging any BCI specific privacy concerns. This opinion research stakeholder 1 support with the following statements:

*“I think privacy is less an issue than for other sensors. So for example a camera or microphone that can easily be hidden or it's unclear whether it's currently capturing data or not.”*

(Researcher 1 - Senior Researcher, November 2017)

*“I mean you put the device on when you want to use it and there is no way that somebody will secretly put EEG electrodes on your head without you noticing”*

(Researcher 1 - Senior Researcher, November 2017)

The comments above support the initial statement in two ways and thereby supporting the justification for research stakeholder 1 not being concerned. The first way is by pointing to other technologies that might be more privacy-invasive currently than BCI devices. The more frequent use and the ability to hide the use of other sensors is used as a justification for why BCI devices are less problematic. The second comment also suggests that research stakeholder 1 anticipate that users will put on BCI devices with informed consent and voluntarily. Research stakeholder 1 is however open to the idea that the current situation of constant camera monitoring might change:

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*“So you actually have a better control about, in which situations you would be influenced by BCI. Than for example cameras which are all over the place in your, on the airport or whatever so. We're constantly monitored basically, that might of course change.”*

(Researcher 1 - Senior Researcher, November 2017)

This indicates that the anticipated concern for BCI devices is tied to the perceived surveillance possible by other technologies, and that research stakeholder 1 is anticipating that this level of surveillance can change with time. Similarly, research stakeholder 1 is aware that the level of information that can be gathered from both other technologies and BCI devices can change over time:

*“Because at least in principle future analysis methods could reveal at least to a certain extent other information than what could be available right now from what you extract.”*

(Researcher 1 - Senior Researcher, November 2017)

While the comments above show that research stakeholder 1 is not considering BCI devices to provide any additional concerns compared to other technologies, the stakeholder did have an additional comment that suggests that this is not the case:

*“For a video, you can look at the video and see, okay this is what you can get out of it, what I would get as a human out of it. And if I am fine with that, I can be pretty sure that there is no hidden agenda there or anything like that. And for BCI data that is more difficult to guarantee.”*

(Researcher 1 - Senior Researcher, November 2017)

The research stakeholder is of the opinion that video and other media is much easier for the users to decode the usefulness of and the level of information contained. The stakeholder is then stating that for BCI devices, this decoding is much more difficult. For this to be consistent with the previous comments by research stakeholder 1, the possible information to gather is the same. The comment, however, suggests that while the information available might be the same, the ability for people to understand the information is not the same for BCI and other technologies. Research stakeholder 2 also points out that the information available from BCI devices might be different than other technologies:

*“Obviously targeted advertising based on peoples brain activity, the possibility that we will be able to stimulate peoples brain remotely. Having those systems hacked, by people who want to say, read your credit card information or what have you.”*

(Researcher 2 - PhD, November 2017)



## Reflections and analysis of stakeholder comments

Research stakeholder 2 is anticipating that BCI technology will provide information that could be abused. The anticipated concerns for privacy being obstructed, is something research stakeholder 2 anticipate because of society and previous technology, rather than the BCI technology:

*“That again is a product of the type of society we have, which is seemingly more and more authoritarian I would say. I mean, as everyone knows now, we have, we have lost a lot of privacy on the internet.”*

(Researcher 2 - PhD, November 2017)

While society is used as the reason to be aware of privacy concerns, research stakeholder 2 is also anticipating that the technical solutions that could be implemented will not always be enough:

*“That could be a technical solution to some extent, although of course then we would see, I think, efforts to collaborate with the companies who sell these systems to create backdoors as we see with cell phones now right. 19:27 So there is a, having a technical solutions is obviously not enough.”*

(Researcher 2 - PhD, November 2017)

The comment above suggests that research stakeholder 2 is anticipating consumer stakeholders to play an important role in society and whether privacy will be upheld in BCI devices. Research stakeholder 2 does however also extend this responsibility to other BCI developers:

*“that COULD be done, and it could be, could go back and bite that person later. The other things that we really have to take seriously when we are developing these systems.”*

(Researcher 2 - PhD, November 2017)

While research stakeholder 2 anticipate privacy concerns with BCI devices in general, research stakeholder 3 and 4 are not anticipating privacy concerns when BCI devices are restricted to research use:

*“No, not at all. Like, I actually have not, with the technology I used there is basically nothing that, that would concern me myself as of to, like, the privacy.”*

(Researcher 3 - Bachelor Student, December 2017)

While research stakeholder 3 in this quote does not specify why there are no privacy concerns, research stakeholder 4 explains why they are not concerned:

*“in research you don't care about privacy because you say, okay we won't, we will do everything anonymous, and your, your user number, whatever is not known to anybody, and we call it X or something. Or number 1, and that's it.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

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Research stakeholder 4 is anticipating that researchers will use anonymous data, and that will remove any anticipated privacy concerns. This idea is further supported by the use case of BCI devices:

*“So that kind of privacy and the kind of experiment we do are let's say. To me, are like very simplistic. Just to show, if we could use some of the, thoughts, brainwaves, you have.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The stakeholder is thereby able to justify the use of BCI devices and the lack of anticipated concern with privacy. Researcher stakeholder 4 is both using the technical solutions as well as the limited use case as justifications for not anticipating any privacy concerns in a research setting. Similarly, to research stakeholder 3 and 4, research stakeholder 5 anticipate that even for invasive BCI devices in research there are no concerns in regard to privacy:

*“What I mean is, if an individual agrees to have a surgery for research. [INAUDIBLE] the privacy is not a problem. But what you mean, I think is in the future, if they have a invasive technology. I: Yeah R: Yeah I think that is a problem. I think that then the neuro data that have, that they will have to follow the rules of biomedical ethics.”*

(Researcher 5 - Masters Student, February 2018)

The stakeholder is also anticipating that the solution to the anticipated concerns is following ethical standards. This solution is unlike research stakeholder 4 which mentioned technologically and use case solutions to the concern. A note that research stakeholder 5 slightly touch on with this comment is the topic of consent, which is something research stakeholder 6 mentions as well:

*“I: Okay, so yeah, another thing that people have raised concern about, is privacy. Is that something you thought about as well? 07:43 R: What privacy? I: Mhmm R: No, no I think, no. At least in the research, everybody gives [consents] to do that so.”*

(Researcher 6 - Bachelor Student, February 2018)

Interestingly research stakeholder 6 say that consent is given as a justification for not being concerned with privacy. This solution is partly working on the assumption that the information gathered is not shared and used for what a researcher has informed the user that it will be used for only. The topic of consent will be further explored in the following section. Research stakeholder 7 is similar to some of the previous stakeholders anticipating that BCI devices could result in mind reading:

*“Even right now, just analysing, how we browse, how we use the internet is easy to understand much much much much more about us. As some people are comfortable thinking. I. I wont touch the really extreme case*

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*about mind reading sometime in the fut. I think that it could be sometimes some, could be possible some day it's not something which scientists should be worrying about right now. But this is something which will come up every time when people talk about BCIs and privacy."*

(Researcher 7 - Masters Student, February 2018)

Research stakeholder 7 is not anticipating the problem of mind reading to be a problem soon. The stakeholder is, however, open to BCI devices getting into problems in the future and thereby anticipating that privacy will be a concern in the future. Part of this anticipated concern is related to people's ability to understand and control BCI devices:

*"That they control it and it less, and are much less confident in using it. And I would, I could imagine that some people don't like it, simply because they might feel that either [sign], might. Much more information is written from them than they want to or something in this direction."*

(Researcher 7 - Masters Student, February 2018)

This concern was mentioned by research stakeholder 1, however research stakeholder 7 is anticipating that it will not only be a problem in terms of information understanding but that users will have problems controlling the information as well. The assumption that this problem will not be a concern until later, makes it so that research stakeholder 7 is anticipating that solutions will be found in the future:

*"So I assume that if, if privacy and mindreading will become a much bigger issue than it is right now, after some time scientist, humanity will act, develop some kind of ethical framework, ethical rule, which will be developed by themselves which will allow people to live some, somewhat normally with, with all of this."*

(Researcher 7 - Masters Student, February 2018)

This allows research stakeholder 7 to move responsibility from himself and current BCI developers to future BCI developers and society. The stakeholder is even anticipating the timeline for future technology and solutions:

*"Brain-computer interfaces will be maybe just the next step on, about it. It will give theoretically even more information about us. But this does not mean that the world will end. We will learn to live with this. We will learn to respect each other but obviously we will learn to. To survive with this. So like I, basically the first 5, 10, 15, 20, 30 years if mind reading becomes a topic or some really deeply privacy [invasion] becomes a topic. As a first 5 to 50 years will be really bad, but at the end of the day we will survive this."*

(Researcher 7 - Masters Student, February 2018)

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The comment above shows that research stakeholder 7 is anticipating that the technology will be privacy invasive until solutions will be found. It also shows that research stakeholder 7 is willing to sacrifice privacy for a period of time to get to a time where the technology has matured. Overall research stakeholders were not anticipating any privacy concerns specifically to BCI technology. Most privacy concerns anticipated by research stakeholders were related to technology in general or was anticipated to be caused by the current society rather than the technology. It was mentioned previously that the ability to give consent to use data in various ways impact the loss of privacy and ethical implications.

### 4.5.3.11 Consent

Research stakeholders have two main considerations regarding consent and BCI technology. One of the considerations is the lack of understanding of the technology, and how to increase this understanding. The other is the topic of different use cases where BCI might be used to gather consent, or where the use case might end up different than was first intended, which could change whether people would have given consent in the first place. Research stakeholder 1 is anticipating that the concern about gathering consent will be about people understanding the technology:

*“So BCI can't be used secretly, I think the informed consent is right now. It's not really an issue, and what is important is transparency so people, people need to have a clear understanding of what the system is measuring and what results are given to, to the application or how the information is used”*

(Researcher 1 - Senior Researcher, November 2017)

The stakeholder is mentioning that when using BCI technology, there could be a lack of understanding of the technology, but a redeeming factor is that the technology cannot be used in secrecy. Thereby the use is justified and consent is considered given in all cases if the user is understanding what the technology does. Research stakeholder 3 is anticipating that most users whoever will not be understanding what the technology does before deciding on whether to use the technology:

*“That's the downside of many of the things that are happening right now. That people are not informed, so I think in general people should be always well informed before making decisions. 24:25 I mean, this is one of the parts, like this is one of the things that should be, should be [INAUDIBLE] to.”*

(Researcher 3 - Bachelor Student, December 2017)

This is something that research stakeholder 4 is also anticipating when working with research subjects:

*“if you just ask them, I would put this on your head, are you fine with that, and we will just do an experiment, so a lot of people already say yes or alright because they feel it's their well, it's their free will to control, what is, being [taped] to them, whatever. But of course. R1: It's a discussion R2: it's an illusion, it's*

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*illusion of, that you think, okay I've now control of, I will. R1: It's a discussion R2: I give consent so it's alright."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 3 and 4 are anticipating that research subjects might agree to something that they are not well informed about. If this is the case, research stakeholder 1's requirement for not anticipating concerns with gathering consent, could turn out to be problematic to fulfil. Research stakeholder 4 is of the opinion that this requires education to keep people sceptical towards technology in general:

*"Yeah, I guess the same, and also, well there can also be an additional, i guess, an educational step, because of course we, you see this image of the BCI and your fancy interactions and whatever. And, but like I guess, 99% of the people who see that. They will never ring like a bell says like, hey, this is also maybe some downsides or. So this ignorance I was talking earlier about while you are using Facebook or whatever. So, educational wise that could also be the step, to say, hey, new technologies, yeah, be sceptical about it."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

Research stakeholder 4 is anticipating that users will not be sceptical and compares BCI technology to other new technology such as social media. Some would use this as an argument for why further action is required to educate people on BCI technology prior to gathering consent. A similar comparison is made by research stakeholder 4 when using the example of the information gathered by Google:

*"There is a big big issue, if you don't tell them in advance, like what [NAME OF R2] says. I think that's not fair, because we, with more and more increasing precision of the BCI systems, you can basically see, I think at one point, any emotion. 50:58 That comes from within. And you can tap off even waves that, that you don't tell the participants, like what Google does to us, happens also with potential, very intrusive applications like BCIs."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

In the comment above research stakeholder 4, is not only anticipating that BCI technology with increased precision will be able to gather more information about us than they are capable of at the moment. The stakeholder is also anticipating that the gathering of information will happen without informed consent in the future. While the use case anticipated in the comment above is towards average users of technology, the stakeholder also anticipates that the use case for people with disabilities will be used to promote the technology:

*"And then they hide it into something, like the obfuscation is really big. Because, yeah we need people that are sort of disabled or have a certain condition or, and then frame it like that. But we just are exploring*

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*what people are all about. This is what I think, and I think this is highly ethical, this has moral implications as well."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

This suggests that BCI development is not only gathering information without consent but that the developers are actively taking advantage of people that could make use of the technology to do so. The use case of BCI devices as tools for disabled people is also something mentioned by research stakeholder 2:

*"And perhaps down the line the hospitals, if this is a successful system, will use it as a way to provide some communication ability to people who are unable to give consent. Who need a family member to give consent."*

(Researcher 2 - PhD, November 2017)

Unlike research stakeholder 4, research stakeholder 2 is positive about the use case of BCI technology for people that are locked in. The use case would allow these users to communicate and thereby give consent. The use case of giving people the ability to give consent when otherwise not possible is used by research stakeholder 2 as a justification for working with BCI technology. Research stakeholder 4 is however rather sceptical towards the authenticity in these goals:

*"It's also, yeah this hidden agenda for, where it's context, yeah the context, so if. That is, that is kind of scary maybe, that, when we say, oh BCI yeah we can help the autistic children to yeah, concentrate better or whatever, everybody is like oh this BCI stuff is awesome, it can help us. And [INAUDIBLE] it's adapted and then, you get stuff like."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comments above show that research stakeholder 4 is anticipating that the good intentions by BCI developers will be misused and not create genuine changes for the better. The stakeholder is also anticipating that the consent given by those helping in the research they are doing, is misinformed and in some cases directly misled by the researchers in this field. Research stakeholder 7 mentions that when doing this type of research, making sure people are not misinformed is a balancing act between how much information you provide them with:

*"Actually this is like, this was a big part of the research which I did. It depends. [Research] is a really fine balance between how much information you want to convey and how much. How much do you have to [INAUDIBLE]. That this, so like, I think that it is possible to do BCI, that BCIs at some point will be easy to."*

(Researcher 7 - Masters Student, February 2018)

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The comment above suggests that while research stakeholder 4 is questioning the intentions of the researchers doing this kind of research, research stakeholder 7 is of the opinion that it is rather a matter of the balancing between information levels to be difficult. Research stakeholder 7 does, however, mention that it does matter what type of people are performing the research, in order to ensure the level of empathy required:

*“mostly the people who do it right now again based on my experience are more IT people. Who not always have enough empathy to deal with people in general. And not. when we talk about elders or disabled people it becomes even worse. But I, I do not have any horror stories about this. But at least, so was my, this was my experience.”*

(Researcher 7 - Masters Student, February 2018)

The stakeholder is anticipating that IT people are not good at being empathic with the elderly which can cause problems in their ability to gather informed consent as well as other concerns with ethical problems and BCI devices. In general research, stakeholders are anticipating consent to be a matter of informing people properly of the technology before usage. One research stakeholder also anticipates that the devices can be used to give consent for those unable to communicate otherwise.

### 4.5.3.12 Enhancement

On the topic of enhancement, the research stakeholders overall are not very concerned. The research stakeholders either anticipate that enhancement will not be possible or should only be used for treatment and thereby be regulated. One research stakeholder was not necessarily concerned about enhancement itself but were concerned about the potential loss of enhancement after adoption. Research stakeholder 1 is even anticipating that people claiming to be able to enhance with BCI devices are lying:

*“If you want to have a general purpose cognition enhancer basically no body knows how you would build those. So there is a lot of focused research in that area, so there are many people claiming they build a mind enhancer, and actually doesn't do a thing, or is even dangerous.”*

(Researcher 1 - Senior Researcher, November 2017)

When research stakeholder 1 anticipate that enhancement is not possible with BCI devices it allows the stakeholder to not be concerned about it. Research stakeholder 1 does, however, anticipate that the pursuit for enhancement could create dangerous situations or devices. This could be used as a justification for being against enhancement, to reduce the harmful impact of enhancement BCI devices. Research stakeholder 2 is unlike research stakeholder 1 anticipating that enhancement could be possible in the future:

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*“BCIs in the future which perhaps will be able to augment our cognition in some way, if we get used to having those and that is taken away from us. It would probably to some extent feel like we had been lobotomized. And I assume that would be very psychologically distressing as well.”*

(Researcher 2 - PhD, November 2017)

The concern about enhancement is not for research stakeholder 2 similar to research stakeholder 1. The anticipated concern for research stakeholder 2 is related to the removal of enhancements that have been applied. The psychological distress is an anticipated concern for research stakeholder 2 where research stakeholder 1 was worried about a general danger, which could be both psychological and physical. The anticipated concern of removal of enhancement is a concern research stakeholder 2 even extends to enhancement that is an enhanced quality of life:

*“In terms of using a BCI, yeah I could see, like if BCIs become more and more useful and you rely on them for certain tasks. I could see it come to the point where say a child who grows up using a BCI from near birth to adulthood, would not really be able to function very well without one.”*

(Researcher 2 - PhD, November 2017)

This classification of enhancement could be problematic as this extends the concept of enhancement to be rather wide, making it harder to understand the full impact of BCI devices on the topic. Unlike research stakeholder 2 research stakeholder 4 is not considering BCI devices capable of cognitive enhancement:

*“And if you really wanna have some more, let's say, if you want to up people a little, you could have, do that in very micro doses with hallucinates instead of using. Technology like BCI. Because I don't believe that a BCI could enhance you cognitively.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

While research stakeholder 4 does not anticipate BCI devices to become a cognitive enhancement device, the stakeholder does anticipate the device to enhance people's capabilities:

*“if you can use it for people maybe that have some, let's say a specific condition it's been helped, fit them out with a specifically designed, on target, fit to function apparatus, yeah. No worries there, no worries. That's like, if you miss your arm, we fit an exoskeleton and all of a sudden you become more mobile again, fine, no worries.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

In this comment research stakeholder 4, is restricting the use case for BCI devices as enhancement tools for treatment purposes. This further complicates the topic of enhancement similar to research stakeholder 2 as



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it increases the type of devices that are to be considered enhancement tools. The reason why research stakeholder 4 consider BCI enhancement devices in terms of treatment, but not as a cognitive enhancement tool could be explained by the following comment:

*“You have to run the whole time so, you are already like, it's just an extra layer to well, so it's not an enhancement, if you are just, some kind of extra gadget you can, [INAUDIBLE] your time with, with a Fitbit. But it's not, it's not, the actual enhancement because that needs to come from yourself.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The comment suggests that BCI devices are anticipated to become training devices like what consumer stakeholders anticipated. Research stakeholder 4 anticipates that societies opinion on enhancement could change over time:

*“But that is for me, similar to what I said earlier in the case of, micro doses of enhancement using psychedelics. And you can see that the whole society is slowly turning towards that idea because, we know from tribes, tribal settings that they do that already for zillions of years.”*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The statement suggests that the enhancement seen from BCI devices is similar to what could be achieved through psychedelics. This suggests that research stakeholder 4 is anticipating that the public opinion towards BCI enhancement will be more accepting and open. This suggests that BCI enhancement will increasingly be implemented into society. Similar to research stakeholder 4, research stakeholder 5 is anticipating that neuroenhancement can be used as a treatment:

*“What I mean that a person with a problem have to, to have a neuroenhancement. In that case, yes I think that would be a great thing, in the future.”*

(Researcher 5 - Masters Student, February 2018)

While the statement above can be used as a justification for further enhancement research, the stakeholder is also anticipating that this type of enhancement would be used in other ways:

*“Yeah, I have a concern, I have concerns about that. I think that the, the nature of human being is being a bit more aggressive. So yeah, I think people will do that. 27:18 And this is about all, I think it's a part from the companies to have it [promote] the marketing to have a if you know what I mean.”*

(Researcher 5 - Masters Student, February 2018)

This suggests that research stakeholder 5 would require some sort of restrictions to the usage of BCI enhancement to limit the use cases. However research stakeholder 5 is anticipating that companies will be

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a driving factor in the usage of BCI enhancement. Lastly, when research stakeholder 6 was asked whether they anticipated any BCI enhancement they responded with a no:

*“I: Yeah, so some have argued that BCIs might lead to enhancement for example cognitive enhancement. Is that something you thought about as well? 18:10 R: No, absolutely I haven't, I didn't. 18:17 I: Okay, do you think, that might be a problem? 18:19 R: No, I don't think. I don't think so.”*

(Researcher 6 - Bachelor Student, February 2018)

Research stakeholder 6 also did not anticipate any problems with BCI enhancement. This could be because they did not anticipate BCI enhancement to be a thing, which thereby is used as the justification for not worrying about that specific use case, however, that is not entirely clear from the comments by research stakeholder 6. Research stakeholders are anticipating that BCI enhancement is not possible, or it will be similar to health trackers which enhancement capabilities are debatable. One research stakeholder anticipated that if enhancement technology could be developed it would be a concern if we got dependant on it.

### 4.5.3.13 *Concept of identity*

On the topic of identity and how BCI devices could change our concept of the self, research stakeholders, in general, agree that BCI technology could have an impact, but that the concept of self could change with any scientific development. Some stakeholders believe that BCI devices could impact the way religion was perceived, however one stakeholder anticipates that religion will survive this change. Research stakeholder 1, unlike the other research stakeholders, are not anticipating that this could be a problem because the concept of identity is not defined well enough:

*“I mean these are constructs, where everyone even struggles to give a clear cut definition of what that would be or how that would, or how that could be operationalised in a BCI.”*

(Researcher 1 - Senior Researcher, November 2017)

By not acknowledging a concept of identity research stakeholder 1 is able to justify not participating in the debate about those concerns. Similarly, research stakeholder 1 mentions that due to an imprecise definition of the concept of identity, it is impossible to create a BCI device that might analyse broader concepts of identity:

*“And as long as you don't have that very precise description of what you want to model, you won't build a BCI which does that.”*

(Researcher 1 - Senior Researcher, November 2017)

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While research stakeholder 1 is not anticipating any concerns, research stakeholder 2 anticipates that BCI technology could be cause for concerns, especially if enhancement technology becomes impactful:

*“So same with, to me it's the same with brain-computer interfacing with neuroenhancement. That I think, will cause a serious problem with our society. Because that is almost, potentially, depends how advanced this technology becomes. That potentially could become almost like a species divide among humans”*

(Researcher 2 - PhD, November 2017)

The anticipated impact on the concept of identity is limited by a requirement that neuroenhancement needs to be advanced. Research stakeholder 2 is however also of the opinion that science itself can change our concept of identity:

*“Yeah, I think, I think that has been happening for centuries, [I mean] science has gradually and often profoundly changed the way we think about ourselves. Some people are more resistant to incorporating that than others.”*

(Researcher 2 - PhD, November 2017)

This idea is used as a justification for BCI devices not being a specific technology that changes our concept of identity by the stakeholder. Thereby it is possible to continue the research on BCI devices as the technology is not the reason for a change in our concept of identity. Research stakeholder 2 also mentions that science changes our relationship with concepts such as religion:

*“I think it's fairly similar to [COUNTRY] but obviously we see in [COUNTRY] there is a lot more religious fundamentalism. Obviously they would be part of the group that is concerned about these technologies but I am not sure that their concerns are founded in a realistic view of the world. And what these technologies are in the first place. However there are people who have I think, realistic concerns that we need to take into account.”*

(Researcher 2 - PhD, November 2017)

While research stakeholder 2 anticipate that BCI will impact religion and the world view of people, the research stakeholders disregard the possible objections from religious people as being unrealistic due to their world view. This allows the stakeholder to justify not taking these concerns into further reflections and actions. Research stakeholder 4 also anticipates that BCI devices will impact religion:

*“R2: No I guess, [INAUDIBLE], same for me, not religious. R1: Agnostic right? R2: Maybe. R1: But with a headset on you can't become religious. R2: Yeah, it's kind of. That's kind of, could be interesting to see that. Well it's going towards reading, of course a, yeah. Smaller boundary between what is inside and outside. So,*

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*maybe this is what is going on, we are just becoming more of a [INAUDIBLE] kind of big creature, and [individualism] will, die."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

The idea that further insight into our brain and how humans work could impact the concept of identity and specifically the concept of religion is something research stakeholder 7 also anticipates. Unlike research stakeholder 4 which anticipate that BCI technology will remove the ability to remain religious, research stakeholder 7 is anticipating that religion will survive:

*"Religion really nicely survived the scientific progress of the last millennium so I think that it will also h[ave] survive anything we learn about our minds. But I think that it will be influenced by it."*

(Researcher 7 - Masters Student, February 2018)

The comment above shows that research stakeholder 7 is anticipating that BCI technology is not the first technology that could change the concept of identity and specifically religion. Research stakeholder 3 also anticipate that technology and science, in general, could change the concept of identity:

*"It challenges your mind, of course there is this kind of technology requires you to think differently, so basically everything that challenges your mind or perspectives probably changes your, your worldview and your view of yourself so. In that sense math does the same thing, writing does the same thing, and like religion. So, yeah sure. It's a concern, but, I mean probably, not I am not sure if a concern is a right thing. Like the right word but it's a thing that, probably will happen and like, I don't see, anything wrong with it."*

(Researcher 3 - Bachelor Student, December 2017)

The idea that science and technology make changes to our lives and concept of identity is building upon a worldview that this is considered progress as shown by research stakeholder 4:

*"Well, definitely will have implications, you can see that, that when the computers, came into existence, and especially when they became personal. They already had a big implications on individuality and also in identity. So yeah, and that will go on, and on. Like this is something that we call progress."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

These arguments are used as justification for multiple research stakeholders to consider the concern of changes to identity as either neutral or even good for society. Research stakeholder 4 does, however, anticipate that these changes could impact important concepts such as memory and people's ability to remember:

## Reflections and analysis of stakeholder comments

*"Because especially in the young, and younger, and young generation. These are people that are born basically with the smartphone in their hands. I think that has major implications on, on our current knowledge, but also on their knowledge. 43:01 And how they are gonna move around in, in the world. So, yeah. Does that matter? For my point of view, yeah."*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

These changes anticipated by research stakeholder 4 are however not limited to the impact on BCI devices, but technology in general. Research stakeholder 4 also comments on how online personas is a concern:

*"And then people say "yeah but I lie on Facebook, that is not really who I am". Like what are you doing? What is this? 1:11:19 You know, like HELLO. You lie? On Facebook. "Yeah, and I lie also on tinder because that's not really who I am, I am a real fucked up bastard but I am on tinder". You know what I mean? 1:11:32 I: Yes R1: Yeah, that has ethical implications. Sure. Yeah. 1:11:38 And I am not religious you know? I am an open minded person. 1:11:42 But I have concerns"*

(Researcher 4 - Assistant Professor and Masters Student, December 2017)

While this comment is not directly related to BCI devices it shows an anticipated concern with technology and its impact on our ability to express different personalities. Research stakeholder 7 also believes that BCI technology itself will not be a driving factor in the change to our concept of identity:

*"I think that, personally I think it would be, it would happen even without BCI but learning more about all of this is something which is needed amongst other things for BCIs. That is, I think, I could see BCIs as, as something which helps developing more knowledge, more information about the brain. So BCI is not a cause in itself, I don't see BCIs as a, a really big factor in itself, but it is stimulation for developing more, more information more, more data but it's not by itself a big factor or so I see it."*

(Researcher 7 - Masters Student, February 2018)

While research stakeholder 7 is saying that BCI itself will not be the driving factor for the concept of identity, the stakeholder mentions that BCI could be seen as a proof of mind reading for some people:

*"I can assume that, at least for some people, life will become much much more interesting because they will actually have a proof that is possible for something to read some of their minds. But this is just like a sub[INAUDIBLE] topic, so not something which I personally found in my research and not something which, which, with which I have come in contact with."*

(Researcher 7 - Masters Student, February 2018)

## Reflections and analysis of stakeholder comments

A confirmation of mind-reading could be a factor in changing how some people view their identity as it would make the concept of thoughts being personal and inaccessible by others open and readable. While research stakeholder 7 does not appear to be of that mindset, the argument could be made by those that are currently needing direct proof of mindreading that it would change our concept of identity. In general research stakeholders, anticipate BCI technology to impact the concept of identity and concepts such as religion. While some argue that religion will be hard to exist in a world with BCI, some are anticipating that religion will be alive and well even with BCI technology.

## 5 What happens when BCI moves from research to consumer settings

In the following section two main discussions will be had. The first discussion will be the impact of this research on the ethical concerns identified in section 2.3.2. The discussion will show that this research shows nuances between the experience of these ethical concerns in consumer and research settings, which are important to consider. The other discussion will be on how these differences and similarities are important for the RRI discourse and the AREA framework.

### 5.1 Ethical concerns related to BCI devices

In section 2.3.2 the ethical concerns related to BCI found in the literature were explored, in the following sections these ethical concerns will be discussed with regards to how the two groups of interviewees relate to the literature. This will show how the different settings of an academic researcher and a consumer innovator impact the ethical concern.

#### 5.1.1 Accuracy / misinterpretations

In section 2.3.2.2 it was described that the literature views accuracy problems as not an ethical problem, but a technical problem which could lead to the ethical problem of misinterpretation of data. (Zander *et al.*, 2011; Yang *et al.*, 2014; Nijboer *et al.*, 2015) Ultimately the ethical concern is embedded in who is responsible for making sure misinterpretations are kept at a minimum. In the literature, it is argued that at least part of this responsibility lies with the developers, as them being part of a team. (Haselager *et al.*, 2009b; Buchman *et al.*, 2013; Lee and Jang, 2013a) It was also a concern that commercial companies were not accurately describing their products and their use case. (Tennison and Moreno, 2012) This concern was directly talked about by consumer stakeholders mentioning that they did not anticipate this problem when developing the technology, but after engaging with users, and reflecting upon the over-importance put into numbers created by the BCI device they reacted and started to change their information presentation. As mentioned by the stakeholder (see page 49 and 92), this process has to be slow to separate the users from their data and making it less of a traumatic experience for the users. This shows that the consumer stakeholder is anticipating the user's reaction to the loss of data they are attached to and are using this anticipation to inform their actions. The consumer stakeholders also acknowledged that the data was not entirely accurate (one even going so far as saying that the argument of inaccurate data was baseless, as Fitbit trackers and similar devices were not considered problematic even though they faced a similar problem). This inaccuracy was for research stakeholders also important though and was often thought to be one of the reasons why the technology was not as useful as they had hoped for it to be. This obvious disagreement between research stakeholders and consumer stakeholders show that the setting the technology is being used or developed in, impacts the way accuracy concerns and misinterpretations were

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anticipated and perceived. Similarly, were the reactions to mitigate these concerns also different. The consumer stakeholders tried to change the technology, and the way information was presented to their users, and the academic researchers relied more heavily on informing the users before use, or by guiding them on their usage. (see page 49 and 57) This shows that while consumer stakeholders might distribute their products to more people, it also limits their ability to hold the hands of their users and explain any information that might be misinterpreted. Thereby will the two different settings impact this ethical concern in different ways and change how each stakeholder group will perceive the ethical concern. Both stakeholder groups comments show that the topic of accuracy and misinterpretation is an important one. The approach each stakeholder group will have to this topic is quite distinct though, as the problem manifests itself differently for each group. For researchers, the main problem is ensuring that the data they collect is accurate and that the information they give their research subjects or patients is accurate. For consumers, it is only to an extent a problem of accuracy, but to some more of a concern of usability and finding a way to make complex information available to consumers without misleading them.

### 5.1.2 Accessibility / digital divide

In section 2.3.2.1 the topic of the digital divide in the literature was described. While the literature was focused on the topic of medical treatment and research participation and the price of these treatments, the anticipated concerns from both commercial and research stakeholders were minimal although larger for research stakeholders. One consumer stakeholder (see page 77) even mentioned that cheap alternatives were already available in China. This confirms that there is a difference in settings not only from academic researchers to consumer stakeholders but also within the research settings that impact the anticipated concerns of the digital divide. While not always directly mentioned, or even directly disagreed with (see page 166), the anticipated concern was rather with some users not being able to use the products than with the products being inaccessible. One strong narrative from a consumer stakeholder was an engagement with a user that was unable to understand his poor performance with the device at a conference. Such narratives show that the increased focus on user engagement in RRI is an important aspect of being responsible for all stakeholders to do. By engaging with a user, the consumer stakeholder not only gained insights into a potential problem and blind spot they had, but they were also able to engage with the distressed user and reduce the negative impact of the technology on the persons' mental state. The difference in anticipated concerns also shows a difference in willingness to speculate about the impact of BCI technology. Research stakeholders were more willing to speculate about anticipated ethical concerns given certain restrictions. One research stakeholder, for example, mentioned that if BCI devices gave a real and clear advantage to people, then the digital divide concern would be a big topic to deal with. (see page 165) This willingness to speculate about future scenarios were something shown more often for



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researchers than consumer stakeholders, and might be a consequence of being in a setting that is explorative in nature and asking questions about hypothetical situations are a bigger part of their daily work than the consumer stakeholders. The consumer stakeholders are on the other hand more inclined to provide specific solutions to problems such as buying a cheap version from China. The stakeholders' comments on the topic of digital divide show that there is important research to be done on this topic. Not only is it required to develop strategies to ensure that availability increases, but also that governments ensure that the divide in terms of ability to use them, does not get too big between user groups. As one stakeholder mentioned, making devices available publicly through institutions such as libraries or other government institutes, would be a possible way to ensure that everyone is able to access and learn to use the devices. (see page 90) It is, however, important to remember that currently, stakeholders do not find this to be a big concern due to the limited use cases of BCI devices. Researchers being able to speculate and research on future directions for BCI technology is something that is also reflected in the literature. (Evers and Sigman, 2013; Huggins and Wolpaw, 2014) The speculative nature found in the literature shifts the discussion and makes it hard for consumer stakeholders to identify with the concerns described by the literature. Having a shifted discussion in the literature is also a potential catalyst for why some consumer stakeholders are critical of the research community.

### 5.1.3 Autonomy / informed consent

In section 2.3.2.3 the literature showed that the topic of autonomy and informed consent was discussed. (Haselager *et al.*, 2009b; Lee and Jang, 2013b; Carmichael and Carmichael, 2014; Schicktanz, Amelung and Rieger, 2015) For research stakeholders and consumer stakeholders, this topic was not an anticipated concern, partly because of how the topic of informed consent was handled in the two settings. This handling was different for the two settings, but it is interesting that it resulted in the same lack of concern. For consumer stakeholders, the actions taken were to try and make the data as easy to understand as possible so that users were capable of using their devices without oversight. (See page 50) This was done to increase user autonomy, but it could be argued that this would also be done in order to improve their ability to sell their products. A product that is easier to use would get better reviews by customers and thereby be easier to sell. In this sense, a responsible innovation approach would also be aligned with industry interests. An interesting note about informed consent in consumer settings is also that one consumer mentioned that informed consent was given when a consumer bought their products. (See page 93) This idea is rather different from the researcher stakeholders which mentioned an anticipated workload in making sure research participants were aware of what the technology is capable of and what the research is meant to achieve. (See page 58) This approach is more aligned with the literature on this topic. However, rather than it being a big concern, it was seen as a solution that just had to be done. Several

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stakeholders also mentioned that the BCI devices could be used to ensure informed consent and increase user autonomy, which referenced the current work being done with ALS patients. (See page 60) This was even a comment made by stakeholders that were not participating in ALS research.

### 5.1.4 Enhancement

In the literature (section 2.3.2.4), the topic of enhancement was very difficult to define due to a wide variety of BCI devices being discussed. This problem of defining what enhancement is in a BCI setting also impacts both stakeholders' approach to the topic. A justification often used not only on the topic of enhancement, was that a certain ethical concern was a problem, but not for the non-invasive EEG devices due to the kind of technology it is. (See page 142) This allows stakeholders to anticipate the concerns, but also allows them to dismiss it as being applicable to their setting and situation. It could be argued that in most cases this distinction is a valid one and that there is a difference between discussing enhancement when done with implantable BCI devices that provide electrical inputs to the brain, and a monitoring device on the head. Some stakeholders compared a BCI device to a Fitbit device, and this similarity is valid to consider as both devices could be classified as a personal health monitoring technology. (See page 85 and 193) One consumer stakeholder also mentioned that given a choice between a BCI and a heart rate monitor, he would choose a heart rate monitor to understand and predict whether a person was anxious. (see page 80) This shows that while the BCI approach to collecting data might be novel in a consumer setting, the enhancement and monitoring abilities are either matched or similar to other technologies at this point. That more invasive technologies or other research areas such as transcranial direct current stimulation (section 2.3.2.4) have completely different implications on ethical concerns is also another indicator that the setting of the technology, and thereby the understanding of what technology is understood as a BCI. That is very important to how the ethical concerns are perceived and handled. The highly speculative nature some of the discussions on this topic requires makes it difficult for some consumer stakeholders to participate as it is so far from their understanding of their own technology. This creates a divide between the literature produced in research settings. The idea that the research literature discusses the implications of BCI enhancement might also be what creates a divide between researchers' expectations of the devices and what they are capable of doing with them. This further increases the topics such as accuracy as researchers might expect much better accuracy with the devices when they are able to read about neuroenhancement and what concerns are related to that.

### 5.1.5 Identity

The topic of identity was in the literature (section 2.3.2.5) difficult to define and varied widely depending on the context, in which the topic was discussed. For the stakeholders, this topic was also met with very different approaches but with no clear distinction between researchers and consumer stakeholders. While

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the literature discussed the impact on identity, some stakeholders were more concrete in their anticipation for BCIs impact on our identity. One research stakeholder even made the claim that increased BCI technology would make it impossible for religion to exist. (see page 195) This statement, however, appears quite bold, as science and philosophy, in general, is having difficulties defining terms like conscious and other crucial elements in such a debate. It could be an indication that the neuroscience community, in general, is impacting both stakeholder groups, and that the split in the general neuroscience discourse is present within both stakeholder groups. This would not be overall surprising as many of the members of these stakeholder groups either are or have been part of the academic neuroscience discourse at some point or at the very least been influenced by these discussions from having interacted at conferences and other events. Generally, the topic of identity was not much of an anticipated concern by both stakeholder groups, although as mentioned previously the research stakeholder group seemed more likely to speculate on whether there would be any impacts. (See page 195 and 197) The consumer stakeholder group were more likely to either dismiss the topic or relate it to other concerns such as how technology, in general, might affect identity. The stakeholder comments on this topic show that the literature on this topic might be right in assuming that it could be important to investigate this topic further. It also shows that the current discussion of the topic is very limited, and perhaps still a philosophical exercise rather than something based on the current technology.

### 5.1.6 Policy gaps / legal concerns

The literature (section 2.3.2.6) discussion on policy gaps (Trimper, Wolpe and Rommelfanger, 2014) shows that the topic of responsibility (which is also a topic in the current RRI discourse (Ceicyte and Petraite, 2018; van de Poel and Sand, 2018)) extends to BCI technology. While the academic literature discusses some of the terms broadly the most relatable for consumer stakeholders would most likely be found in discussing specific use cases as it would help clarify whether they are responsible for certain aspects of the technology or whether they should expect regulation in specific areas later. Unfortunately, the topic of regulation is another area where the research literature is far from the reality most consumer stakeholders live in. Most of the consumer stakeholders commented on this issue that they expected regulatory changes but most also mentioned that these changes were already considered, and they had made design changes to account for such changes. (see page 48) Some stakeholders even tried to work with the regulatory institutions in order to make sure that their voice was heard, and so that they could help improve the legislation. (See page 70) While it must always be questioned whether such partnerships can be fair and in the best interest of society, it is important to note that in this particular situation it was not the company alone that were trying to improve the legislation, but academic researchers were also involved (see page 51). This type of engagement is very much in the spirit of RRI and confirms what some RRI advocates have mentioned

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(Zwart, Landeweerd and van Rooij, 2014) that all elements of RRI are not new, and that many companies or governments might already be doing RRI on various levels. While the consumer stakeholders mentioned what they had done to meet regulatory needs, research stakeholders were more willing to share their anticipated concerns with the legislation and how legislation was made. One researcher mentioned that while he anticipated new legislation to be made, he did not have confidence in the lawmakers' abilities to understand the technology. (See page 156) This lack of confidence is partly why a consumer stakeholder also decided to create a forum to discuss BCI with legislators and academic researchers, as they had found a need to promote BCI knowledge. (See page 51) Both stakeholder groups were also adamant that while BCI technology was a new technology, especially in the consumer setting, that the technology did not bring anything new in terms of policy gaps that were BCI specific. But due to current policy gaps with technology, in general, there would be a need for making new legislation. This need is interesting as some of the literature were describing BCI as revolutionary and requiring major changes to the legal system. This once again shows a distance between the academic literature and how stakeholders perceive the technology.

### 5.1.7 Privacy

The literature (section 2.3.2.7) was largely concerned with BCI data not being protected and kept private (Lee and Jang, 2013a; Trimper, Wolpe and Rommelfanger, 2014; Klein, 2015). The literature also mentioned a concern for BCI data being used in commercial settings by advertisers. (Fisher, Chin and Klitzman, 2010) These concerns are largely dismissed by both stakeholder groups interviewed. While both stakeholder groups anticipate privacy to be a concern, the concern is limited to a general privacy concern which is not specific to BCI devices. A concern that was specifically mentioned in the literature was a concern for additional information being available in the future, which was not available when the data was collected. This concern is one of the major concerns that would be important to solve before BCI data is gathered in larger contexts. Whether the concern for data collection is a concern that is limited to BCI technology is questionable though. As mentioned by a stakeholder, was the privacy concerns of windows also a concern we learned to live with. (See page 89) A concern regarding what can be interpreted is also extended to other health monitoring apps such as heart rate monitors which also allow additional data to be interpreted either in the future or currently. The same stakeholder also mentions that if he was interested in figuring out whether you were anxious, he would rather use a heart rate monitor than a BCI device (See page 80), and image processing could potentially be more accurate in analysing your mental state and behaviour. These statements indicate that the problem of additional information being extracted from the data collected in the future is not a problem limited to BCI devices. A possible solution for some of the issue with privacy is establishing an overall approach to information similar to the concept of privacy as contextual integrity described by Nissenbaum (Nissenbaum, 2004). By implementing an overall agreement

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that information is only allowed to be used in the context, it was originally gathered many of these concerns are solved. The GDPR (*GDPR*, 2018) in Europe also follows this principle and while the outcome of the GDPR legislation is still too new to evaluate, could potentially be the overall legislation that could protect BCI data in commercial settings, and specifically answers the concern of advertisers gaining access to BCI data. A final note on privacy from the literature was the concern of BCI data being gathered without properly informing of the implications (Tennison and Moreno, 2012). This concern was largely dismissed by both stakeholder groups, and it was specifically mentioned that BCI data required more consent than surveillance videos and similar technologies. (See page 183) One stakeholder also mentioned that legislation could be implemented to ban the use of BCI technology in concealed use cases such as a BCI concealed in a hat. (See page 123) While this would already be covered by the GDPR, it could be argued that such laws would be ignored by those that were interested in gathering BCI data unknowingly and as such regulation would not be a way to take care of the concern. When brought up to the stakeholders that in some cases there were no option to refuse to put the BCI on a few of the stakeholders were also agreeing that a BCI could be problematic. (See page 123 and 173) It could be argued that this situation is not much different from other technologies being forced such as polygraph machines. This area of technology is one that needs to be explored further but based on the interviews it does not appear to be a unique concern to BCI devices. Both user groups also took actions to prevent privacy concerns, which is interesting as it shows that while they anticipate the privacy concern to be relevant to technology in general, they appear to have some sense of responsibility to act to ensure privacy. (See page 185)

### 5.1.8 Public perception

In the literature (section 2.3.2.8) the topic of public perception was discussed as something that could be of concern to the BCI community as a general (Haselager *et al.*, 2009b; F Nijboer, 2015). The problem was largely on how a bad public perception of the technology could be hurtful to the research community. This concern is a sentiment that was echoed by the consumer stakeholders as well. The negative public perception could be hurtful to their business and thereby livelihood. One consumer stakeholder also mentioned the public perception as a blessing for those that made good products though, as good reviews on Amazon could be a good way for consumer stakeholders to gain popularity and sell more products. (see page 92) The fear for an overall bad impression of BCI technology was, however, something consumer stakeholders mentioned. The main concern from consumer stakeholders was an overhype created by less developed BCI companies to sell products, which could make the entire BCI market slow down or die due to a loss in faith from consumers and the public. (see page 80) This concern was very different in the research stakeholder interviews, as it rather appeared that some stakeholders had been influenced by overhype and were disappointed in their products (see page 161). The public perception was rather a fact they tried to

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deal with than trying to mitigate the problem before it existed. In this sense, research stakeholders were anticipating that research participants were poorly informed and had set up ways to cope with this by going through the technology and the research participants expectations of it before engaging in the experiments. (see page 70) In the literature, the public perception topic also brought about the discussion of what it would take for BCI devices to be accepted by the public and specifically were the points of the products comfort, aesthetics, reliability and usability mentioned (F. Nijboer, 2015). Research stakeholders mainly mentioned how poor the usability was, and how they had to adapt them to make them usable in the setting they had intended (see page 58). The consumer stakeholders though mostly mentioned how they had spent a lot of time taking actions to address these concerns. This shows a clear conflict where research stakeholders were not satisfied with the current state of BCI devices, but where consumer stakeholders were more concerned with the actions they had already taken to improve the usability and how they were continuing this work. (see page 91) This shows consumer stakeholders to not only anticipating the concern of usability and how it might affect the public perception, but also that the anticipation led directly to actions taken. It is also a potential area where both stakeholder groups would be able to work together. The research stakeholders that modified the devices could share this work with the companies developing and manufacturing the devices and improve the usability which would improve the public perception of BCI devices. By doing so, the consumer stakeholders would also make sure that research stakeholders were not upset about the lack of usability and the amount of work having to be put towards changing the consumer products. This would save future research stakeholders a lot of work, as well as it would allow for the consumer stakeholders to discover new potential use cases for the devices. A problem which currently limits the further expansion of the BCI market. (see page 78)

### 5.1.9 Security

The topic of security in the literature (section 2.3.2.9) was mainly a concern for implantable devices (McGie, Nagai and Artinian-Shaheen, 2013). Not surprisingly the main comment to this type of concern was that they could understand the concern, but that for consumer stakeholders it was not something they entertained much as their products were not implantable. (section 4.5.2.9) Research stakeholders were also in agreement with this and did not have much to share about this topic either. This suggests that this potential concern is not as big for the BCI community in general as it was also not a big topic in the literature either. This means that the topic is limited to invasive BCI and thereby should be restricted to that conversation rather than having it expanded to be discussed on a general BCI level.

### 5.1.10 Side effects

While side effects were part of the discussion in the literature, the anticipation of the concern for side effects was nearly non-existent for both stakeholder groups. While some stakeholders did acknowledge the

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concern and one stakeholder even mentioning actions were taken early in the development process (see page 48), most stakeholders had to have the topic of skin irritation or societal side effects mentioned to consider whether it was a concern. This shows a clear distinction between the setting of a medical researcher and the general BCI researcher or consumer developer. The literature (section 2.3.2.10) was largely influenced by implantable BCI devices or transcranial direct current systems which shows that limiting the discussion about ethical concerns based on the settings are extremely important to make sure that the ethical concerns discussed are fitting to the technology and how that technology manifest itself in the settings. Discussing side effects of implanting devices is a much more sensible discussion than discussing whether there is skin irritation from wearing a dry EEG cap. As such irritation is also a factor for manufacturers of watches, Fitbit trackers, and similar objects. Whereas the discussion of implantable BCI devices is much closer to the discussion of side effects from pacemakers, and other medical devices. Having this clarification is important to reach conclusions that make sense for the technology and the people involved with the technology as a discussion set in a too broad of a setting will result in stakeholders feeling distanced from the topic and problems. Which is especially important in an RRI setting where stakeholder engagement is a central pillar of making sure ethical concerns are handled in a responsible way.

### 5.1.11 Societal

As mentioned in section 2.3.2.11 was the literature on societal concerns explorative (Trimper, Wolpe and Rommelfanger, 2014; Hildt, 2015b; Schicktanz, Amelung and Rieger, 2015), which has proven to be problematic. The societal concern that resonated most with either stakeholder group was about BCI changing our idea of the mind. One stakeholder mentioned that this was indeed a concern they were already experiencing as people were getting attached to brain scores. (see page 49 and 92) This also shows that concrete problems that occur are easier for stakeholders to act on than theoretical futures of how the technology will develop. Various stakeholders also mentioned that they were more concerned with social media and other technologies impacting our view on ourselves than further insight into how our brain works. (see page 140) The societal impact of BCI (due to impacting religion) could be argued as something BCI developers should be concerned about. This topic is obviously a rather complicated debate though, as it puts into question whether religion is a good or bad thing for society and whether technologies that promote or reduce religion in society are good or bad. This discussion spans outside of the scope for this research as that is a larger debate, which would be a research study in itself. The topic of military usage of the technology which was mentioned in the literature, was also mentioned by various stakeholders, however due to the limited usability and accuracy, the discussion about military use cases such as desensitising soldiers or reading minds, is not relevant at this point unless it is discussed in a futuristic philosophical setting.



## 5.2 Settings and the impact on RRI and AREA framework

Overall this research shows that there is some clear difference in the way each stakeholder group not only deal with the ethical concerns regarding BCI technology but also how they think about them. In this section, some of these differences will be discussed in relation to RRI. This discussion will show why these differences are important to RRI. In section 2.2 it was shown that RRI is meant to be all-encompassing and to change innovation from thinking about ethical concerns as an afterthought to be the catalyst for doing innovation. This section will discuss how these goals are impacted by the results of this research and how RRI as a discourse could respond to these challenges. This section will also discuss how the AREA framework was useful to describe these differences between stakeholder groups, and how the AREA framework could potentially be used in an RRI setting with this research in mind.

### 5.2.1 Ethical concerns setting and the impact on RRI

The two sets of stakeholders come from different backgrounds and with different goals and ideals in mind. Without interviewing the stakeholders, it could be argued that industry stakeholders are set in a place where they must sell products to survive, and research stakeholders are required to produce new knowledge to survive. These two differences in settings are shown in this research to have an impact on how ethical concerns are experienced. The previous section discussed these differences and similarities (section 5.1). It was seen that while there were clear differences, often the stakeholders were not far from each other. Researchers, for example, mentioned that due to the way their experiments were set up, they did not record or store any data which largely removed the privacy concern for them. (see page 59) Consumer stakeholders, on the other hand, took different measures by making it clear to customers that their data was owned by the customers themselves and they were free to retract all their data if they wanted. (see page 88) Small nuances like these show different ways of reflecting upon the concern of privacy and finding different solutions. While either solution could have appeared in both settings, due to the nature of what each stakeholder was trying to achieve with their BCI, it resulted in different actions taken. These small nuances in the actions taken are more apparent in other topics, such as the topic of public perception. While both groups acknowledged this concern, for researchers it appeared like a general issue they had to engage with in their daily work. (see page 57) However, for consumer stakeholders, it was a matter of keeping their livelihood intact. This meant that their attention for not overselling their products and engaging with customers that had bad experiences was highlighted. (see page 66 and 79) The difference in settings also meant that the form of feedback the stakeholders were given on their work was very different. Research stakeholders got direct feedback from their research participants on changes they had made on the BCI devices. (see page 71) However, consumer stakeholders did not only get feedback from a few internal testers on their products, but also through online reviews which once again made them



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more sensitive to feedback as bad feedback could result in their livelihood being affected. (see page 92) These small nuanced differences could spark a heavy critique of each other's work and impact the ability for each stakeholder group to sympathise with each other. Researchers criticized consumer stakeholders for being greedy and not doing the work for the greater good of patients and customers, and consumer stakeholders criticized researchers for not being focused enough on real-world applications and solving problems that were currently an issue. Such a critique of each other can be a very limiting factor for RRI that tries to bring the two groups together and wants to push both groups towards more responsible research and innovation. What this research also shows is that when interviewing the two stakeholder groups, it is exactly the points of critique that some stakeholders mention as one of their key interests. Multiple consumer stakeholders mentioned their reasoning for making BCI products as improving the usability of the technology or improving the ability for costumers to either meditate or train their brain. (see page 56) While research stakeholders mentioned creating usable technologies as a major goal for their research. (see page 59 and 62) This suggests that the idea of the intentions of the other stakeholder groups does not match the self-reported intentions. Before moving onto the impacts for RRI regarding this, it is interesting to note that part of the RRI goal is already part of the research stakeholders experience. While RRI aims to make research more meaningful for the people paying for it, the researchers are already mentioning that they aim to do research that makes sense, and that will be used. (see page 59 and 62) This indicates that the goals of RRI either have already been adopted at some level by researchers or that the RRI discourse falls within a movement in innovation in research that emphasize the importance of research being meaningful to the public. Similarly, industry stakeholders mention that they have always been innovating for the public. In both cases, RRIs role becomes to facilitate these intentions of meaningful and responsible innovation, rather than to change the intentions and goals of research and industry stakeholders. The split in opinion between these stakeholders is a point of interest for RRI advocates as it shows a need for RRI work to bridge this gap between the two stakeholder groups. Therefore these nuances are important to the RRI discourse to acknowledge and discuss in the future. It might be possible to develop some general concepts and ideas that could be usable and applicable for both industry and research stakeholders and bridge this gap. However, if the RRI principles are to be implemented, there needs to be a greater focus on adapting the RRI principles to which settings they are going to be adapted for. While a research setting might share technology with industry stakeholders, the differences between the two settings can make it impossible to consolidate both stakeholder groups in agreement to the current state of ethical concerns, and what actions needs to be taken to act responsibly. It could be argued that this is already part of the RRI discourse due to the focus on engagement both in the AREA framework and in the idea behind RRI, which seeks to bring in all relevant stakeholders, however, even the concept of

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engagement is understood differently and can manifest itself differently in the two RRI settings (research and industry). An argument could be made that RRI work can focus on either setting, without having to focus on both. While this is true for some work, the very naming of responsible research and innovation, as well as the explicit goals of RRI, means that both settings at least to some extent need to be considered. To which level both settings has to be considered is most likely depending on what type of research is being done, or whether a specific piece of RRI work fits into a greater narrative that considers multiple settings. What this research shows however, is that RRI is capable of working with both research and innovation settings, which could be considered a critique to the previous argument. While this could be argued for the AREA framework which this research used, the division in the current RRI literature (see section 2.2) shows that the RRI discourse could potentially be splitting into two different directions. One direction working towards implementing RRI in industry, and one for implementing it in research. This research shows, that for RRI to be applicable in all aspects of innovation, these two directions have to be connected more strongly. In the early RRI literature, the focus was largely on research stakeholders and the interaction between researchers and governance. While it is clear that RRI needs to embrace responsibility in industry settings as well (which the literature shows the discourse has (section 2.2) been working on), this research shows that a clear connection has to be made between the two settings. Working on changing each setting to become more alike would however be a challenging approach to take in this matter. By having different motivations for innovation and multiple ways of working with innovation, it is a method to ensure that multiple stakeholders would be considered. By having both an academic research setting and a consumer innovation setting, it ensures that innovation is not only happening on the basis of a market and consumer setting or on the basis of patients and research participants. Combining the two settings ensures that both types of innovations will occur and expands the potential stakeholders benefitting from this innovation. Another possible way to deal with different settings would be to split RRI into responsible research and responsible industry. A criticism of splitting the discourse into two distinctive areas of research, would be that the RRI vision is to reduce the distance between research and industry innovation and splitting the discourse would achieve the opposite. If this key aspect of RRI is to be uphold though, the RRI project needs to make sure that the vision explicitly acknowledges the importance of context and background while making efforts to work with both settings. Therefore before anticipations can be made, or before actions can be taken to deal with ethical concerns, a strong definition of context has to be made for RRI frameworks. For technology projects, it will be important to define what type of technology the ethical concerns are related to, what type of settings the ethical concerns are implemented in, and what kind of stakeholders the technology is relevant for. This type of work is not new, but for RRI to improve its rigor there needs to be developed RRI methods to deal with these questions.

### 5.2.2 What was learned about the AREA framework

This research has been using the AREA framework to analyse the different stakeholders' experience of ethical concerns. Overall the framework has been good at finding interesting perspectives on ethical concerns and describing how stakeholders respond to these concerns. The framework has shown itself to be adaptable enough to describe both a research setting and a consumer settings experience and thereby allowing it to show some of the differences and similarities between the settings experience of the ethical concern. Where the framework falls short in this research was discovering new ethical concerns, as no new ethical concerns were encountered during the interviews. The lack of novel ethical concerns being discovered could, however, be attributed to the methodology of this research, which had already produced a list of ethical concerns for BCI and thereby investigated how these were experienced by both stakeholder groups. If the AREA framework were to be used to discover ethical concerns in a new setting without an established literature background, it would require the framework and interview questions to be adapted to this purpose. By interviewing stakeholders on their anticipated concerns, their reflections upon the technology they worked with, the actions they had already taken to mitigate concerns, and how they engaged with stakeholders, and what this had given them in return, a study could be created that largely discovered ethical concerns and how they were experienced by certain stakeholders. That the AREA framework is adaptable is both the strong point of the framework, but also what could be problematic as it can quickly be too broad a concept that is not distinguishable if adapted too much to fit a certain setting. This research shows that the definitions of anticipation, reflection, engagement, and action is very broadly defined which makes it very hard to use precisely and it quickly becomes a matter of interpretation whether a stakeholder is acting upon an ethical concern or engaging with a community about a concern. Such interpretations are in itself not a problem, however if other projects plan to use the AREA framework, the definitions of these key terms could be more strictly defined to improve the usability of the framework. Once such strict definitions have been made however, the framework allows for a useful analysis of how stakeholders experience ethical concerns and can show stakeholders what areas of their work might require further improvements, and which are already in a responsible state for research and innovation. By using the AREA framework RRI advocates also have a more understandable way to communicate with various stakeholders, as it allows for an analysis of their experience with the ethical concerns that translates rather well into direct recommendations for their future work. It also puts stakeholders into a responsible loop, which can be started at different stages of development without being forced. The comments from stakeholders in this research shows that various ethical concerns are considered at various levels depending on the setting of the stakeholder, the maturity of the technology, and an unknown number of variables. By using the AREA framework, it is possible to analyse whether an ethical concern is

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currently in an anticipated stage, but not yet mature enough to be an ethical concern needed to act upon. Such analysis of ethical concerns can be a useful way for RRI advocates to get stakeholders involved with a process that ensures that stakeholders are engaged with ethical concerns before research and innovation is started.

### 5.3 Reflection on the research process

In this section the process of this research will be discussed. This section will evaluate the research in terms of the results based on the chosen methodology as well as discuss improvements that could be applied to future research seeking to follow a similar approach and using the AREA framework. Using the AREA framework as an analytic framework for the interview data showed itself to be very useful and could identify very detailed differences and similarities between each stakeholder group as discussed in sections 5.1 and 5.2. The usage of the AREA framework in this way is however novel, and not without problems. These problems will be addressed further later in this section, however firstly the importance of the usage of the AREA framework will be discussed. Using a novel approach is important as the practical usage of framework is required to further develop the theories underlying the framework as well as the framework itself. By using the AREA framework in this way, it showed the usability of the AREA framework in a practical analytic setting for ethical concerns. This is important in the RRI discourse as a key part of the discourse appeared to be a desire to make research more marketable and usable outside of research settings. Practical applications of frameworks is also important to further develop and improve them, as by employing the framework in practice will potentially provide insights into practical concerns that might not have shown itself during the theoretical development of the framework. While these key points are important for using the AREA framework in a novel approach, the research process was not without limitations and problems. Overall, the lack of definitions was a major concern for the research, as it affected both the analysis of the data in terms of the AREA definitions, but also in terms of defining the limitations of interviewees. When it comes to consumer stakeholders, this resulted in a rather limited number of interviewees, which were hard to increase due to the limited amount of companies that fit the definition of BCI devices interesting for this research. This however could be a problem for similar studies wanting to study newly emerging technology as this point of technology maturity will often include a small number of companies. In terms of research stakeholders this was less of an issue, however as these could be identified by the usage of certain commercial technologies in their research. Due to the aims of this study to not introduce generalised theories (as mentioned in section 3.1) based on the data available though, these limitations were not so limiting as to not being able to provide meaningful results. The lack of maturity and definition of the AREA framework also proved to be an obstacle as it meant that direct integration of the AREA framework into the interview questions was not possible. This meant that the

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usage of the AREA framework was bound by interpretation which is a source of variability in terms of the results. While the results for this study turned out to still provide meaningful enrichment of the data collected, it could have been interesting to see a direct integration of the AREA framework in the interview, to further test the AREA frameworks robustness and usefulness. For future research, to avoid some of these limitations and to provide even more meaningful results, a robust development of the definitions of the AREA framework is suggested prior to undertaking the research. By further developing and defining the AREA framework it is possible to ensure the usefulness of incorporating the AREA framework into the study. By having better definitions of each aspect of the AREA framework it is possible to inform the interviewees about the aspects of the framework. By informing the interviewees of the different aspects of the AREA framework, it allows the researcher to directly ask participants about specific aspects which might not be clear otherwise. While actions and anticipations were shown to be rather easy to identify, reflections specifically proved to be difficult to identify as interviewees were shown to be unlikely to talk about sitting down and thinking about ethical concerns. To aid with the number of participants, a different approach could be viable when it comes to recruiting interviewees. Interviewees for this research were found by attending an industry conference which revealed companies and interesting persons to interview which were not otherwise publicly available. While most companies were identified during the initial interviewee search, the attendance at an industry conference proved that when dealing with emerging technologies, the traditional ideas of companies might have to be altered to fully explore the consumer grade market. By increasing the scale of number of interviewees it would also allow for further research to make general theories, which this research was unable to. It could also have been useful to engage with multiple stakeholders at each company as this would have improved the general breadth of knowledge and type of stakeholders engaged with. This however, is suggested being done as a snowball effect rather than initially, as this approach might prove more successful in getting more people involved.

## 6 Conclusion

The following section will describe the conclusion of this research study. This section will conclude how this thesis contributed to knowledge and what this thesis provided in terms of answers to the research question. This chapter will also include detailed results for both BCI stakeholders and RRI stakeholders summarising what this study provides for each group of stakeholders, as well as potential future developments. Finally, this section will explore what further research could improve the understanding of what happens when technology moves into a different setting.

### 6.1 Results for BCI stakeholders

In this study it has been shown that BCI stakeholders have a diverse background and approach to ethical concerns related to BCI devices. It was shown that these differences in approaches can impact the perception of the ethical concerns as well as how actions are taken to handle concerns which are either considered relevant or not. This diverse background and approach are something BCI stakeholders should take note of as this is an important acknowledgement that can be used by BCI stakeholders. A diverse background and approaches to BCI devices makes the possible solutions to concerns that are anticipated or stumbled upon larger and increases the possibility for good solutions to be available. By actively using this diverse background the BCI community could produce better products for BCI consumers both in commercial settings and more broadly. The diverse background however is also a cause for concern for BCI stakeholders. If the differences between the different stakeholder groups are not acknowledged, misinformation and miscommunication is likely to happen. This has been shown to be a cause for disagreements between the two stakeholder groups taking part in this study. Research stakeholders might mistake companies need for making a profit as their main motivation, and consumer stakeholders might mistake researcher's ability to investigate specific details on BCIs as a lack of understanding for the usability of their proposed changes. While the findings of this study do not provide evidence for these misconceptions to be true or untrue, it shows that each stakeholder group is able to agree on many of the ethical concerns related to BCI devices and able to find common ground on solutions suggested for these. Such agreement between two stakeholder groups could be a very valuable base for further cooperation between the two stakeholder groups. This basis for cooperation is however only usable if stakeholders can look past initial understandings of each other's intentions and goals. Most importantly, this research has confirmed that there are significant ethical concerns that need to be considered regarding BCI devices. While the relevancy and to what extent ethical concerns are pressing to handle can be debated, based on the interviews performed, ethical concerns do relate to BCI devices and need to be dealt with. Some of the ethical concerns that are crucial to deal with prior to BCI devices making a major impasse into the average consumers daily life, is topics such as privacy and usability. For both researcher and consumer stakeholders

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these issues were brought up, and some of the other issues related to BCI could be linked back to these two topics. Topics such as informed consent and the accuracy of the devices were mentioned as being part of the usability problem, as lack of accuracy and information about how the technology were barriers to ensure usability and understanding of privacy implications. For BCI stakeholders, it is therefore critical that privacy and usability concerns are being looked at as a major implication for the future of BCI devices. This focus on privacy and usability does however need to include the understanding of how other ethical concerns might implicate these concerns. While some argued that these issues were less of an issue for consumer grade devices, this research shows that this understanding is not universal and therefore needs to be addressed by stakeholders. Finally, this research has shown that the understanding of what a BCI is, can be very impactful on the understanding of ethical concerns, and there are many issues where the identification of invasive, non-invasive and other categories of BCI devices heavily influence the experience of the ethical concerns. Finding common ground for these different devices and potentially finding a specific term for consumer grade devices that distance them from other BCI devices, could be a crucial element for the BCI stakeholders to create distance from technology they do not identify themselves with.

### 6.2 Results for RRI stakeholders

Like BCI stakeholders having to be aware of the diverse background of people working with BCI devices, RRI stakeholders need to be aware of this diversity. While BCI stakeholders need to be aware of this diversity in relation to how they can move BCI development forward, RRI stakeholders can apply this diversity to a broader set of technologies. For RRI stakeholders this research shows that a diversity in how ethical concerns are viewed could be a potential disruption to generalisations for ethical concerns. This is quite possibly not a new acknowledgement for the RRI community as it already includes an understanding of having to engage with different stakeholder groups to discuss ethical concerns. This research however does show directly how small these nuances can be and how difficult these differences can be to uncover due to how these nuances are shown when interacting with stakeholders. This piece of work shows that while different stakeholders might anticipate ethical concerns, they might have different solutions or actions they take to deal with these issues. Another important outcome RRI stakeholders can use from this work is how practical applications of frameworks is important. This work shows how the practical application of the AREA framework highlighted the lack of definitions. It also showed that the order in which each element was presented could be arranged differently to increase the connection between the narrative of the framework and how research subjects talk about ethical concerns. By arranging the AREA framework in the way that it was in this research (Action, Engagement, Reflections, and Anticipation, rather than Anticipation, Engagement, Reflections and Action), it was possible to more closely follow the narrative of the stakeholder's explanation of their experience. This was done by first talking about what stakeholders

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had done, who they interacted with (if anyone) to reach this course of actions, how they reflected upon these actions and engagements, and finally which anticipations or lack thereof that had led to these actions and engagements in the first place. What RRI researchers could learn from this is, to create frameworks that reflect how people interact and explain their understanding of ethical concerns related to technology. By doing so, the frameworks created will be easier to apply to the data collected and will create a more meaningful understanding of what experience stakeholders have of ethical concerns. This is different to an approach that assumes how ethical concerns should be dealt with. This approach is especially useful when trying to understand and analyse stakeholders and could potentially also be applied to frameworks used to teach stakeholders how they should approach ethical concerns. By being aware of how stakeholders experience these ethical concerns, it is easier to provide meaningful guidance to the stakeholders on how they could approach these concerns.

### 6.3 Contribution to knowledge

In section 1.1 the gaps in knowledge were defined as, a lack of understanding of the differences in the experience of ethical concerns between different settings. This gap in knowledge were present in both the BCI discourse and in the RRI discourse, however in different ways. This research filled this gap in knowledge by firstly providing an initial list of ethical concerns in the BCI literature (section 2.3.2). This list was then explored through interviews in both settings. The two stakeholder groups were often closely aligned on the understanding of ethical concerns related to BCI devices however, the analysis showed that the difference in settings often caused nuances in the experience of ethical concerns. (chapter 4) Based on this analysis it was discussed whether these nuances were of importance to both the BCI discourse and the RRI discourse. (chapter 5) It was found that these nuances were essential to both discourses to consider. For BCI stakeholders it is was found to be important to distinguish what type of BCI and what type of setting were being considered when discussing the ethical concerns. There was found to be a conceptual muddle in the BCI literature regarding the ethical concern that resulted in differences in the literature and interviews. (section 5.1.4, 5.1.9, and 5.1.10) These differences were found to cause challenges in creating a shared experience of ethical concerns. It was also found that the settings were important to the RRI discourse. In section 2.2 it was argued that RRI were intended to be useful for both research and innovation, but that the discourse often discussed RRI in relationship to either one of these rather than trying to understand RRI in both settings. This research has argued (section 5.2) that for RRI to be effective and reach the goals set forth, there needs to be a consolidated effort in dealing with ethical concerns and creating frameworks that can span both academic research and commercial innovation. This study also shows, that while the implicit difference in innovation and research is clear in the name of RRI, there needs to be an explicit effort in discussing these differences. This study argued that while the differences might be in nuances, these



nuances have a significant effect on the experience of ethical concerns in each setting. Failing to acknowledge these differences would be problematic for RRI to being able to work with multiple settings within one framework. (section 5.2.1)

### 6.4 The answers to the research questions

This research was performed with the goal of answering the following question *“what happens to the understanding of ethical concerns when brain-computer interfaces are moved into a consumer setting?”*. To answer the overall research questions, the answer to the related questions needed to be answered first. Firstly, the research answered the question of *“what ethical concerns are related to brain-computer interfaces”*. This was answered by a literature search (section 2.3.2), and furthermore by the interviews specifying whether these concerns were experienced by research or consumer stakeholders. The interviews showed that most of the ethical concerns identified in the literature were experienced and that no further ethical concerns were discovered (section 5.1). The question of *“how are ethical concerns experienced in research and consumer environments”* were answered through the AREA analysis (chapter 4). This analysis showed that ethical concerns related to BCI technology were experienced differently in the two settings. It was shown that while the different stakeholders could agree upon aspects of the ethical concerns, they often disagreed on the reasoning behind these opinions, and had different ideas of how to engage with the ethical concerns (section 5.1). Lastly, this thesis argued that the answer to the question of *“what does these differences mean for RRI and the ethical concerns related to BCI”*, is that both discourses have important work to do (section 5.1 and 5.2). The BCI discourse is found to need a much clearer definition of what a BCI device is before discussing ethical concerns. There also needs to be a focus for BCI stakeholders to be aware of the difference in how speculative questions can be, while keeping each group of stakeholders interested and engaged. When BCI stakeholders do share the same understanding of ethical concerns, these needs to be acknowledged as these are potential areas of interest that both stakeholder groups are interested in solving. The RRI discourse was found to be impacted by these differences as well, as the main goal of RRI were found to be challenged by them (section 5.2.1). Finally, the answer to the overall question can be given which is that when brain-computer interfaces move from research to consumer settings, the understanding of the ethical concerns changes to be influenced by the background of a new setting. Thereby when consumer settings are influenced by having to sell products, the ability to speculate about the future is reduced, and what becomes relevant is the ethical concerns that can be handled in the present. Thereby the interest in problems in the far future is reduced, as more pressing issues are focused upon. This created a natural gap between the experience of the ethical concern in consumer and research settings.

### 6.5 Further research

This study has created the groundwork for a large variety of further research activities that could be made. The main question of what happens to ethical concerns when a BCI moves from research to consumer settings have only partly been answered (as described in section 6.2). However, this study also shows that a large portion of this question remains unanswered. Some of these questions relate to the BCI discourse, such as defining BCI technology and creating a rigid understanding of these different devices to ensure that the literature reflects such definitions. Another BCI related question is how specific ethical concerns could be understood better or handled better in the BCI community. Concerns such as privacy, usability and public perception appear to be crucial questions that need to be explored further within the community. How RRI could be used to improve the public perception of BCI devices, could be a very interesting research project, which could show how RRI can be used in both research and innovation settings. For the RRI discourse, this study has shown some major work is required to strengthen the usability and rigour of the concept. Specifically, there needs to be an explicit discussion of the differences between research and innovation furthermore, there needs to be a discussion on how the bonds between the two streams of the discourse can be improved. It is crucial for RRI to keep its novelty compared to older and more mature approaches to ethical concerns which means to keep the combination of research and innovation intact. Lastly, further research can be done on the difference in the experience of ethical concerns in general. While this research has shown the difference for BCI technology, there is a vast amount of research to be done on other technologies, and to investigate which characteristics of the settings that impact the experience, not only for BCI technology but technology in general. Additionally, there is a strong need for more practical applications of theoretical frameworks created in the RRI discourse. Specifically this research has shown that applying the AREA framework proved to be difficult in certain situations, and improvements were suggested to it. These kinds of practical applications of the theories and dilemmas dealt with in the RRI discourse need to be further encouraged. This is to both strengthen the tie between research and practice on ethical concerns, but also to improve the usability of the theories and ideas developed in the RRI discourse. For BCI stakeholders this also holds true, as practical applications of the technology and especially the ethical concerns need to be investigated. The goal of this research was to enrich the data we currently have on ethical concerns in both research and consumer settings, and hopefully create a platform for more research to further expand our understanding of what happens to ethical concerns when technology moves from research to consumer spaces. By increasing our focus on this transition, it is possible to hopefully change the direction technology has in an early state of development, so the final consumer products are more ethical and more suited to the society that will be impacted by the acceptance and broader usage of these technologies.

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This study concludes with an encouragement to both discourses to continue the work that has been started in this thesis to improve the understanding of how ethical concerns are experienced in different settings.

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### 8.1 BCI literature

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### 8.1.2 Ethical concerns identified

Name	Sources	References
Ethical concerns	0	0
Accessibility	26	86
Information accessibility	2	8
Accuracy	20	91
Misinterpretation	14	35
Autonomy	20	51
Informed Consent	18	74
Doctor-Patient Relationship	5	20
Incidental Findings	5	10
Misinformation	2	2
Sense of purpose	1	2
Vulnerability	5	6
Conceptuel muddle	3	5
Enhancement	21	104
Exploitation	1	1
Identity	28	157
Animal research	2	4
Free will	2	3
Legal and policy concerns	13	31
Liability	9	25
Privacy	20	96
Public Perception	22	106
Acceptance	4	10
Astetics	4	7
Comfort	6	18
Discrimination	4	24
Longevity	5	24
Quality of life	6	22

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Reliability	3	3
Reliance	11	13
Usability	7	20
Security	5	10
Side effects	24	83
Societal	11	27
Abuse of power	5	11
Militarisation	1	5
Misusage	5	15
Competition over funds	2	6
Transparency	1	1
Globalisation	1	3
Solutions and recommendations	0	0
Approach to selecting ethical concerns	1	2
Defining keyterms	2	2
Design methodology	14	37
Autonomy	1	1
Utilitarian Approach	1	1
Encryption	1	1
Expert regulatory board	1	1
Legal Restrictions	3	10
Neuroethics education	2	17
Public education	2	2
Request for research	20	64
Standardisation	2	4
Usecases	0	0
Analyzing Actions	7	10
Assistive technology	12	18
Authentication	1	1

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Device Control	6	13
Exoskeleton	1	1
Speller	1	1
Wheelchair	1	1
Education	1	1
Enhancement	8	14
Entertainment	1	1
Knowledge transfer	2	7
Liedetection	2	4
Memory blunting	1	1
Military	7	11
Rehabilitation	6	7
Robot Arm Control	1	2
Training	2	5
Treatment	16	27

## 8.2 Interview transcripts

### 8.2.1 Consumer stakeholder 1

I: Interviewer

E: Employee/Employer

0:00 I: So, could you just try and introduce yourself in a couple of sentences? And what you do at your company, what is your work position?

E: Okay, so my name is [NAME], I am founder and CEO at [COMPANYNAME] and [COMPANYNAME] is a UK based neuro feedback company. We manufacture consumer EEG headsets and we have a tool which is a video player which allows video to change based on human emotion response. Which was originally designed around automating mental health therapy, but ultimately morphed into kind of a entertainment based brain training tool.

0:38 I: Okay, I guess that ties into my next question, is what do you actually hope that people will use your BCI for?

E: Good question. I think that the answer to that actually lies in the application, because the point is, BCI is showing us that there actually are a lot of use for it. So for example there are uses in mental health, there are uses in field based research, there are uses in neuromarketing, there are uses for psychotherapists, and actually now there are tremendous amount of uses for support. So in terms of myself and my grand vision, I think that the thing that is the most exciting for me is how everybody has a fitbit.

1:23 One day everybody will have the same access to their brain data and their ability to train their brain the way they say train every other muscle. But in the meantime, I think that the core market is researchers, athletes and people within the area of mental health who are looking at alternative ways of treating people.

1:46 E: But really it's all about brain development, I think is the exciting thing about BCI. It's got nothing to do with controlling things I think it's more about learning to control your mind, which is the most exciting.

I: Okay, that's interesting. So if your focus is on training. E: Self training I: Yes, of course. Is there any uses that you might be concerned about that might be what you intended, the devices to do. but that you might be thinking about is possible?

2:15 E: Well it's a BCI at the end of the day right, so what it's doing is giving insights into brain, and then the more we are learning about emotions, the more algorithms that occur, the more patterns we start to determine. We already know, things like priming behaviour thanks to brain trigger and brain technology. And now I think one of the scarier things is, the potential for neuromarketing to hone down the science of essential manipulation. So, they use our own restraints and our own limitations against us, when they are trying to sell things to us. And I think that is the only real fear, but then I think that there is another way to look at this, and that is. If people actually are using it for the original purpose of training their brain and becoming more emotionally aware and conscious and mindful.

3:00 They are also less likely to get affected by those very standards because those standards are based on, understanding the way the brain works. It is as though you were judging human physical abilities by looking at physical training a hundred years ago. Where as if you look at what a free runner can now achieve with his body. I don't think we ever thought that was possible, and I think the brain has the same potential.



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3:21 I: Okay. Yeah that's an interesting perspective, that there mere fact that we are actually training ourselves that helps shield us. Okay.

E: Well for starter it's the consciousness because we have convinced ourselves that our brains are not malleable, they are not trainable, and doesn't matter how many TED talks we listen to that tell us that our brain can change. People are then like "yeah, but not me, I am the way I am", and it's like. It makes me sick when I hear that, because I think well, that is just stupid. That's like saying well I am skinny so there is no point in going to the gym, it's just the way I am.

3:55 You know, everything can be trained, you just have to first be willing, but before that, you have to put your cynicism and scepticism to the side. And I think this is where the academic world actually, pardon my French, screws everything up. Because they put so much empathies on ethicacy and this well, that is not spot on, and that is not spot on. Well who gives a shit? It's a 200 pound or a 100 pound piece of kit that is giving them 80-90% the ability to do something that costs thousands of pounds.

4:26 It gives them insight into their brain even if it's not 100% accurate. It is like no ones bothered about or worried about the fact that the fitbit was like 12% accurate to your heart. But we all took it as law because it actually still made us all conscious, and then as the technology improved it became more accurate because [INAUDIBLE] the money in the industry. Where as if we keep knocking the technology, before it has had a chance to develop and on the slip side, keep overselling the technology. Everyone thinks well, I might as well wait until it gets to that level.

4:56 I: Yeah, yeah E: That's the frustration. I: Speaking about misinterpretation of data, the accuracy of data. Is there anything you guys do to try and prevent that, and try to help people use your devices?

5:15 E: Well for starters we believe in don't say shit that is not true. Which I think my industry could really take a lesson from. Don't over sell, technology is amazing as it is. You don't need to over sell it. But in terms of accuracy, what do we do, so we partner with a number of universities, we also supply tech to a number of universities. We have published papers that have used our technology to work out it's ethicacy. We test everything thoroughly, but most importantly we are completely honest in the fact that technology has limitations.

5:51 Accept it, but be grateful for it's progress so far. You know, to know that we live in a world, where for under a 100 pounds, you can buy something that actually gives you insights to your emotions, and more importantly the fluctuation of your emotions. And how triggers affects you, and how insults affect you. You know we did an experiment, a commercial experiment, a paid for commercial experiment, for a company called [COMPANY] that makes soap. And they wanted to look at how a mother reacts emotionally, so in terms of relaxation and pleasure whilst doing things with their children versus doing things on their own. So kind of traditionally we timed children engagement things like playing and making things together and baking versus having a massage, sitting and reading magazines, spend some time on social media.

6:42 You know, the most interesting thing to come out of that study was, when somebody spends just 5 minutes on social media they put themselves through this huge emotional roller coaster. And it's completely dictated by this stream of information that's coming in, so you get happy, sad, envious, jealous, happy, angry, frustrated, in about 8 seconds.

7:08 And that leaves a mark, now if we are living in this world where we are information overloaded, emotionally overloaded, suicides are higher, depression is higher, surely we should be promoting brain intelligence and brain control and emotional intelligence. Even greater than academic intelligence because

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we have reached a point where we are comfortable with academia. We are pushing boundaries like never before, and yet we are doing absolutely sweet buggers all to help ourselves. Like children, you teach them to go to school and to pass exams, but you're not teaching them with how to do with failing an exam.

7:44 You tell them that you live in a social world, go and make friends, but you don't teach them how to deal with rejection of social groups. You know, this is to me almost insanity. You are not preparing them for the real world, you are training them to become completely reactive to the environment. And what happens is when you get overwhelmed, you become docile, and you stop giving a shit. So I think one of the real benefits of this technology. And it saddens me, you know, when everyone is talking about this tech and they are talking about controlling lights and cars. And I think, come on man, how lazy do you want us to be. The real benefit of this technology is your brain. Knowing that you can control, so if you can control your attention, you can control your thought process. If you can control your calm, your alpha frequency, you can control your emotions, which means.

8:34 You not only control what comes in and out of your mind, but you also control how that thought is processed, emotionally. And that to me is a power, that is Jedi in its kind of ability. And something athletes have been training for, for years. But yeah, sorry that was a really long answer. I will give you a few short ones, I will start mixing it up.

8:52 I: No it's good, the good thing is you are covering some of my questions yourself, so that is fine. E: Okay, cool. I: Actually tying into that, there is some concern that, having this insight into our brain, can change our concept of identity and autonomy, and who we are. Is that something, I mean. E: That makes no sense to me at all. I: No, okay. E: No, I mean, I am curious, where is the argument for that? See if you were using the argument for things like neurostimulation or trans-cranial magnetic stimulation, or electrical magnetic stimulation or whatever. See then I can understand, because then what you are doing, is you are essentially re-cunning your own abilities, by training your brain to become dependent on this other stimuli. Where as what EEG and BCI does, is it says, actually you have the same control.

9:45 It's a harder. It's the equivalent of going to the gym and lifting weights, or sitting at home with one of those electrical pad things, that makes your stomach jiggle. In the hope of getting a six pack. That one will make your stomach hurt, it will give you cramps, and it will give you some form. But the minute you stop doing it, and you try and do a crunch with a real weight. You are realizing that you haven't actually developed proper muscle.

10:08 You haven't developed strength, you missed all the supporting muscles and everything else. Everything that came with that training. So you got a six pack and you got the weakest lower back on earth. So this is the fear, of that. Where as with the EEG, it's like saying, are you afraid that the heart rate monitors are going to change the way we look at humans because we realize that we all got hearts.

10:29 Like no, that's bollocks, that doesn't make sense. I: Okay, yeah, interesting. So, you make that distinction quite clearly between those who quote on quote simply read the EEG, contrasting. E: And those that manipulate yeah. I: yeah, those that manipulate. Okay, yeah. Another concern is often privacy. E: Privacy of what? I: Of your, well, I guess what I am thinking of is for example with as you mentioned the neuromarketing. Where people can interpret your EEG, and read things that might not want people to read. E: Okay I: Is that something you think about as well? E: Yes and no, so in the positive way that we think about this, is that. So there is a caveat here right.

11:42 A method that is required to process, so the only way you can capture, what you can define as a known emotional response to something. Is if you know what the stimuli was, at that exact given time.

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Right, if you don't know the stimuli knowing the brains emotional response is entirely pointless. So in most situations, unless you are voluntarily telling people what you are doing at that time, or you are connected to a device or an app. That was monitoring your behaviour at the same time. Then yes there is a concern, but that concern is more with the app, less with the technology.

12:16 Because the technology, doesn't explain thought processes. You are not going to accidentally give away your pin number. All it is going to do, is it's going to allow people to look at the changes in electrical activity. Which means they may be able to see that at some point you got relaxed. And unless we are all wearing caps that change colour based on our EEG, it is not something we are ever going to be projecting.

12:37 So we don't have to worry about others getting access to it, and sometimes access is good. So, for example if you imagine a movie theatre, there is 200 people in it right, so you know they are all watching the movie. Now, movies are amazing at creating an emotional response. They make us cry, they make us laugh, they make us jump out of our seats, they make us scream, right. So if you can create a movie and you know that at 1 minute 48 seconds there was a point that should make the majority of the people laugh. And there was a point that should make most of the people in the room scream. And there was a point that make most of the people afraid, you start to develop really cool algorithms and patterns. That can actually then be used by the humans to then take control of another facet of emotion.

13:21 So for example, you may be partially Jedi, right, like an athlete. So you got very good focus, you got very good emotional control, you got very good calm, however, you just so happen to be really shit around people you don't like or people who happen to insult something or insult you in a particular way. You may have a particular thing with an eye brow or a tooth, and nobody knows it. But this one son of a bitch figures that out, and he says it to you just before your game. And it's going completely ruin your performance. That was your trigger, right. And one of the things about athletes is how do you make somebody who is already amazing more amazing, is by training them away from their triggers.

14:00 So this kind of technology has really cool potential, in terms of where data collection can be made possible. But that entirely relies on the individual being a willing participant, in that, at that time.

14:16 I: Okay, so you're not really afraid of unintentional information slipping out based on E: No. I: Okay, sort of related to that, I have a sense that I already know your answer to this. Some research has raised concerns with just the security of brain computer interfaces. And they have related it to when hackers figured out they could hack into pace makers and stuff like that. E: Yeah I: I suspect because you already made that distinction between purely monitoring and those who are

15:03 E: Well, yes and no. There is another element to that, which is the reason those pace makers and things can be hacked is because they are cloud based, they are online. If something is not connected, and doesn't have the potential to be connected. There is no potential to be hacked. I: Yeah, that's true. E: So, unless you are building a headset that broadcast to the cloud, I don't think you are at risk. I: I mean, quite a few of those that are out there right now is connected through blue tooth and stuff like that E: So, bluetooth, can be hijacked, but the minute it's hijacked you are notified because bluetooth again by it's limitation. The headset can only connect to one device, so the minute your device becomes inactive it's potentially been hijacked. But you would have to be around some kind of a Jedi within 10 meters of it in order for this occur. And they really desperately want your brainwaves, and unless he was also a neuroscientist that would be entirely useless to him.

16:00 I: Okay. E: Plus it's encrypted data, so if it was hijacked in the middle, it would make absolutely no sense because it's proprietary data. And most people have proprietary data, very few people are actually

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streaming, I think the [RIVAL COMPANY] is the only one that streams raw EEG data and it is then processed on the computer. I: Yeah, I actually haven't looked into how the different devices actually do that. But that might be interesting to look at. E: Well they are all pretty much the same, isn't it. There is nothing particularly different in any of them. I: Yeah, that's kind of what come to the same conclusion. E: It more comes down to the sensors and the positions of the sensors, and what they wish to do.

16:44 I: So, one thing that is often raised as a concern is stuff like side effects. So for EEG devices E: Side effects? I: Yeah I mean, the thing is the researcher are very bad at combining things that are purely monitoring and devices that are also manipulating. And puts it all into one category so there is a bit of a miss match here. E: Yeah, which is insane because it's completely different technologies. It's like putting a heart rate monitoring and a pacemaker into the same category because they got both to do with the heart. I: Yeah, so one thing I am thinking of side effects could maybe be stuff like skin irritation and stuff like that. Is that something that you think about?

17:38 E: Okay no, so you're right so there are, so traditionally we had. Everyone used to use metal electrodes. But the problem with protruding metal electrodes is that they leave marks on your head, and they can be unsanitary if they are used between multiple people. So, we realised that we had to make them more comfortable and more functional and easier to wipe clean. So we used a conductor fabric instead. So that helps with the hygiene, we also use bio premated bacterial headband. Which helps kind of reduce that as well, so no these are genuinely actual concerns, and I tell you, there is one other concern.

18:12 And it's one I hadn't come across until I experienced it. And that was making, sensor inadequacy right. So I have had thousands of thousands of people on my system, and there was this one guy. Who came, he couldn't do it very well, and then three days later I was told by security that there is a guy who has been standing there watching me every day, 8 hours a day. And he didn't do anything else, and I realised it was the same guy. So I went up to him, and I said, what is wrong? And he said, is there something wrong with my brain? I said, what do you mean? He said, well, how come everybody else could do it, but I couldn't do it? Does that mean that there is something wrong with my brain? So I took him back to the stand, and I said, well actually no, it just means that you haven't understood the control mechanism of your brain. That is all, so I showed him, I put him on the system and I went through some exercises with him that raised his focus. Then I went through some exercises that raised his calm, and I said, look the problem is, that you are putting so much pressure on yourself. But the thing is, had I not known, the moral of the point is, had I not known that this had effected him so badly, I wouldn't have been able to fix it. And I would have had somebody going away feeling that they were somehow inadequate.

19:22 But that is not nice, so, I guess the one thing is explaining to people that look. It's a cycle, it's like I always use the example of sudoku. The first time you try to play sudoku, it looks like black magic. It's like how the fuck are these people pulling numbers out of thin air and just populating? There is only 4 numbers to start. The thing is, once you have done it, you get to a certain point, you play every day and within 3 months you are as good as those people filling out the intermediate level at lightning speed. But if you expected yourself to do that at your first attempt. You would be foolish, or you went to a gym and you said I am going to curl a 100 kilos, you bloody wont. But if you then felt that you were somehow an inadequate human being.

20:11 So it's really weird our expectations and everything else from our brain is very different. And I think that is a concern for me.

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20:20 I: Why do you think that is the case? E: Because of the amount of nonsense that is spewed about the brain. You know, being told for example that the brain is not trainable, so then if you feel you can't do something, then you think well I can't do it, I can't do it. Because you don't think about it as learning in a traditional sense. You don't think I can learn this like I can learn a skill. You think, this is something that is hard coded and hard wired, and it's inadequate. No wonder I have been like this my whole life. But then you have to show them that, no, just like anything, a little bit of training and you will get far.

20:57 E: So one, second. [phone call disturbs and interviewee tells someone to handle it]. Yeah, sorry go on. I: Yeah, that actually ties very nicely into my next question. If BCIs becomes something as of household items like laptops. Do you think there is a risk of having an A and a B team? Where some will be very good as using them, while some might not, or some might not even be able to?

21:28 I: Do you live in the same world I do? E: I would assume so? I: So if people are better than everyone, everyone else at different things. Why am I not an Olympic footballer or an Olympic boxer? Because I am not, so there will always be people that are going to be better than others. But the great thing is, this becomes an equalizer, where for example if you are privileged, your life experiences will train your brain in a certain way. If you are given the right motivation, the right love, the right attention, the right lessons, you will develop in a different way, where as someone who doesn't have that will develop in a different way. And for them it will be much harder because they are much tougher, they rely much more on instinct than thought. And the others will rely much more on thought and rationality than instinct. So, you know they are both going to be good at certain things, in a fight I am pretty sure that the guy from the street will win, but you never know. So, it just comes down to there will always be some people. I don't think there will ever be an A and a B team, because in the real world, it isn't like that. It's like A to Z and then infinite amount of numbers. You know you got the 1% down to the 99% type of people, and everything in between. So, but I see the potential for this.

22:40 And I actually may be almost contradicting myself somewhat, is that I believe that most humans in terms of this type of control, have the same potential. Because it is not academic, and it's something that can be learned. And because the brain is beautiful, and it changes and it amends itself and it fixes itself, and it grows in the right places if you provide the right stimulus. I think that, it can be a great equalizer because emotion is something that you can see across the border of wealth, across the border of academic intelligence. And you see this whole spectrum in every walk of life. So it's not something that is restricted to a class or a type of person.

23:21 You know I always use the example, I say smart people commit suicide more often than stupid people. Because stupid people tend to have been through more shit in life to realise that there is a bigger picture. The academic intellectualizes it as if there is no fucking point, what is the hell is the point. I've done this, I have destroyed this and I have done that. The other guy thinks right, I am going at the pub, I am going to get pissed and by tomorrow morning I'll have forgotten about it.

23:43 You know so, I don't know. I don't know if that answers your question, but that is my thinking around it.

23:49 I: Tying into that, do you think there is anything we can do to maybe, make it more accessible. E: Schools, yes. The educational system needs to get involved. Because it starts early, and the earlier you can train the children to deal with life, the better. The earlier you start to develop their brain, it's like anything else, if you teach a 4 year old a new language and get them to start at that age versus a 14 year old there is

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a completely different cycle of learning. So I think with EEG, the kind of safe age is 8+, because at that point, you have had most of the development of the prefrontal cortex anyway, and it's kind of all settled.

24:28 And then from that point onward, they are pretty much ready to be trained. Because that is actually the point at which they are in the point of school where they become conscious of their surroundings and their environment and their social environment, and their social status amongst their peers. And this is when it's important to realise oh, well when I am in charge of my brain, I don't really give a shit about all of this stuff, and you move on. Can you imagine how much of an effect, it would have on crime, gang culture. Gangs are all about weak minds, it's a few strong men leading the weak, emotionally. You train that out of people, you solve problems of anti-terrorism, you solve problems of crime, knife crime.

25:12 You know one of the most successful, I guess projects that we have had going on literally since the day we started, is with the prison service. We work with private prisons as well [PRISON NAME] and in [PRISON NAME]. And they use our system as part of a program called [PROGRAM NAME]. And they use our technology to show at first, how weak their emotional control is. So we actually build a game, a movie, called the [GAME NAME], it's 24 minutes long, and you are tested with your patience and your aggression and we deliberately try to make you angry but the minute you get angry your character on screen gets into a fight, and then he gets kicked out, and then it gets killed. So the only way to complete the film, is to train yourself to become less responsive to deliberate aggression. And the results have been amazing.

26:06 So, much so, that [PRISON NAME], which is a private prison with [COMPANY NAME], has 20 of our stations setup, for their guys to basically train and play games with their mind. So that it encourages them to become more in control.

26:21 I: Interesting. Yeah, so when you are developing BCIs what do you do, to try and make sure that what changes you might make, what software you might create is something that is actually desired by your costumers and society as a general?

26:50 E: Well it's always hard to please everyone all the time. So, our objective was I guess a little bit simpler. It is, keep it cheap, so accessible, make it affordable, make it customizable, so that way people don't need to buy different headsets. So our headset is actually a kit, so you can put it in a cap, you can put it in VR, you can put it in a band, you can put it in your own head wear. So the point of that was full customizability. And then the last thing was costumer experience. Just make it easy to use, make it intuitive. Now that is hard to do, with a technology that people are naturally sceptical about. So, I guess the things that we do, are those really. Think about the costumer experience, think about really what they want, but at the end of the day. You are always going to have people want different things, but I am quite involved with my customer base personally. Like we have just put a new website out.

27:45 And I took feedback actually not from anyone in the industry, I took it from my costumers as well. Is this better, is this a better experience for you, like is there anything else you want me to add. And everything that we have had come back, that's reasonable, get's implemented. Not just in our website, but in our software. But that's the point, what's the point in fighting them and giving them something that they don't want. If you got the luxury of having development. Bloody change it.

28:13 I: Is there any way, where you might draw the line though? Where you say. E: Yeah, when they are wrong. If they are wrong, we are just like "No mate, you are wrong." or if it's about personal preference. Like we have had a few people say look I really don't like the colour black, but it's like yeah but you hug trees and I don't really like wearing flip flops to meetings, but hey, we are all different right. So that is a personal opinion, whereas when someone came back and said actually why don't you put your best selling

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apps first. And why don't you put recommended features and you know, you didn't have a telephone number on there, that would be really useful. So we did all of that, where it was actually useful.

28:49 And when it came to the software, we had people saying look [NAME], you know we really want to add a marker in, or can I have a second headset connected, and can your player allow me to record. And actually every thing, every piece of software that we've build, has been something that somebody has asked for.

29:04 But it's like I said, you have to be selective, because otherwise you spend all your time doing that, and you don't actually sell anything. But I think, it gives you, if you have that as a starting point, you end up with a portfolio of products that has potential to [INAUDIBLE].

29:17 I: Yeah, so another thing that is typical in the research setting, is the talk about human enhancement. And that's something where people are worried, about how that will change humans and whether we will still be humans.

E: You answer the question, in your question. So you said human enhancement, how can human enhancement ever be bad? Unless it is done in an immoral way, then it's different. Or if you are trying to mess with nature, or you are doing it in a way that you don't know. But with EEG, because it's a monitoring device, all it's doing is giving you access and saying: See if you can change it. And make yourself better at controlling it. So, I don't see.

30:11 I: What if you combine the EEG technology with something additional like bionic arms, or robot control. Is that something that would change the way we look at enhancement and how?

30:29 E: No, but even that is really cool, because, I guess unless you wiring into the brain which I know they have been doing, and I am not naturally a big fan of. If you are going to allow people to do it in non-invasive methods, then why not? But again this comes down to the use of the EEG. So, you have now changed the use, you have gone from kind of measurement and training, to control.

30:49 Now control is a very different thing, and for control to occur, the technology is not there yet. It's getting there, but it's not there yet. And I don't even compete in that arena, because I am specifically pre-frontal EEG. So I am interested in emotion, I am not interested in whether you want to go left, right, up, down or circle so. Where as other headsets like [COMPETING EEG] they train you to use thought processes to control motor movements. So for example you still can't think left and go left, you can't think clench my fist and clench my fist. Unless you link it to the nerves and you make it that way. So it's not anywhere near where it needs to be for that. And if it does get to that stage with some kind of a helmet, brilliant, it's better than putting some chip in someone's brain.

31:40 And I don't believe in mixing organic and non-organic matter in that way. So I am not a huge fan of any form of chip or anything that goes inside the body or medication and stuff like that. You know it may give you better monitoring, it may make people live a couple of months longer, but I'd rather die.

31:55 So, everyone's different I guess, so there is always going to be people who are going to be comfortable with it and there are going to be those that are going to be uncomfortable. See I don't even like facebook, so, I am slightly different to the one billion people who do love it so.

32:12 I: Okay, so in research and in the medical field there is a big need for getting informed consent, especially when employing treatment and stuff like that. Is that something you think about as well?

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32:32 E: No, because most of my stuff is entertainment or if it is training, your consent was you willing to be putting the thing on your head. But because we don't do it in a lab or a hospital or a controlled environment it's all about doing it yourself, and where it is done in a controlled environment or in a lab or used in that way, by a psychotherapist. Then we expect the expert to administer their own controls.

32:54 I: Okay, so. E: So it's the deliverer of the training, who is responsible and if that happens to be you that's on you. And if it happens to be your therapist it's on your therapist.

33:09 Because they would all have been familiar with EEG, it's just another way of doing it, that's all.

33:15 I: Okay, so a lot of these topics basically at least on some way tie into the fact that there is policy gaps and legal concerns when a new technology is introduced. Is that something you think about as well, and if so.

33:35 E: I think about it a lot when it comes to neurostimulation. I think it 100% has to be a controlled industry. You do not want people zapping themselves at home. That is scary, because product malfunction, amplitudes change, resistors burn out, you do not want to be pumping electricity into somebody's brain because we do not know how the brain will cope with that.

34:01 At all. Think of it from a real world example right. So, after the introduction of satnavs, people have slowly slowly slowly stopped picking up landmarks visually. So you can take the same route 8 times, and the one time your bloody satnavs dying, you haven't got a freaking clue where to go.

34:19 Which is insane, because we never been like that. I mean we were once, people who could use stars to navigate, now we can't use the pub because we can't remember what the bloody pub was called. And this is what satnav has done, so if we know that when the cab driver learns knowledge, that part of his brain increases, surely by taking away the need for knowledge, knowing the brain's organ, the way that the organ works. And the way that it preserves itself and uses itself. It doesn't keep hold of stuff it doesn't need anymore. It's why you forget the number of a girl the month after you dump her, but for the time you are with her, you know it off the top of your tongue.

34:52 It's just the way our brains work. We have to respect that. But then the danger is, if you start doing this thing, where people becomes reliant on this technology. Now that doesn't make the technology evil. It just means that it must be controlled. So for somebody who is a severe depressive, he is not at a point where he can be trained, because he is not stable yet emotionally.

35:12 If you could use that technology, in a controlled environment, to reduce activity in the right, and to increase it in the left side, then you have automatically shifted that person in an instance. Now during that phase, that person is more susceptible and more comfortable with training and developing. Until then, rational is pointless, so there are environments and settings in which it is incredibly valuable, however from a consumer perspective, it is equally if not more so, dangerous.

35:47 Because we just don't know it's long term effects. It's not a well known technology, and it doesn't have the best history. I: So, you worry about it when it comes to manipulating E: Yeah, but not just within my sector, I mean in any sector where it comes to manipulating the human mind or the human body in a way that it's unnatural, I think has a risk. Especially when the body is trainable.

36:15 I: So, what then about the monitoring, is there any concerns there, regarding policy gaps or legal concerns? E: No, because, I don't understand where the risk potentially lies. I think regulation could be something along the lines of, you are not allowed to conceal it. So for example you go and you wear a cap



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and all of a sudden you don't realise but now your brain has been monitored without your knowledge. To me, that is wrong. Not because of what they could do with the data. But because it's an invasion of your privacy, so that to me comes under more kind of human privacy and natural law, rather than a specific technology based law. But I think it has to come under the same category.

37:05 So, you know it is the same as secretly recording somebody is illegal, unless you make it known. The same way secretly recording somebodies brain or somebodies heart, or anything along those lines, should be illegal because they haven't consented to you looking inside them. I: Yeah, so basically you feel like most of it is something we are already discussing, or is covered by how we treat other technologies?

37:29 E: Correct, I don't think there is anything specific, but with neurostimulation it is different because there are very few technologies, and there were some technologies that were left unregulated. So for example, isochronic, and binaural beat, and light and sound systems that essentially do the same thing. They manipulate your brain into a particularly frequency in order to help you relax, or to help you sleep or whatever. And they went on for a long time, and they are dangerous in their sense.

38:02 Because for certain minds, you can't cope with the fluctuation. It becomes overwhelming, including myself, the first time I used one of the systems, I jumped straight into one of the advanced sessions, and after like 18 minutes I just felt like, okay, I was gonna puke and everything at the same time, it was so horrible.

38:22 But then I understood what it was for, but I still found that I didn't want to use it, because I didn't like, the concept behind it. Regardless of whether it worked or not. You know, heroine works as well, if you really want to get out of your mind, I don't recommend it. So you know there are people that are trying to replace drugs, and I think, if you are trying to do that, you are always going to have a bad, a bad beginning and a bad ending with any technology.

38:49 I: That really sort of, ties this all together at the end, before we end this, are there anything, any concerns your users might have raised, or something you stumbled upon, that we haven't touched upon already, or something you feel like should be empathised more?

39:12 E: I don't know if there is anything specific in that way, but I think that, one of the things, that my industry needs to do better for the consumer, is to hand hold them better, through the technology and through technologies like this. So, what we intend to do, is we create the technology and we just expect them to understand it, because we understand it. The real problem is the difference is we have been developing it for years, they haven't. So you kind of, when you are talking about it, you almost feel like you are repeating yourself for the 9th million time, but for them it is still the first time.

39:46 So what happens is they buy the technology, and they don't know what to do with it. Like imagine this fitbit with no app, or just an app, that allow you to do one thing. It didn't monitor your steps, it didn't give you this information, which is 99% of the time pointless shit, but it's there. And you actually feel good, and it gives you something to go up against, and it gives you targets and things like that.

40:11 And I think that is where, we have not done so well. In terms of understanding the consumers lack of knowledge about it. And I think that is the issue with it, and the fact that this still requires multiple software applications and the fact that it is a device that needs to be paired by bluetooth, which automatically means, the less techsavvy are going to be a pain in the ass costumer.

40:33 So you got to be prepared for that as well. So I don't know if I've had anything else like that, but nobody has really given any, I mean I have had some amazing feedback from people. Like, one of the things

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I think the most exciting thing, the greatest thing about having this business is, because I come from a therapy background, when someone writes to me and says. You know I have never spoken to you before but I have been using this for this long and it's had this profound effect effect. And you just think, you know, I feel good. Well, that is kind of what you did it for in the first place. But it kinda also would be nice to get filthy rich at the same time.

41:03 You know, there is nothing wrong with mixed ambition, as long as they don't collide in any way, I think it is alright.

I: Okay, yeah, that's basically it. So I just want to say thank you for participating.

## 8.2.2 Consumer stakeholder 2

I: Interviewee

E: Employee

I: Before we really get into the questions, could you introduce yourself in a couple of sentences? What you do at the company and so forth?

E: Sure, my name is [NAME] I am the chief scientist at [COMPANY NAME]. My background is neuroscience research. I was a cortical physiology researcher before in universities before I became a publisher with the nature publishing group in frontiers of neuroscience. Now I run the research team and the research partnerships at [COMPANY NAME] and we make the [PRODUCT NAME] EEG BCI headband.

00:56 I: Yeah, extending on that, so what exactly does [COMPANY NAME] do? You mentioned you're the creator of the [PRODUCT NAME] interface. E: Yeah, so we make a sparse EEG, research and commercial BCI wearable, that runs on four channels. It's used primarily to teach meditation through neuro feedback. So it's an assistive neuro feedback device. I: So yeah, you already mentioned mediation, so that is one of the things you hope people will use your BCI for, is there anything else that you're hoping or expecting that people will use the BCI for?

01:53 E: You know I think there is always an interest in the wearables community, that whether it's BCI or other things, that we will be able to develop health interventions or particular conditions or diseases that have significant [indulgetarious] effect on the population at large. And the possibility of developing a behavioural or a brain bio marker for disease, so we have a lot of research partnerships aimed simply at that. Looking at, what are the kind of things that we can detect with brain signals. Healthy and unhealthy individuals and can these be. Can we get enough information from these things, to make a meaningful biomarker for say mental health or anxiety or depression or something to that effect.

02:51 I: Yeah, great. So through history we have sometime seen technology been used in ways that wasn't intended, just look at the internet for example. Is there anything that you fear, or have thought about that maybe could be unintended usage for the BCIs you are making?

03:17 E: Uhm, I mean there is always, you know when it comes to BCI the one that always comes to mind is the lie detector or the brain lie detector. Or the, applications like covert information concealment, and the detection thereof. I certainly have seen the work that has been done by ministries of security and information and agencies like the CIA on this. And they seem to have, they seem to have systems that working on high density EEG, or at least they claim. Can detect the concealment of information. So that is a tough one, because you know. There are ethical concerns around lie detectors and the concealment of information and information, I guess you would call it sanctity and security in the individual.

04:17 It's not a concern for me as it applies to the [PRODUCT NAME], because, you know we are a long way from using sparse EEG for the same thing that we use high density EEG for. And there may be, to my mind some of the barriers to the use of sparse EEG in the same ways that very high density EEG are used, maybe technically insurmountable.

04:47 E: So there may be a signal to noise issue, or you know you can't do source localisation in sparse EEG. There is just not enough information to do it, despite some manufacturers claim that you can, and they make interfaces that make it look like you can. But you simply can't. There is just not enough information in

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the signals a lot of the time to do source localisation or to do some of the things people claim that they do. So I won't name any competitors to us that do that, but I am sure you can have a look around and you'll be able to figure out who they are.

05:26 I: Actually tying very well into that some researchers pointed stuff like misinterpretation and accuracy of data as being an ethical concern, is that something you are trying to deal with as well?

E: So, misinterpretation in the sense of? I: As in users misinterpreting the feedback or the data from your devices, and basically because of the accuracy of the data and how you know might misinterpret something as a truth where it might not be possible to actually do that.

06:09 E: I mean, I think there is a minor concern in the same way there are concerns about the experimentation on first year undergraduate psychology students. That someone's feelings might get hurt because they might get attached to a particular idea about their brain that they related to by the technology. But, that kind of thing works, special care when you are developing the technology and designing the software and the way that it's used by individuals. You know one of the things that you learn is that people get very attached to numbers, related to their brain.

06:52 So if you use our device you learn that. We give you a score, a basic percentage score to score your meditation. And the idea wasn't so much that this was going to particularly help you learn to meditate better, it was just a, a thing that quantified self, some of our users were very into quantified self movement, were asking for it. What we learned was that it wasn't particularly helpful, you know it didn't really reflect anything, in a real basis about brain performance or meditation performance. So we have been gradually walking our users away from numbers, and towards self reflection.

07:42 And this is, you know you have to make the change gradually, you can't make all the numbers all go away all of a sudden because people get upset. So what we have been doing is inserting more information and more context around the learning of meditation. So that as the numbers disappear, and they don't completely disappear, they just, they go onto different screens and they are a little more hidden until we can gradually get rid of them.

08:06 I: Okay, very interesting approach to actually dealing with that, and especially since I guess, sort of the box has already been open and people have seen the numbers so now it's, you know taking that away, can be a difficult task.

08:26 E: Yeah you can't just suddenly change fundamental aspects of how your experience works without upsetting a lot of people who have gotten used to using it in a certain way. So, you know the numbers aren't hurting anyone, they are just, they just kind of an ego attachment I think that people have to their performance. But they are not creating any real risk, in my mind for the users. So in that sense, you know, I think there is a tremendous interest in the brain across really, you know, kind of all of society because the brain is this hot topic in research and because it produces really cool graphics. And, because people are interested in their own brains and they are interested in the brains of their family members and they are interested in how they perform.

09:17 There is a lot more attachment to these kind of things and a lot more interest in these kind of things than maybe to some other kinds of science based technologies. Or research based technologies. So you know I supposed there is a bit of a risk of misinformation, I think ethically it is, manufactures of consumer BCIs should concern themselves what they are telling their consumers and their users. And they should try to impart as much information as is reasonable.

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09:58 Given the varied backgrounds and the diverse backgrounds of their user base, so misrepresentation is something that they should try and avoid. That being said, you know, there is a careful balance between the level of accuracy that a neuroscientist would desire and the level of accuracy of information that a lay person would desire. And you can quickly overwhelm a lay person with neuroscientist level of information.

10:30 I: Good points, so you already sort of mentioned it, but there seems to be a lot of public awareness and interest in neuroscience and BCIs. How do you see all that and are you concerned about how you are portrayed in media?.

10:59 E: You know I am not, it's a double edged sword, because there is so much interest the industry sort of stands out which I think is in some respect a positive thing. You know I think it is a good thing for people to take an interest in brain health. To take an interest in, I think it's a real opportunity to teach people a little bit of neuroscience and you know where ever I go I try to make sure that I give some context and history around the background of brain stimulation and EEG and the future of brain computer interfaces and how while we have some understanding of the brain now that we didn't have a hundred years ago, we are still in the early stages.

11:40 Of really understanding how the brain works. And because, it's a public policy issue as well right. Like brain health is a significant issue for ministries of health, for public health agencies. I think there is a real opportunity given the level of interest. I think, you know, brain computer interfaces are still not in the main stream. They are still in the early adopters stage and they probably will be for another 5 years. Because we don't have, we don't have a wide spread super compelling use case for everyone to have one.

12:25 You know, if you are interested in meditation, you want one that is great. If you are kind of interested in neurogaming or controlling a game with direct brain interface that is, you know, a small area that's kind of a niche area. The big problem I guess supposing consumer EEG is that we, we have done a lot of user experience work to develop a means of having a naive user put an EEG system on their head and figure out how to get the right connection and the right signal. And how to use it and what it means, and what the signals mean, and then how to control it a little bit.

13:12 That is a very different approach to brain computer interfaces than the laboratory based one, like if you were for example in [Bosema Lamps] lab at [EDPFL] and somebody is rigging you up to control an electric wheel chair with a 128 channel system or something to that effect. You know there is a lot of individual hand holding walking through the, what to expect and training the user over hours or days. To learn how to interface the system and how to control it. The challenge in the consumer space is that, we got a few minutes to help the user get some idea how this brain computer interface works and how they are supposed to use it.

14:07 Before they get frustrated, so you have to make something happen very quickly and that requires tremendous amount of user experience research and testing, and it limits to some extent the depths to which you can go initially. You know, people talks about degrees of freedom of control with brain computer interfaces. And the question almost always comes back to can I control something with my mind.

14:39 And you know, the way it's talked about in the media and I think that everyone is a little bit guilty of this in the research space, and to some extent the consumer space, although I don't think we are. There is definitely a promise that hey, you know, mind control is just around the corner.

15:08 And that's probably not ever true, like it may never be the case that there is a better brain computer interface than, you know, that something that more degrees of freedom or more degrees of control than a

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users hand. So if you are talking about [paraphilics], then it's a great technology that has real potential to change someones life. But that's like 50 thousand people a year globally, so it's very small number. So when it comes to, you know, brain computer interfaces as a control device, I think that people will always be disappointed.

15:43 I think that, that promise of control BCI, or what Thorsten Sanders calls active BCI is probably never going to be at a point where the science fiction has sort of told the story that it's going. That being said, I think, the foot side to that is that the conversation ignores a little bit the potential of BCI of passive and reactive BCI in potentially controlling augmented reality.

16:24 In you know changing the frequencies of notifications in or the number of distractions in a work place environment if you are wearing a sparse brain computer interface. You know a non-invasive one that doesn't bother you. Something that can detect whether you are concentrating or that can detect whether you are really not, or you are distracted or you are in a particularly kind of cognitive state, that software should adjust to.

16:54 To help you work better, or you know another example is machine learning to develop classifiers for brain health and then monitoring brain health throughout the life course. So, we are still not at a point where everyone can get an MRI every year, but you know, we are not that far from where everyone can get an EEG every year.

17:24 And being able to detect biomarkers of brain disease with EEG, or biomarkers of brain aging or cognitive decline with EEG, and that creates the possibility of early intervention for brain disease or of you know maintaining better brain health.

17:41 I: Yeah, good points. So another concern that researchers discuss a lot is a concern that BCI might change our concept of identity and who we are. Is that something you talk about as well?

18:06 E: Not really. I think that, you know, my take on that and it could be a naive one, that's sort of a, going as far as transhumanism and you know invasive BCIs and really really effective BCIs that allow us to interface with machines, in a really effective and engaging way. That does change, you know that changes our concept of who we are, changes our concepts of ego.

18:41 That it sort of extends the human cognition beyond the biological. I just don't think that we are. I mean, I just came back from the society for neuroscience and we're. We are sure that we can implant electrodes in individuals now, even chronically to some extent, but we still haven't solved some very basic problems that may not have a solution.

19:12 When it comes to invasive BCI, chronically implanted BCI. You know, we still don't have electrodes that you can put inside an animal much less a human for many months, that don't end up having, creating all kinds of problems. Like immunology problems, and you know, risk of infections and things like that.

19:35 So non-invasive BCI has, you know, probably a couple of orders of magnitude lower resolution when it comes to determine cognitive states and determine, you know, if you are looking for an n-gram or something. Than an invasive or an implanted BCI, and the implanted BCIs are still probably decades I would say, from wide spread adoption. So sure, you know, if you are looking decades out, there may be some ethical issues there, related to identity, related to transhumanism, I feel like some of those have been addressed a lot by the transhumanist writers.

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20:14 And it's still in the realm of science fiction, so you know a lot the stuff about that is. We can't even tell when it's going to be here. I think we are still decades away, from that kind of BCI.

20:32 And I certainly think that, while there is, sure there are things that non-invasive BCIs can do, and some of them are powerful and potentially helpful, they don't cross the boundaries with the implanted BCIs or with the kind of things that we see in science fiction the [inaudible] kinds of BCI.

20:59 I: Okay, yeah, so yeah obviously, as I mentioned before, privacy is something that a lot of people are concerned about. Is that something that your users has raised as well with you?

21:15 E: You know, it's been brought up by a few of our users, but I think we still have a lot of early adopters. Who are maybe a little bit less [resident] to share their information. The one of the ways we have worked around this. We have anticipated as a challenge, so we created something called the [NAME OF INITIATIVE], which is a non-profit entity, with a bunch of members of the industry. From the brain computer interface industry, specifically consumer. And we try to setup best practices, so we have some philosophers from the university of [CITY] who are [INAUDIBLE], you know, they concern themselves with ethical concerns around privacy among others.

22:02 The other thing that we do, is participant centric consent, based on the safe bionetworks model, where we ensure that users know that they own their data. That they can remove it from our servers at any time. You know we do, use any data that is stored on our servers, to try and improve their experience, and we owe that to them. So there are some longitudinal brain models that benefit from data storage and from cloud data storage of brain signal.

22:38 But we make sure that users know through our end user license agreement and through our research program signup that they can remove their data at any time and that it belongs to them. So if you engage actively, or pro-actively in ensuring that users feel comfortable about the privacy and ownership of their own data. That problem to a certain extend goes away.

23:08 E: And of course the other thing is you can't just go on and share that data with everyone. You have to be responsible about it, so we have sort of two layers of data sharing. One is that the end users share their data with us and we improve their experience on that basis, and then we ask our users to participate in our own research program which enables university based researchers under the [perview] of an university ethics panel to look at the data and to try and derive new insights from large scale, the identified, brain data, population data.

23:51 That has actually produced a couple of papers already, so there is a paper coming out in e-neuro in about three weeks on a sample of 6000 users and what it told us about age related mark changes in the brain. I: hm interesting. E: So yeah, that's one of the opportunities that large scale BCI adoption presents is that you can dig into much much larger populations so. Even though you got a sparser EEG system than the higher density ones in laboratories your signal to noise problem, your signal to noise ratio is still very good because you have this, the population of users is enormous that you can actually get, you can find things that no one else can see.

24:42 So, that's, from my perspective as a neuroscientist that's the most interesting part of my job, is that we have the potential to find biomarkers of brain health and disease. We have the potential to find new insights in neuroscience that no one else can find because of the sheer size of the database, of the users that we have. You know we can collect, i.e. a university research lab or a hospital research lab can collect

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maybe two or three sessions of brain data a day in EEG. We can collect thousands, tens of thousands. And we can ask other questions of our users to see if we, if we can derive any other insights as well.

25:30 I: Yeah, good. One thing that has been raised is, relating to a concern about security. But not so much in a privacy sense, more of a could you do physical harm or could you break the products by breaking the security. Is that something you think about as well?

E: Sorry say again? I: So, one of the things that, that researchers has sort of related to is, sort the same hacking that we saw with some pacemakers where they hacked the pacemaker and obviously there is some issues there and some concerns regarding patient security and stuff like that. And they related BCIs to that, that might be an issue we need to think about in the future.

26:41 E: Sure, for a deep brain stimulator that absolutely an issue, that has real health implications. For a non-invasive feedback based BCI it's a very different question. So, I think that if you are looking at neurostimulators, parameters has to be very carefully controlled and that is why those things are regulated. And that is why the trans-cranial director [INAUDIBLE] will eventually all be regulated by whether it's the FDA or the health ministries of whatever country. You know, they did a crackdown on TDCS, and they just haven't written the regulation yet. But neurostimulation is a very different thing than a passive bio feedback approach. So while I think that the information security and integrity of whether it's an invasive brain stimulator or even something that just a warn stimulation device. Like an external non-invasive stimulator. That's a concern, you know, what really could you do if you hack an EEG system. What really could you do if you hack an [INAUDIBLE] system? The worst thing you can do is compromise the data quality. Or change the feedback parameters, but bio feedback and neurofeedback are not so powerful, that they can harm people.

28:19 You know, they are subtle and small effects that cumulatively over time can help someone to change a behaviour or to change a certain aspect of cognition. But it's not something that can spiral out of control realistically because of homeostasis in the brain. So I think that, that concern about hacking and security applies to stimulators but not to sensors, to the same degree.

28:55 Let me think about that one more thing. You know, I think that there is a bit of a trade off in the sense that if you are making a stimulator or if you are making something where, you know, hacking and harm to the user are serious concerns. Then you make a very different system than the kind of system we made. Our system is designed to be open so that people can develop more tools and more apps, and they can use it in research and they can get access to the raw data.

29:21 And we did that very intentionally because we wanted lots of people to use it for lots of different applications, and push and see where it went and. So if we were building something for high security and we didn't want anyone to be able to break into it. We would design it differently. Yeah, that's basically it.

29:42 I: Yeah, makes perfect sense. Yeah so, another thing that has been raised as a concern is stuff like side effects and just to make a bit of an example for stuff like your EEG it could be something like skin irritation. Is that something you think about?

30:19 E: Yeah, I mean, we have done a fair bit of research on it ourselves, skin irritation from the worn device. You know, the material design and selection, and to some extend that is controlled by consumer and health standards. You know, there are certain materials you can use and you can't use. There are always going to be some, challenges and trade-offs between quality of signal coming from the signals that you chose and the, the risk of say an allergic reaction or a skin reaction or something to that effect. So you



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have to balance that when you are designing your materials and when you are choosing what to use as an electrode material or as a skin interface material.

31:06 And it can be a trade-off, you know, this gets into material science and bio impedance and things like that. And you have to look carefully at to what you are trying to achieve and what's the, you know, what is the risk associated with this material versus that material. But that I think is not so much as an ethical issue as a design challenge, you know it's. You get user feedback, in the consumer space you get user feedback very quickly on if there is a problem. And then you change your manufacturing practices or you change your software of whatever that you need to change. Very quickly and you can improve that in a single product cycle.

31:53 And that generally addresses the problem. I: Maybe not so much pure physical side effect, but what about the side effect of having done a meditation session. Is there any side effects that might come out of that?

E: I mean the literature on meditation is pretty clear, it has very few side effects and very few risks. There are certain contrary indications or things where it is known to not work for, so that gets into medical device regulation and claims regulation. You know, what are you allowed to say that your technology or your medicine or your whatever it is does. On the basis of the research that you have done.

32:47 So, meditation is not a regulated term but you can't go out and say, you are not allowed to go out and say "our device will help to treat you your depression" because that's, you know, that's a medical diagnosis, or [INAUDIBLE] diagnosis and you can't just go and make claims about it. When you have to go run a clinical trial and get it approved by the FDA and then it takes years. So you know there are no known side effects to meditation, and we are. The claims that we are making are really just, with our technology are just that we, we will help you learn how to meditate and help you to build a habit and build motivation to do it.

33:35 Yeah, we are very very careful about what kind of claims we make about health benefits. And we have to be, and so does everyone in the industry because those are. You know, these are regulated practices.

33:56 I: Yeah, okay. So one of the things that is being talked about is, what might happen if BCIs becomes something that everyone has in their house. You know, as in most western cultures people have adopted laptops and TVs and stuff like that. Do you see any risk that there might be an creation of an A and a B team where the A team knows exactly how a BCI works and how to operate and then you have B team that doesn't?

34:34 E: Sure? I mean, that's a possibility. I don't know that that's. You know, the cost of BCIs is coming down so fast, that, you know, it will match the cost of smart phones and cell phones. So I think that the divide will not be along the lines of economic opportunity, so much as technical expertise. It's hard to know what, you know, we still don't have an easy to use BCI beyond what [PRODUCTNAME] does and it's, or you know, what some of the other players in the space do. In terms of teaching meditation. If you want to really get the most out of a BCI, if you want to push it and you want to develop new applications or you want to do those kind of things. You are going to have to dig into bio signals research. You are going to have try and understand it. So that in a sense is the challenge that, we have tried to address by partnering with [ORGANISATION] to help them. And they have actually developed some courses on you know, how to interpret a BCI.

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35:45 Do you have an android phone? I: I do. E: You should try downloading [APP NAME]. I don't know if you have a [PRODUCT NAME] but if you get your hands on one. It's worth trying [APP NAME]. It teaches BCI from sort of the ground up. You know, what is an EEG brain computer interface, and how does it work, and what does the signals mean and etc.

36:08 I: Okay, so you have actually taken some active steps and trying to bridge this gap?

E: To educate yeah. So I think the barrier is in like technical proficiency and you know, who adopts it and who gets into it more so than economic opportunity. You know, I mean, you can pick up a [COMPANY NAME] now for 30 bucks in china. You know, they are not very good, but they are a brain computer interface or a very rudimentary one.

36:34 So, the challenge then for the BCI community is to, is to educate new users and engineers on how to use the devices. One of the biggest challenges for us was that, because our device is cool, all the hackathons wanted to use it, all over the world. So we kept getting these requests, can we borrow 10 [PRODUCTNAME] can we borrow 20 [PRODUCTNAME]. So we started doing that, and every single time, at the hackathon, someone would produce some stupid thing that didn't work.

37:12 And so, no one was making good apps at hackathons, and the reason why was, if you have a 48 hour window to make an app, and you are starting from scratch on brain computer interfaces you are not going to make anything good. So you know, part of the reason we wanted to, part of the reason why we helped the [ORGANISATION] develop this app was, that we wanted this as an educational tool for engineers and for hackers and app developers.

37:41 And then what we realized was this is actually a really good tool for our end users. And it's a free app, and so they can get it and, it's a really good tool for neuroscience education. So universities that we work with are using it to teaching their undergraduate courses about EEG.

37:58 So I think there is still a lot of education to do, I think there is a lot of work to do, but I think we are getting somewhere.

I: Yeah, good. So when you are doing all your developing, obviously you are saying you are getting user feedback, but are there any other things that you do to try and get user feedback and to make sure that the changes you make is something that is actually desired by your users and other stakeholders?

38:39 E: Yeah, I mean we have, you know, we get a lot of feedback from our users, feature request, we get a lot of other kind of things that just sort of, that come in from the community. And when we are developing we do a lot of user testing, so any new feature that goes into the wild we test on, you know, dozens of people in our office. Not just people who work in our office, but we bring in user testing volunteers and we pay them and we have them go through the experience from scratch and try the new feature do some a-b testing.

39:10 So yeah, so there is, in consumer technology you have to. You have to test with users, because otherwise you'll end up releasing something that no one can figure out and that nobody uses.

I: Since you said, you've been in academia and the research life, is that one of the things you think is rudimentary different between the two settings?

E: I think so yeah, I mean you have different goals. In the research lab BCI you got lots of time with your participant, you got, they are, they can't just get frustrated. They can get frustrated and walk out, but they

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frequently don't. But a consumer will, if you make something that is hard to use and didn't test it and that doesn't really work. The consumer will, walk away from it. They will take it back to the store and they will ask for their money back, and then they will write a scathing review on amazon or something.

40:09 So you know, you have an incentive to make something that is much easier to use, and to test it extensively and to make it. And I think this is part of where the criticism comes from, from the academic community about consumer BCIs. That they say, well it's hopelessly simplistic. And well you know, the answer is of course it is, it can't be a 128 channel system. Someone has to be able to take this out of the box, put it on their head and figure out how to use it without your help.

40:38 And you know, it has to be, and it has to cost less than 30.000 dollars, like your EEG system in a lab. And, so it has to, there are a lot of things that are very different about the way that you design for an end user experience than what you do in a research setting.

41:01 I think, there is a lot that we certainly learn from them. I mean everything comes from the BCI research community, from the EEG research community that we do. Or at least when we started, and now we are starting to generate some knowledge of our own. Some of our open minded partners, and we got a lot, we got probably 200 university research partners. Some of our more open minded partners are saying "hey how did you figure this out, can we use this in our lab?", and the answer is yes of course can.

41:32 And so there are lots of cool, there are a lot of cool applications out there. Whether it's taking [PRODUCTNAME] because it's so portable and so low cost, and the battery life is so good, lasts so long. Taking [PRODUCTNAME] into environments where you typically couldn't use EEG, like hiking up mount Everest and doing altitude physiology research or, stopping at monasteries on the way up to Everest and doing meditation research or cognition and meditation research.

42:09 Or taking an EEG system into the emergency room and getting a really quick reading whether it's on the patient or the doctor. Whatever it is. I can send you a couple of videos that some of our collaborators have produced. And you can have a look at the application that they do.

42:28 And some of them are artistic and some of them are research based and some of them are, you know, applied research. So it's an interesting cross section. I: Yeah that is always interesting. E: Yeah, I'll send those to you. The researchers who are really open minded about it and say like, hey this is cool, if this works I can get some great, I can do some EEG where I couldn't do EEG before.

42:52 And they get, they are actually, there are sort of, I think there are two camps in the research community. One is, well this can't possibly work because this only has 4 channels, you know, and it only costs 250 dollars and EEG should cost 30.000 and. Then the other camp is hey this is really cool, I wonder if I can do something that I've never done before because I got this low cost EEG system I can take with me in my pocket anywhere. And record on a smartphone.

43:21 And those, that latter group is actually publishing a lot of papers now, so you know, we are seeing more and more. I get, I have an email, I have a google scholar alert for anything related to [PRODUCTNAME] and about once a week now, a paper pops up that someone has produced, somewhere in the world, you know using [PRODUCTNAME] as an EEG acquisition system.

43:46 Yeah, so that's kind of the, some of the more rewarding ones.

43:55 I: In the research community there is talk about BCIs leading to enhancing the human being and the experience, we talk about the transhumanism group and stuff like that already. But besides that, is there

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anywhere where you might see BCI leading to enhancement and do you see any benefits or concerns with that?

44:27 E: Uhm, sure. You know I think that, the potential definitely exists for enhancement, obviously associated with that there is the question of access and inequality as there is with every new technology. You know, does this augment or reduce inequality in the world, and among people as it relates to you know, whether or not. If only westerners have access to this technology, what does it do for the developing world and what about inequality within a society. Then, I think those are very important questions. I think that, we're still, [INAUDIBLE] away from, from using BCI reliably to augment cognition or to augment healthy individuals, beyond just some of the basic benefits like "hey you can learn how to meditate and that will benefit you".

45:32 So, in terms of enhancement and augmented cognition, there is certainly, there is a, it's not so far away as to be, totally ignorable. There is a great book on this augmented cognition by [fenly markham] [INAUDIBLE] that looks at, you know, what's gonna happen and what are some of the ethical issues. And I recommend, I always recommend that one, but uhm I can't see non-invasive BCIs having a significant effect in the next 10 years. Maybe even in the next 20. You know, the best, probably the 10 or 15 years from now will, we might be looking at a much smaller, much more intuitive version of. What's the Brazilian guy with the exo skeletons suits? I always forget his name.

46:32 I: Aww, what's his name. E: One sec. I'll just look this up. I: Yeah I am drawing a blank as well. E: Uh, it is, Nicoeles, Miguel Nicoeles. I: Ah, yeah. E: Yeah, you know there will be a better version of that. But there might not be. I just don't see non-invasive BCIs being control mechanisms. And I don't see, you know, I don't see them being things that really significantly augment human life, beyond the way that they can do in active or in passive and inactive BCI where, you know, you might get subtle benefits from having a thing that teaches you how to control cognition a little bit better or that responds to, responds to your cognitive state to, to change the way that stimuli or information is presented to you.

47:50 So in that sense yeah, but yeah. I think the cost pressure on the BCI systems from the consumer side, is, is to drive cost down so that, you know, one of the big drivers for us is, how much more can we bring the price of a [PRODUCTNAME] down? So that more people can buy it. So in a sense the capitalist imperative is, like, make this as accessible as possible to as many people as possible so you can make more of them and you can make more money at it. And that is at odds with this inequality concern. You know, and there are already knock off versions of [PRODUCTNAME] in China, that costs less.

48:38 So I think that, the cost pressure will continue to bring these things down and, inequality and accessibility will, while there will always be a concern at the cutting edge of the more expensive technologies. There will be a, there will be a democratisation effect. That's one of the words we like to use, when it comes to BCIs, democratisation, you know, BCIs can come out of the lab now and anyone can, can theoretically have one and they can play with it, and they can learn about their brains and they can use it for whatever application they want. That they can, that it works for.

49:17 I: Okay, yeah, ties a bit into the next one, so in research there is the, because a lot of it is related to medical research, there is a lot about getting informed consent and keeping user autonomy. You already talked a bit about disclosing information about how you keep data, and letting users know that they own the data and stuff like that. But other than that, is informed consent and keeping your users autonomous something you think about?

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50:01 E: Yeah, absolutely. You know, informed consent, you have to do those things. There are [parts and parcel] of doing a good job on informing users on their rights and their, their ownership of their data and their privacy. I think that, you know, I think that those are unavoidable, challenges that. But there is a clear path to how you do them. And the path has been laid out by other dev, medical device and partly by the medical device industry.

50:33 And partly by the consumer technology industry, so there are best practices out there that you can follow, they are fairly clear and concise and about how you communicate with users, about the kind of language that you use. The one that I really like is the participant centric consent of sage bionetworks. They have even created [ecknoografi] around information ownership and privacy that's open source that you can use in your own apps if you want to.

51:02 Yeah, so I, I recommend that you look it up, participant centric consent, and it's on the sage bionetwork site. So they are concerns but you know, there are, in a sense, it's a bit of a solved problem because there are so many different approaches that have been tried in consumer technology and consumer information technology. Wearable technology, and we know what works, and we know what doesn't. And as long as you follow the best practices that have been laid out and sort of guided by ethics researchers and by consumer technology companies, and you avoid the pitfalls of what people have already done wrong and shown you what, you know, how not to do it.

51:46 Then I think that, I think that that's, in many respects an avoidable problem.

51:53 I: Yeah, okay. Yeah so, most of these, or at least some of them are topics that tie into maybe policy gaps and legal concerns, are there any policy gaps that you are concerned about, right now?

52:18 E: Uhm, it's a good question, I think that, there is not a lot that concerns me as far as non-invasive passive or you know, BCI that records information. I have concerns about BCI, about stimulators. I think that there is a regulatory gap on brain stimulation, certainly, you know, we don't know what the, we don't know what the ethicacy and the long term neuro plastic effects of transcranial direct current stimulation or alternating current stimulation are.

52:58 We know that there will in all likelihood be effects, we don't know how significant they will be but, I think that the fact that these things are unregulated and that anyone can release a device is, right now, is certainly a challenge for regulators and the people concerned about brain health.

53:21 I think it will get resolved, but I think that it is not currently resolved. You know, my concern, there is always a balance, there is always a delicate balance, that you don't want to stifle the development of interesting new technologies. But at the same time, people will always push, you know innovators will always push and try to create something that is more powerful or that has a more significant effect or. And so, there has to be a balance between public interest and regulation and innovation. And getting that right is very tricky, that's a question as much for health policy makers as it is for technologists. The most important thing is that everyone, everyone gets together and talks in the right forums.

54:11 So that, so that regulation doesn't overreach, and innovation isn't stifled and that consumers and the public are protected. I: Yeah, is that something you guys are engaged with as well?

54:29 E: Yeah, we talk to the FDA we talk to health [COUNTRY]. You know we, went through the TUB certification and the CE certifications so. We, you know, we're regularly in contact with regulators and making sure that we got, that we are on the right track and you know, if we have a question about what kind of claims we can make or where regulation is going. We will just call them up, they are relatively open,

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they will have a discussion with you, they will tell you what they think and you know if you want to do something new they will give you an idea of where, where regulation may apply, may not apply.

55:11 So in many respects, the regulation, the regulators are becoming more open and more flexible, and they have to because, you know, the pace of the release of new products is, much faster than it used to be.

55:23 I: Okay, but you actually, for you it seems like they are actually getting better at adapting to how you guys are working. E: I think they are yeah, I think they are getting better. You know if you look at the times to approval for new medical devices by the FDA it's gotten shorter. Which is very encouraging.

55:45 I: Good, so yeah, this basically brings me to my last question is, whether there is any concerns that we might not have talked about that you run into with your users, or someone has mentioned to you or, just that you think about yourself might be a concern regarding BCIs?

56:08 E: You know that, yeah, there are a lot of ways I can answer that question. To my mind I think that the, the biggest concern is over promising and under delivering with BCIs. I think that there are others in the space who certainly. You know there are a lot of, it takes very little to release an app for a [COMPETITOR] device and say, hey this can tell, this is a lie detector or hey this is a, you know, this is going to allow you to roll a remote controlled ball down the hallway.

56:40 It's, you know, there is over promising and under delivering in a repeated fashion, by the BCI industry, by the consumer BCI industry. It's probably the biggest risk, because what that does, we are in the hype cycle to some extent, the technology hype cycle, and where we are is up for debate. But I think that, there is certainly, there is over claiming on the part of some participants in the industry, and the risk is that, we end up in sort of an AI winter kind of situation. Where BCI is you know, the thing that never was, and that couldn't deliver on the promises that it made and, and that really dampens enthusiasm for among consumers, among investors, among you know, sort of the whole industry, and killed it for ten years.

57:40 And I hope that, that doesn't happen. You know, I think that, we are, one of the reasons we work with so many researchers, is because we want our technology to be pushed in as many directions as possible. But in a rigorous way, that has, you know the [INAUDIBLE] of peer reviewed researchers to back it up.

58:09 I: Okay, yeah, is there anything you are trying to do, to combat this, this repeated behaviour. I mean of course E: Uhm, we think we can do this through, partly through the center for responsible brain wave technology. You know, I think that we are probably, we probably sell more devices now, I don't know that this is true for sure, but I think that we sell more devices than [COMPETITOR] and [ANOTHER COMPETITOR]. So we seem to get as much or more press than anybody else in the industry because of I think our technology is a, I think our hardware and our software work really well together.

58:51 And I think that we haven't over promised and under delivered to some extent. So, I think that in, in many respects many of the ethical concerns of the industry take a back seat to this risk. This sort of existential risk that, the whole industry gets ruined by the technology not working the way it's supposed to. And making claims that can't be backed up.

59:15 You know, and that, as a leader in the industry, we have the, we have the capacity to, maybe set the tone a little bit. So we try to do this through, like I, you know we talk to a lot of the other members in the industry the, [EMPLOYEE POSITION at COMPETITOR] is now also a neuroscientist and a very good one. So they are more responsible about the claims that they make.

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59:45 Uhm, I think that some of the new players coming along, hopefully will hue to the practices of the leaders in the industry. And I think, we, we have an opportunity to lead by setting the tone and, you know if enough people see what we are doing, and see that it's backed by real peer reviewed science. And use the device and have a positive experience and find that it works.

01:00:16 Or use, you know, consumer BCIs and find that it works. Then that in many respects discourages, new entrances from coming in and claiming ridiculous things and. Because it forces them, you know they won't be listened to, unless they can back it up. So, in a lot of respects I think it's consolidation of standards of evidence in the industry.

01:00:47 E: You know, whereas, whereas you could release a [COMPETITOR] headset and make all kinds of claims about what it could do in the past. Now, if you do that, someone is going to say, can you show me the evidence. Can you show it in papers that people have published with your device. And I think that is a very positive development, certainly in the scientific press and in to some extent in the, you know the, traditional journalist press, whether it's the wall street journal or the New York times or whatever. People talk about you know, when you get a real reporter coming to you they say, can I talk to some scientists that you with and they will do the digging and they will test it and they'll.

01:01:28 And so in that respect it's, in order to get into the traditional press, it's, you have to have something that works and that's backed up. Where the hype gets out of control is in the tech press. So if you read the, if you are reading these tech, these consumer technology websites. They make all kinds of crazy claims about what a device can do, or they take in many respects, they take it at the words of the new company that claims that their tech can do this or that or the other thing.

01:02:07 And they just reprint it, verbatim. And that, that's where you get the garbage kind of communication and the nonsense. So, I think, you know, the peer reviewed literature is sort of the, and the standard around peer reviewed literature is going to become, hopefully the, the barrier to ridiculous claims.

01:02:34 I: Yeah, I mean it seems a bit like you are trying to create a, a community between both BCI users, and BCI developers where, the, the low standard is to have any peer review papers, basically.

01:02:52 E: Yeah, or, either demonstrate, a clear demonstration of efficacy. You know, you have to have. It's not that hard to trick people. As I am sure you have seen. You can put a device on someone and then you can, and if it's for the first time they are wearing it. You say, and you are doing this, and your brain is doing this, and they kind of get a little bamboozled. Like, it's not that hard to trick people in a demo.

01:03:17 But it's hard to trick them, multiple times, and they take the device home and it doesn't quite work the way they want it. So you know, long term user reviews are also a powerful indicator of whether or not a technology works. So you know, amazon reviews are generally a better way of looking at something, rather than some tech reporter trying something for 5 minutes at the consumer electronics show.

01:03:43 E: So there are standards that are coming forth, that you know, will help us distinguish between what works and what doesn't. And some of them are already out there, peer reviewed is one, long term you know, consumer reviews is another. And, I think, scientific credibility is who you are working with and what they are doing with your technology. And what, developers can do, and who the developers are, and what, you know. So there are a variety of, there are a variety of ways we are addressing this.

01:04:21 We are hopeful that this is, you know, that this will protect the industry from the kinds of risks, that I identified.

01:04:33 I: Yeah, good, that's it.

### 8.2.3 Consumer stakeholder 3

I: Interviewer

E: Employee/Employer

0:20 I: I first want you to do, is maybe if you could introduce yourself in a couple of sentences.

E: Yeah, well this is [NAME] from [COMPANY NAME]. I used to be a hardware engineer for at least like 8 years in the past. And now I am doing business [INAUDIBLE], doing like sales, marketing and talking to costumers to figure out what their needs are. And figure out what kind of EEG or ECG [INAUDIBLE] they are looking for.

I: Okay, very interesting. Yeah, and in the same sort of sense, maybe you could explain what [COMPANY NAME] does and what you're trying to do.

E: Sure, so [COMPANY NAME] is trying to be a biosensor solution company, so not only are providing EEG technology but provide like other technology like ECG, blood pressure, we try to provide the biometric that the customers require. Sometimes, you know, people want to dig deeper than a simple EEG, while, they want to see like certain metrics. Maybe like [INAUDIBLE] meditation, of a certain person or expense of a certain person or expense of mental effort of a certain person. So they, we want to be able to like kind of simplify metrics that people can understand. We kind of have all the researchers here, and we also have all the hardware engineers to simplify the signal analysis and the signal processing in the house.

1:49 I: Okay, good, yeah so sort of in line with that, what do you actually hope that your users will use your BCI for?

E: So, in terms of, in the beginning we started with entertainment. We had this company called [COMPANY NAME], they actually created this toy called the [PRODUCT NAME]. So they, in the beginning, they were asking us if, how do we recreate [CONCEPT] in terms of, like in this real world. And we went, why don't we use the attention level. So how much attentive you are, that means how much [CONCEPT] you are applying. And we created this simple demo where you [INAUDIBLE] attention level. And the [PRODUCT] kind of marketed it kind of [CONCEPT], you know, using your mind power to actually control this ball through slopes. So that was kind of the entertainment section, and then we kind of moved also into educational market.



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2:52 Educational markets we are looking at people when they are learning a certain task we want to see how [proficient] you are in this certain task or if you are familiar with that certain task we want to see the mental effort. So we actually look at how much energy, energy or mental effort you are actually [INAUDIBLE] thought problem. And depending on the, if you are exerting too much effort, we actually scale down the problem. So that you can actually get into problems and learn more.

3:20 And in the end, the most simplest thing was probably get into medical, you know people that want to diagnose depression, they want to know when the migraines are coming, they want to know Alzheimer, there is concussion protocols, these are all like survey based and they don't have an objective way to actually diagnose these situations. So they wanted to create objective way of diagnosing these, mental health aspects. So we are working with various hospitals on doing that too. I mean in terms of ECG we also work on like, detecting arrhythmia, trying to help preventative maintenance so that people can start taking data and help them, you know, eventually stay, or like in 5 years later if you keep on doing this you're gonna, you're gonna get a heart attack or something. We can actually provide them with a preventative [INAUDIBLE].

4:15 I: Okay, interesting. Yeah, so, throughout history we have seen that technologies are often used in many ways that wasn't intended. I guess the internet could be used as one example. Is there any such usage for BCI that you might be concerned about?

E: I mean, if it goes, for kind of a mind control, I think I would be kind of a scary aspect. But I mean, what we do, at [COMPANY NAME] is just to simply read peoples mind. I mean, I guess if you go further in and if you can actually read peoples mind in terms of like credit card numbers and all those privacy things. That might be difficult, uh, be interesting but I don't think it's going to go that far. Because you would probably have to embed sensors to actually capture that level. We're just looking at very like, you know, limited patterns being like alpha wave, beta wave, and those don't typically reveal anything like that.

5:15 Creating images from EEG is far out of our current technologies right now is.

I: Okay, yeah, okay. So uhm, in research there is a a lot about misinterpretation of data and the accuracy of the data as one of the things they concern about. Is that something you worry about as well?

E: Yeah, it's very difficult to create, capture that accuracy because everyone, these are all subjectively when you are like staying happy or sad, or when you are like concentrated. These are, we are trying to use very subject surveys to these. So in order to get really really accurate we need to figure out a way to, measure certain [INAUDIBLE] like you know, core strength for example. We did actually look at [critical INAUDIBLE] analysis very objectively of measuring strength.

6:11 I: Sorry, it broke a bit, what were you looking at.

E: [a cortical] I: Uhm, it's E: [a cortical AUDIBLE] I: Okay E: Yeah. I: Yeah sorry, it's breaking up a bit so it's E: Oh, can you hear me? I: Yeah, this is, yeah. Okay, yeah, so this is something you are actually trying to trying to look at?

6:37 E: Yeah, I think that's one of the difficulties of actually. Designing experiments for these algorithms that we create.

I: Okay, good. Let me just see here. So yeah, when you are presenting this to your users, how do you actually deal with that then? Because one thing is you create these algorithms and stuff like that. But how do you actually then present to your users when there might be an, you know bits and pieces missing in the data and how do you actually prevent that, so that they also understands what that means? If you even present that, I mean. That might not be something that they actually ask for.

7:34 E: I see, so you are saying that the that measurements are done in the background and. I: Yeah I mean, I am just wondering whether [interrupted] yeah I am just wondering whether there is any, guidance to the users so that they know, when they E: That they are being monitored or measured. I: Yeah or that the thing. The feedback they are getting might be inaccurate or something like that.

8:07 E: I think with all the AI technology that we have, I think we can start creating more of a self-learning. Technology. So it will be taking in the EEG and then we will probably provide feedback to the user. And the user can say "oh this is not what I feel actually." and then we can actually self correct ourselves. I: Ah, okay yeah. Yeah I guess that's a good way to. E: Mhm, EEG is very different from person to person so we probably have to adjust. And if we want to increase our accuracy we have to probably personalise our algorithms to each person.

8:42 I: Okay, good, okay. E: It's just like, you know, probably, when you are looking at medication you have to personalise, but I think we are looking into starting to look at personalised medication we have. People looking at genome and they, it's going to work on certain people that had these chromosomes or like that. And you know, people are starting to be more personalised, so I think that's gonna probably happen on all levels. Especially for EEG and ECG soon.

9:10 I: Okay, interesting. So following up a bit on that. In media and in the general public awareness about BCIs is there anything that is concerning you in the way that BCIs are portrayed or how people come to you and expect your devices to behave?

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E: Aww, I think the biggest thing is people think that we can soon be reading peoples mind and get credit card infos and I think those are things that are like out of what, like right now I don't think it's possible at all. Looking at the limitness, limited knowledge or limited picture that you can actually get from an EEG. So, probably [INAUDIBLE]. I: I mean. E: And even if we, even if we can, you will have to be strapped into a very very huge EEG system to do that. So if anyone is looking at like a one single sensor or two or three, that's. It providing a very limited picture of your mind. So, people shouldn't be scared about that. I: No but that's definitely something that seems to be portrayed around BCIs in the media, is this, you know, it's a mind reader or it's mind controlled. Yeah, there definitely seems to be some hype words around BCI. So yeah, I am just.

10:40 E: Even if you can do absolute like control things, like, even if you're a messaging BCI, I mean if you want to do, simple right or left you know, it's like, if you just simply think right or left, it might just turn right or left. You might be thinking something else on right or left. There is different levels of right or left and like controlling right or left. And so, I don't know if we can actually get to that subliminal like level of right or left controls. It's like how you know that the person is saying go right, when you are driving. Or you might just be saying, oh can you, can you get something on the right side. It's like, in your car, and it might just turn right on you.

11:18 So. I: Yeah I mean, I noticed on, on your website you also make it explicit that, that it's reading brain waves and not thoughts. I thought that was interesting that you made that distinction. I sensed that this was sort of trying to combat this public awareness and how people are perceiving BCIs as you know, thought reading. E: Yeah, that is correct. I: Okay.

11:51 I: So yeah, in research there is also some people that are worried that BCI and this deeper insight into our brain will change our concept of identity. Is that something you think is a concern as well or?

12:14 E: Identity, uh, how are they phrasing that? Are they saying that it might gonna enhance the brain waves so that they can actually be new things? I: I mean, that's. E: Or augment. I: That's definitely also a concern but I think there is a separate concern where just the fact that we know how our brain operates and whether knowing how our brain reacts to things, will change our perception of free will, and autonomy and stuff like that. Will change the way we perceive our own identity. E: I see, I see.

12:56 Well, let me just think. I haven't thought that far actually. I: That's fine. E: But yeah, I can see that. It can change the identity. But I don't know what would. We don't know what we can actually find out with the EEG so. I: No yeah, okay E: We don't understand, yet. I: Uhm, then this one is probably something you thought about because there is so much in the media about it right now. Just in IT and in general, privacy, is something people are concerned about. Is that something you are thinking about as well?

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13:39 E: Uhm, so one thing is EEG is probably providing very limited information so. I don't think it's going to be too much, and you also, secure information by saying that it's. We are just [INAUDIBLE] maybe certain metrics like age, height, and sex or gender. So that those are the things that are probably named, but then all the other information like name, those are obscured by putting some ID numbers, that people can, that's already done with all of the internet technology. So, I think we use [INAUDIBLE] security systems that we have, simply where other, other security systems. We can use those actually help keep it, security for the identity of the people.

14:29 I: Okay so you don't think, BCIs are particularly interesting regarding privacy concerns or bringing something new to the table? E: mhm, yeah I: Okay, good. Okay, some researchers and I partly contribute this to the fact that there is a tendency to collapse into one giant clump that includes both invasive and non-invasive BCIs. When people are talking about the ethical concerns. E: Mhm I: But some researchers have raised the question of security being an issue, in regards to, the same way security is an issue for pace makers and stuff like that. So that, they raise a concern that we need to make sure that the devices are secure so that hackers can't physically harm people with them. E: mhmm I: Is that something you, have thought about as well, or is that something you don't feel is related to you?

15:44 E: Well at [COMPANY NAME] we have been looking only at [observation] ones, so I don't think it would relate yet. Ugh, I mean I personally, I am interested in like, some day like, maybe augmenting my body and be able to run faster or think faster. that'll be interesting to be able to update or upgrade a computer in a way. But, but yeah, I, in [COMPANY NAME] we never looked at the ethical issue of actually putting invasive. We always empathise that our productive is in-evasive and we just [sit] on your head. And not inside your head.

16:24 I: Yeah. Okay, yeah, just a little side question, is this confusion between different types of BCI something you stumble into as well? E: We used to stumble on, but it's starting to, people starting to realise that EEG is like a surface EEG and there is also, invasive ones. And I think people are recognising the two technologies now. We did, we definitely, went through that in the beginning, whenever we were coming out because the company has been around for 10 years. And I think the first two or three years, it took a lot of people to understand the limitations of the EEG, and people are concerned about how much reading we can actually do. And now I think that people, general consumers, are starting to understand that it's really difficult to actually mind read and also putting the EEG in our heads.

17:21 It's not, it's not what the technology that [COMPANY NAME] is providing.

I: Okay, I guess that's just a matter of fact because it's been so much public awareness around BCIs. E: Yes I: Did you guys participate in that whole discussion and how did you actually deal with those concerns and people questioning how you felt about these issues. I mean, if you did?

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E: I mean most of the people recognise it after they try it. Once they recognise that what we are looking at is a white scribbling line that is coming off of the screen, and like how do you read peoples credit card numbers from this line. That's like virtually impossible yet.

18:09 I mean you would have to have multiple scribbling lines to actually properly get those [ideas] so, they understood that you know, it's really impossible to get that.

I: So it's really you engaging with people and letting them try. E: I think that engaging with people. Yeah correct.

18:25 I: Okay, okay yeah so, one of the things that is a big issue in research is BCI and people are talking a lot about are side effects, of using BCI. Is that something you think about as well? And if you have, what kind of side effects have you stumbled upon?

E: We definitely look into of what kind of side effects [it'll] create, but we haven't seen a huge population, I mean enough testing into the long term testing. [INAUDIBLE] The side effects of people using bio feedback, or you know, so. Yeah we tried to look into it, but I don't think we have enough data support any side effects right now. I: Okay, what about some of the maybe minor ones about skin irritation and stuff like that. Is that something you think about?

19:28 E: Oh definitely yeah, we definitely use materials that are friendly to the skin. So we take, you do the medical [360] now, stainless steel, we definitely use like, medical graded material so that it doesn't do any skin oration or anything like that.

19:48 I: Yeah okay, do you by chance know how that came about, was that through user testing, that someone brought it up or was that just implemented from the start or how did you actually? E: I think it was implemented from the start, I mean, when we think about something that goes to your skin, definitely we definitely have to look into like sensitivity to skin, skin allergies and everything, once we looked into it, I mean we definitely thought, oh man, we should definitely follow the medical standard. And when we thought that there was a stainless steel that for a medical grade, or like oh we definitely should use this, and that's how I think we went through it. And we, along the way, I guess, you know, [INAUDIBLE] came along, [INAUDIBLE] also started to create sensors, that are on the wrist and I think they had some issues with their sensors too so. I was like, I think we were lucky that we made that decision I think.

20:43 I: Yeah, do you know by chance why you chose the medical [certification] and you went with that route, rather than maybe just looking at other user products and user consumer.

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E: I think that, because you know, they are heavily monitored and you have to go a lot of certification, you have to go through FDA and everything so, I mean those are materials that are heavily tested, so that's what we trusted, and that's what we went for. I mean, EEG already has you know, you pulled up that public awareness of like people think it's dangerous and everything. So we have to take extra steps on being careful, so that's why I think we chose the medical route.

21:30 I: Okay, yeah it makes sense. Yeah, do you think that had a difference on your business making, did it make you sell less or more products? That you actually took this care for people and chose some materials that should protect them?

E: I think people, most folk thought that was the standard. Yeah, I think it was a given, I mean, once, if there was a problem after wearing it too long, that's probably when people would complain. But I don't think that was something that people decided on.

I: Okay, yeah makes sense. Okay.

22:13 So yeah, next question is, if BCI becomes something that every house hold has, do you think that there might be an issue where we create an A and a B team where, someone is really profound at using BCIs and some are not, and that could cause some issues?

E: No, I don't think so. I think I mean, people have different ways of enhancing themselves, and I think EEG is one of them. So I don't think it would create any different groups. I think it might also be because I am living in [CITY]. [CITY] of ways of thinking, so, I think there is ways to, I mean some people look into acupuncture, and you know, eastern medicine for medical, some people look into [e-western] medicine so, I think it's just one selection. And I think, medical industries also kind of changing, at the same time. I mean, people uses, don't look into [INAUDIBLE] information, but they, now they are interested in getting the [INAUDIBLE] information because you can see how much a person is exercising. Rather than asking, how many, how often do you go to your [INAUDIBLE] and exercise. Do you exercise 3 days a week, 4 days a week, 5 days a week, rather than asking that, you can actually see the data. And see how much exercise a person is getting, so.

23:39 I think there is different ways, I mean, people have their, it's like a, I think people have different ways to actually look into enhancing themselves. And I think EEG will be one of them.

23:51 I: Okay, actually tying into that a bit, you know, laptops and computers have sort of taking a massive place in the work place so people who are good at using computers have an advantage when they are looking for a job. Do you see BCIs being useful in the workplace and do you think they have a space there?

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24:16 E: I think it's one, part of the sensor, I feel like there should be, so we have a cell phone that you carry every day. You have a laptop that you carry most of, I mean, around most of the time too. I think there is one more device that people would start carrying, which is kind of a tri-corder [and] to actually diagnose yourself with different. You can actually get your blood pressure, you can get your glucose level, you can get your EEG, you can get ECG, you can send all that, to your doctor, and say, you actually have this. Or not even a doctor at that point, you can actually send it to a server, and it will diagnose you to a certain thing and say, you might want to take these pills. Or you might want to take these vegetables or like meat, it might actually do some recommendations like that so.

25:02 I think, I mean the device, is what I would think. But I don't know what the [for factor] at all yet.

I: No, yeah. Okay, interesting. Okay. E: But yeah, I mean, computer is equipment of many different sensors, speakers, you know, cameras and everything, I think there will be another device that's for medical. [INAUDIBLE]

I: Okay, and you don't see BCIs being a part of that medical device or?

E: I do see, BCIs being part of that, not like the dedicated BCI device. So, the BCI, I guess it's not BCI but I think there will be EEG technology embedded into that, tricorder to diagnose you to, during symptoms.

25:55 I: Yeah, okay. Interesting, interesting. So, when you are developing your BCI and you are making changes to it, what are some of the methods you use, to make sure that the changes you make are stuff that the users and society wants?

26:15 E: Sorry, can you repeat that for me?

26:27 I: Yeah, so when you are developing your BCI, and your software around it. Obviously you probably have to make changes now and then. So what are some of the things you do to try and make sure that the changes you make are stuff that your users actually want and desire in your product?

E: I guess we just try to make sure that we are accurate, for a certain test. So we always conform to testing by going back to our data, and retesting, and making sure that the accuracy is increasing towards a positive way. Those are the changes that [INAUDIBLE].

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27:20 I: So you, are you. I am assuming that, most of the, the changes you are asked for is making your software more accurate then? E: Yeah, I think so, and user friendly. I think user friendly and accuracy is probably the two things that [INAUDIBLE] work out.

I: Okay, what are, what are some of the things that people complain about? I am just curious.

E: I mean, it, people would say probably like I am expecting this to happen, but the other thing is happening. So it's like you really have to fix that as in terms of like user friendliness.

28:02 I: Ah, yeah okay, yeah. Okay, so in research there is a lot of arguments about enhancement, and we have talked about that as well. Do you see any concerns with enhancing the human being, and using BCI for that?

E: I don't think so, I mean, I think we need more enhancement so that we can actually advance society in terms of well for, and I think in having more of people being enhanced could help the local community to move forward.

I: Okay, and how do you see BCIs helping with that?

28:49 E: I think BCI would because, and in terms of the mind, I think a lot of people don't know how powerful the mind is. And I think we need to provide that feedback to each one. And maybe, if we can actually slow the decline of the mind because of the certain behaviours that's also a benefit for certain people too.

I: Okay, interesting let me just see here where I got to in my. Okay yeah, one of the big things people are talking about in the research community is the issue of collecting informed consent and keeping user autonomy high. Is that something you think about as well?

29:35 E: Can you repeat that, I don't quite understand that one.

I: I mean, the thing is, in research there is a lot of work going on in regards to using BCI as a communication tool for people who might not be able to communicate otherwise. So in order to actually use BCIs for that, they need to get some sort of consent from the user saying, you know it's okay for you to put this device on me and interpret my, my signals, in a way so we can communicate. And obviously if they have issues communicating, that process can be kind of hard. I don't know whether that ties into anything you are



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doing, but it's definitely a big topic that they are discussing in the research field figuring out how do we actually make sure that there is informed consent and users understand what a BCI does and how to use it.

30:47 E: While we actually do have one [INAUDIBLE] that is kind of similar to that. We have a project that's called, for the ALS people. They usually you know, lose all their muscle activities and eventually not be able to talk and you know, can't even blink, move your eye blink. I guess we would have to take a consent right before they lose all their communication levels.

31:13 I: Okay, but I guess then, for your average consumer this is not something you worry about. E: No. I: Okay. E: I mean, they definitely have the choice, I mean to put the EEG, the headset on or not, so I think they, that's the consent that they gave.

I: Could you think of, I am just brainstorming a bit here, whether you could think of any situations where they might not be able to actually make that decision, where it could be an issue? I'm trying to think, for example the, in research they mentioned stuff like, if it's being used as a lie detector, you might not have the choice because if you, you say you don't want a lie detector then people will expect that it's because you're hiding something. I am just thinking whether, maybe you know or have stumbled upon situations where you seen people not feeling they were able to actually say no.

32:28 E: [COMPANY NAME] is typically are not on the application level, so that probably like, as at, costumer level, so we provide the technology to probably detect lies, but then we don't. They, I mean whenever we are doing the, the [INAUDIBLE] department would definitely have to get consent so, I, I guess we don't experience such things at a day to day.

33:00 I: Okay, that's fine. So, a lot of these issue tie into some sort of there might be a policy gap, or there is some legal concerns involved some of them. Especially when we are talking about new technology. Is there any policy gaps or legal concerns that you guys have had to deal with, or still have to deal with?

33:28 E: I think, there is a lot of legal concerns, well not legal, I get certification like the FDA levels, in terms of EEG technology. I mean, I think there is great usage for EEG, but then, when you start to diagnose for certain diseases, or a certain mind state, it might require some FDA. I think FDA, the policies for that is kind of [INAUDIBLE] right now.

I: Okay, but, so you haven't actually run into you know, someone suing your or something like that. E: No, not yet.

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34:09 I: Okay, do you see any policy gaps, where BCI might have changed something, that might not be covered anymore?

E: Not that I know of.

I: Okay, so yeah, this is pretty much the final question. So, basically I want to hear if you have any concerns maybe you've stumbled upon yourself, or something that you worry about a lot in your day to day work. Or maybe something your users have brought up, that, that you have taken in and redone something either in your organisation or with the product you are making.

E: In terms of ethical issues, correct? I: Well, I mean, it could even be you know a technical issue that you, that you actually stumbled upon that, you know, might have been interesting or anything.

35:19 E: I see. Well I think a lot of researchers look at, try to create new metrics, like, but then I feel like there is no specific use case yet or like looking at specific [INAUDIBLE] ones. So I think that, that's one thing that I think researchers should look at. They should look at it from a pay point view and then say I am going to solve this problem, that's why I created this algorithm to provide. And I feel like, people are trying to create all these kind of different metrics and it sounds cool, but then there is no actual viable solution, I mean usage. And that's kind of, I think, one issue I think I see. [INAUDIBLE] active with all the research funds, that effectively I feel like, that is the one thing that people should probably think about.

36:12 I: Yeah, I mean that's definitely a good and interesting point, I know, specifically some of the new research goals set up in Europe has, is very much evolved around research being something that actually you know, provide something, directly to society. E: Exactly I: So I think that ties, very much into that.

36:46 Okay, so yeah, any other things you might come to think of? E: No.

#### 8.2.4 Consumer stakeholder 4

I: Interviewee

E: Employee

I: Before we really get into the questions could you describe yourself in a couple of sentences and what you do at the company?

00:17 E: My name is [NAME] I am the CEO of [COMPANY NAME], my background is in PhD in microbiology MBA in financing. Working before in technology transfer, business development in medical device.

00:38 I: Okay, and yeah, so in a couple of sentences, what is it your company is trying to do.

00:48 E: Okay, we develop the technology for brain wave analysis which allows us to, extract relevant markers, and specifically markers for attention. Using only one channel EEG, in very short measurements. Less than one minute for auditory audible test which is accepted test in neuroscience for a variety of applications.

01:18 I: And when we talked you mentioned that you have both a product for researchers and the medical industry and then you have another for a consumer market?

E: Yes.

01:32 I: Okay, could you describe a bit the difference between the two products.

01:38 E: Eeh, okay, so, the first product for now it's only for PC and the software which allows you to measure online attention and we collect [INAUDIBLE]. So you get index and it is designed for research in a way that you can define areas of interest and the way that you can extract the data, it doesn't have any features like you would expect for consumer applications regarding recommendations or things like that that.

02:24 I: Okay, so the research one is the pure data and you can do with that whatever you need to do. And the consumer one you provide a bit more feedback to the user, is that correct?

02:35 E: Yes, so the consumer one for now, with predominately for mobile app for migraine, migraine loss, migraine patients. Okay so for this application we put more, you know, emphasise on user experience and user interface. Like to people be clear about what you are getting out of it and how you use it.

03:06 I: Okay, yeah so, one of the big things in the research industry is that one of the concerns is misuse of devices where you might develop a tool for medical purpose but then the military industry or consumers take your product and misuse it in some way. Is there anything like that you worry about regarding the product that you are creating?

03:39 E: What is misuse? I: Well that's really up to definition isn't it? That depends on who you are asking.

E: I don't really understand the question? I: No I am just wondering if there is any use cases that you can see your devices being used for that you wouldn't be so happy about?

04:08 E: [...] Not really. I: Okay, no okay. So another one is misinterpretation of data or accuracy of data is one of the big issues people are talking about in research regarding BCIs. You already sort of mentioned it regarding the different, different products you have, but is that something you are worried about as well?

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04:40 E: Yes, and specific applications that we could approach, like mobile app for people with depression, so for now we did not develop it as a mobile app, but a research tool for psychiatrist. Because in this fact I could see a potential for people to get the data and which might affect them in a bad way. So we would rather wait with this either to develop it as a medical device or [deliver it] within the research field, than to take it out.

05:26 I: Okay so you made the choice to not actually provide this to consumers yet? E: Yes. Not in the stage that it is now. Like we can continue and develop it to a stage where we will not be concerned about misinterpretation, it's not there yet. I: Okay, what do you think is the key issue there providing information to people. Is it people not knowing how to interpret brain data, or is it the way brain data is collected that's the issue?

06:02 E: No it's the feedback, for people, specific psychiatric applications, the feedback may effect the indication, the state of the person.

06:21 I: Okay, so a bit of following up on that, another key issue in the research literature is public awareness and how BCIs or neuroscience is portrayed in media is something they talk a lot about. Is that something you have encountered as well?

06:46 E: Actually not in Israel and not with Israelers and not in the US. With people from china, Korea, this is something that was brought up as an issue. I: Oh really? E: Yeah. I: Do you think that's a cultural thing, language issues or what do you think is the issue? E: If I understand correctly what you are asking, is that people are worried about brainwave data accumulated or? I: Yeah E: Yeah I believe it is a cultural issue.

07:29 I: Okay. That's quite interesting. What about the, because there is also the notion that EEG you can read peoples thought, and you know mind reading and stuff like that. Which also, in the public being raised as something people are concerned about. Is that something you encountered as well?

07:52 E: No. I: Not at all? E: No.

07:58 I: One of the things that the research literature is also talking about is BCIs having the capability to change our concept of identity. So because people put emphasis on free will and how the brain changes the concept of all that, there is this concern that if we, if BCI can give some insight into how the brain actually works that might change how we see ourselves in a sense. Is that something you can see or is that something that philosophes are able to conjure up?

08:55 E: I don't have anything to contribute. I: Okay. No, that's fine. So yeah, the next one is a typical tech issue. It's privacy, is something that is being talked about a lot, is that something you think about as well?

09:14 E: Obviously and we take the measures that are accepted in the industry, which means the HIPAA compliance for mobile app, and this [INAUDIBLE] that we collect. I: Okay, do you see that BCIs needs to take extra steps towards securing privacy or do you see this as just another, this is a piece of technology so of course we need to think about privacy and security?

09:42 E: Standard technology, like any other. I: Okay, because that's something you often see in the literature is that brain data is perceived as something that is even more private than say your heartrate or something else. E: I don't really see why. I: Okay, that's okay there is definitely also people in the research literature that has the same opinion so, you're not alone.

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10:18 I: So, this is a bit of an odd one, especially because I from my understanding, you only have non-invasive EEG signal that you work on. And I guess this might apply more to BCIs that actually has either invasive features or some sort of other applications but, in research there is this concern related a bit to the issue that pacemakers had where they were hacked and then that had an implication on peoples health. I assume since you're only using non-invasive EEG, this is not something you are concerned about?

11:02 E: No. I: Okay. So yeah, another big one is in the research literature they are concerned about side effects of using EEG BCIs, is that something you think about as well?

11:23 E: What are they raising? What kind of side effects? I: Because they kind of lump together invasive and non-invasive there is a lot about the body rejecting the EEG, there is also some about skin irritation. E: The body? I: Yeah so if you like with surgery insert a reader. E: It's non-invasive EEG, it's passive so, it's [INAUDIBLE] it's no constant, and they don't see any irritation like the sensors are compatible, bio compatibles every consumer sensor. So it's the same issue as headphones. I: Okay, so you don't see that one as a big one. E: No, I don't see it at all. I: Okay.

12:21 I: So, let me see here. So another one is that people are predicting in the future that BCIs might become a household item like laptops and cell phones and they are talking about the concern that, if this become something you need to use in the workplace you will see the same divide between people that laptops and computers have created, where some people are very good at using them and are easy to incorporate them into their work. So they are talking about how can you actually reduce this gap between people who have the technology and those who does not. Is that a concern you see for BCIs at all?

13:21 E: Again I don't see what I can contribute to this issue. I: No it's not so much about whether you can contribute to anything or solve the problem, but just whether that's something you thought about at all or is it just? E: No. I: Okay.

13:37 I: Let me see, actually kind of extending on that one. Some people talk about creating programs for schools or libraries to incorporate BCIs and teach people about the technology. Is that something you can see as well?

14:04 E: Yes. I: What, do you see any benefit of that or why would that be useful? E: What we are doing for example when measure attention, which can be very useful in e-learning in order to evaluate how much your engaged in learning activity. And you can tune basically the level of the material, the study material. So to fit personally to the student and this can be done with e-learning with computers, but basically it can be done also with the teacher sitting one on one [I see for now]. In order to decide when to take a break, when to change from one exercise to another. More difficult, less difficult and so on. [Time relevant]

15:04 I: Okay, so do you also think that would improve peoples ability to understand how BCIs work and what you could use them for, if they had experience using them, say in school or something like that? E: Yes.

15:24 I: Okay so, one thing they also talk about is how to make the, the development of BCI products more usable by users. So they talk a lot about different ways to do user testing, market surveys and stuff like that. Is that something you use as well to engage with your costumers and figure out what to do. E: To do what? I am not sure I understood the question. What are they doing? I: Well basically in research they are slowly I would say, starting to think about the impact that the tools they are developing might have on their users. So they are starting to basically do user testing and stuff like that so that their devices are not only usable in a research setting, so that their devices can also be used by patients and stuff like that. And

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basically there is a large discussion about how do you actually figure out what the user want, and what is useful for them. So I am just wondering, because as a company I assume this is quite a large part of what you are doing, is figuring out what do people want and what can we sell them.

16:58 I: So I am just wondering what kind of techniques you are using to actually figure out what your users want.

17:05 E: The same technique that any industry is using, we did some market research for specific applications we are checking. Once the product, the non-medical product we give users and get feedback. I: Okay, do you have any like, on your website do you have feedback forms or is it, how do people actually engage with you?

17:31 E: Okay so, not yet, we don't have so many [free] users I would say. So we have, we did market research, so we basically asked the 300 subjects that elected to specific products and [INAUDIBLE] one product for the consumers. So we simply gave to friends and families and some advisers and we get the feedback [INAUDIBLE].

18:06 I: Okay, did you already know what the next step will be when you maybe make this product public and stuff like that, how do you plan to increase the user feedback?

18:18 E: Not yet. I: Okay, so in research they talk a lot about enhancement, and how BCI products can be used to enhance your brain productivity enhance the human being and there is quite a lot of philosophical debate about enhancement, and I was wondering if that is something you think about at all or, do you have any stance on that at all?

18:54 E: No I: Okay, just out of curiosity, what do you think about researchers debating this at all? E: Never thought of it. I: Okay. E: Depends what they are saying you know, and I didn't go into the literature, explore. If they have anything smart to say, I mean it's.

19:34 I: Okay, okay so, in research there is also because a lot of the research using BCIs has at least in the later years evolved around people with locked in syndrome and ALS, a lot of the literature about the ethical concerns is about getting informed consent and keeping user autonomy high. Is that something you think about as well?

20:03 E: Obviously when we do any medical research we get informed consent, and if you are not able to get there are ways to approach [diabiant to get release one] informed consent, so this is obviously something we. We play by the rules. I: Yeah, then when you have a, when you are developing a consumer product as well, how does that change? E: We have a terms of use, within the mobile app. E: Okay, but do you think there is a difference between the two settings when it comes to informed consent and how those. Because I understand there is different rules but, does your mindset also change when you are developing the two products? Are you thinking differently about the procedures you have to go through?

21:09 E: Yes, it's completely different. I mean, definitely the medical device it's very clear path that I have to follow and if I am going for a consumer device it's a different one and the informed consent is part of medical device and the term of use is part of consumer device so. But you need to play by the rules, whether you are going to.

21:40 I: Do you think the rules are clear in both cases, because I can understand in the medical case there is quite clear rules about what you need to do, but in the consumer sense I would assume it's less clear

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what you actually need to do to make sure that your users are understanding of what your product is providing and stuff like that?

22:02 E: There is, I mean it's, it's not specific to brain, brain wave data or applications related, you can ask the same questions for every mobile app you have. Is it specifically clear, do you have rules for ECG, snapping, whatever, I mean. I don't see the difference and I don't think there is a difference.

22:32 I: Okay. E: I don't think that your brain waves are more private than your pictures on the Facebook. I: Okay, let me just see here what we got to. Okay yeah, so quite related to that, and actually to quite a lot of the other topics. In research they are talking about there being a policy gap and a legal concern, when it comes to BCIs and I assume based on your previous answer that, you don't think there is anything special and any special legal gaps because it is brain data. You think that it falls under any other technology out there?

23:24 E: Yes. I: Okay, could maybe extend a bit on that, why don't you see a difference between brain data and any other data?

23:38 E: I don't think you can do anything more vicious or problematic or, it's, there is nothing unique with extreme to any. I mean what could you do it? [INAUDIBLE] Brainwaves you have a possibly you have, can be connected to specific disease but then, it's the same with heart, it's the same with mobile app which doesn't measure your brainwaves, but only you give information regarding specific disease. The issue of brainwaves it doesn't add or reduce any. I really don't understand what the, you know what are the argues, what extra safety or extra concerns.

24:34 I: But would you then still put it in that box as for example heartrate data and other quote on quote medical data? Or is it the same as your emails and stuff like that?

24:54 E: It depends to whom, you know. But yes I would put it with health, I would call it health information. I: Okay, so in that sense it does need quote on quote extra protection, because at least that's the trend we see with yeah, medical data, health records, and stuff like that?

25:17 E: So it's not, it depends. The line between medical and wellness, so you will start to for every pedometer you would start to [require] medical device, you wouldn't have anything.

You need to define the line, and people need to define what they are giving, in the site whether they want to make it or you know leave it.

25:38 I: Okay, do you think we, is that something that is already starting to shape out, where this data is gonna be categorised or is that still something up for debate, whether this is you know, a pedometer or where it falls?

25:55 E: I think that the FDA made quite good guidelines, regarding the wellness and mobile apps in the sense they kind of, I would say free. No there are many mobile apps which are on the borderline of medical devices. They understood that the technology is there and they decided not to block it as long as you don't claim something like, heavy medical.

26:31 I: Okay, okay that's actually quite interesting, yeah so actually my final question is that whether there is any concerns that you have, or your users might have brought up, that we haven't already discussed?

E: No I: No, good.

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8.2.5 Consumer stakeholder 5

I: Interviewer

E: Employee

I: You could maybe introduce yourself in a couple of sentences?

E: Sure, my name is [NAME] I am a psychologist and a neuro-psychologist as well, I am focusing on psychophysiology and stress mainly. And I am doing some technical development of apps and systems that involves psychology and psychophysiology.

I: Okay, and yeah so expanding a bit on that, my research is evolving around brain computer interfaces but my understanding is that the company you had didn't actually do anything with brain computer interfaces

E: correct I: but were about wearables evolving around stress and stuff like that?

00:58 E: That's right. I: Can you expand a bit about that, what you were trying to do?

E: Sure, we're we are trying to take the stress inoculation training and mindfulness training into breathing training with the applications and psychological sensors and we are combining all of it into packages at the moment, it is direct to asthma patients, and the future it will be directed to other stress related psychopathology and medical conditions.

01:41 I: Okay, is, so what kind of psychology are you looking at? Heartrate or? E: Heartrate, at the moment we are looking at heartrate variability. We have some PC systems, that work with other psychology measures such as skin conductance and electromyography and more. But for the applications we are focusing on the heartrate variability.

02:18 I: Okay, and is that because that's the best indicator of stress or? E: No, not really, I think, to indicate stress you need a few channels. You can't really use only one channel, but I think that it's evidence based, and there is more data about heartrate variability and the connection with the autonomic nervous system it's very easy to tie with breathing and people can see change, quite quickly when they apply the techniques that we teach. So as a biofeedback system it's nice to start with breathing and HRV. I: Okay, and is that why you were interested in brain technology and what sort of biofeedback you could get from that sort of technology or is that unrelated to that?

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03:21 E: No it's unrelated, we also, we're familiar with EEG biofeedback or neurofeedback, but it's harder to implement at the moment and it's also controversial in some aspects so it was easier to start with the peripheral physiology, maybe in the future there are good accurate system, we can also add some neurofeedback.

03:57 I: Okay yeah, that's actually, so that might be where I wanna push the interview towards that sort of your thoughts on that technology you are not using yet. But maybe the potentials you see in the future and your thoughts about that.

04:16 I: So the first real question is, so we have seen throughout history that when new technology is being developed, people often create a use case for it, and then it goes into the market and suddenly users find another use of it. Sometimes this can be a good use but sometimes it can also be problematic and I was wondering if you see any of such use cases for brain computer interfaces and neurofeedback that could be potentially good, but maybe also potentially things we need to worry about?

04:53 E: I'm not sure, if side effects of neurofeedback has been properly investigated because if you are intervening and if it works, and you are strengthening one muscle, one brain muscle, you have to check what it does to other brain areas. And I am not sure how much of this has been done. We know from other biofeedback or let's say psychologically interventions we know that for some people it's a. There is a contra indication to using, say using relaxation with psychotic people. It's something that is not recommended.

05:43 E: So the same way I am not sure how developed is the knowledge regarding, what happens when you train one area, what happens in other areas, can it make someone oversensitive you know, so.

06:03 I: Okay so. E: I am also not a very big expert on neurofeedback because I have been focusing mainly on peripheral physiology but I know that when I was using neurofeedback those questions were concerning. I was concerned with those questions.

06:25 I: Okay, yeah no, that's good. So in the research setting there is also a lot of concern about the misinterpretation and the accuracy of the data. Is that something you could see as a big concern for neurofeedback as well?

06:44 E: Sure, there is the skull that is masking the information coming from inside the brain and with this masking you have to have very good analytics and statistics to get correct [INAUDIBLE] and to get clean signals and I think that there are a lot of artefacts that many times are not being accounted for. Say muscle activity around the eyes and many other things that happens, so, I think that it's a problem, I know that people are working on several statistical analysis to improve the reading. But again I think that, I see the

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brain as a system, that is interacting with many areas in the brain are interacting and when you focus on one, on one or say you can focus on several, but I think it is still not very accurate.

08:05 I: And is this part of why you decided to go with other biofeedbacks rather than neurofeedbacks? E: At the moment, yes. This is the reason and although I have been checking the, you know from time to time I go to seminars and I am taking workshops in neurofeedback I still feel that there is a lot of confusion, different protocols, different hardware and software that give different results and there is still not enough agreement in the field in many aspects of training so. That is why I think that, that's why I haven't invested a lot of, too much effort into understanding it deeply at the moment and I am waiting for it to be in a more consensus you know about regarding, protocols and the effect of protocols. For heartbeat and heartbeat variability its much easier.

09:13 I: Yeah, okay yeah, that's an interesting point. Following up on the whole misinterpretation of data and stuff like that, another concern in the research setting is that. Basically public awareness on how BCI, neuroscience is portrayed is something that they discuss a lot and they are concerned about how normal media, consumer media is actually giving the neuroscience information to people that are not a neuroscientist or psychologist like you. Is that something you think about as well when developing your products?

10:07 E: You mean the education of the public about the? Sure, of course, I think that it's also relative to stress and like 10 years ago when I begun, mainly in the eastern societies it was very difficult to sell stress or destressing applications because we like, when we were negotiating with Koreans they would say "Well stress is good, we don't think you have to do any regulation or you know, we prefer investing on cameras and pixels, and not investing in something that reduces stress because we don't think stress is so bad".

11:01 There is a lot of education and educating the market in order to succeed in using such applications, in these days it's better. I mean 10 years after, the situation is better but I still think that people need to be more educated about stress, and definitely about brain waves and stuff like this which is, which is also, that is, people are not as familiar as they should be.

11:38 I: Following up a bit on that, one of the thing they discuss is how a better understanding of our brain which BCIs inevitably will give us, that might actually change how we see ourselves, how we see our ability to change ourselves and our sense of free will. Is that something you stumbled upon as well?

12:06 E: Less, again because it's not my area of research at the moment. It's not, these are not questions I am concerned with at the moment because I am not. Like philosophical I can agree with you but, you know, it's not something that I think about daily because it's not something that's related to what I am developing at the moment. I: No, yeah that's perfectly fine.

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12:38 I: Let me see. Yeah the next big thing and I think this is basically any technology there is a large concern about privacy and there seems to be at least in some part of the literature there is an increased concern because it's brain data. Is that something you can follow as well or do you categorise brain data the same way you do heartrate data and stuff like that or?

13:15 E: Privacy is important because you can also understand from heartrate variability you can understand medical condition of a person. So we do, we are concerned with it, and we take certain steps in order to keep the privacy you know like encryption of the data and this is something that does concern us. And we already in the development you know, to keep the data as discrete as possible.

13:52 I: Can you understand the argument that because it's data about our brain that this is in some sense more concerning? E: Yes, definitely. I do.

14:10 I: Yeah so, this one is a bit, of a different one. Because in research there is a tendency to lump invasive and non-invasive BCI together into one instead of two. There is a concern that, regarding security which is related to the same sense as pacemakers where pacemakers were hacked and that then caused health concerns for the patients that had pacemakers implanted, so is security something that you could see as something that's a significant concern regarding BCIs?

15:06 E: I am not sure, I am not sure how, can you give me an example of how it can concern like? With pacemakers I can understand what the problem, but. I: I think it's basically the same issue like, if you have an invasive BCI and someone is able to hack it, can they then inflict harm on you or? Something like that.

15:47 E: Well yeah, I think that it will mainly be disclosing some information that if the person wants to use this information say, someone is interested in getting a top secret job and you can see that he is stressed you know, over stressed in some situations. You know things about him that he wouldn't reveal himself. So yes, in that aspect, you can get a lot of information about people by hacking a device that is on them, and if the recording stress levels and this I can see maybe problematic.

16:39 I: Okay, so yeah the next big topic is neuro enhancement. And how BCIs could be used as a neuroenhancement, is that something you think about as well?

E: Sure, any skill that you practice a lot not only at the physician's office, but daily will become automatic and will become better learned, so this is something that is definitely going to change the ability of people to learn new skills and to use them.

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17:23 I: Okay, so related to that they also raised the concern of side effects. You already mentioned this a bit, but is that something you want to elaborate a bit?

E: Again if you practice a lot in something and you don't know, say the example if you strengthen one muscle and it does not know what it does to the other parts of your body, because the body compensates, so it may lead to some damage if you are not doing the training in the right way or the right intensity and I think its the same problem that happens in the gym, can happen with the mind.

18:14 I: Yeah, okay. So another one is people are predicting in the future that BCIs could potentially be something that we have in every household it's something we use at our job, and they are concerned with the fact that in the same way as not everyone having access to a computer means that they might be a bit behind the people who have had access to this technology throughout their life. That we have, that we might create an A and a B team for people who are familiar with the devices and the people who are not. Is that something you are concerned about as well? This creation of two different type of people?

19:07 E: This is a, this is something that can be said about anything that is new. Any technology that some people have and some people don't like. I think that this is what happens with any technology. Some people can use the advanced technology and some don't have the ability to use it. I think I can see it with let's say you know, the banks are becoming more and more automatic, right? Now, older people they find it hard to work with the bank, with their bank account only by the, with the using of the web. So they encounter much more problems in catching up with very basic daily activities, and they have to get help or assistance so we can see it in every when things are being computerized and developed.

20:19 E: Some people who don't catch up with the learning may find themselves in trouble, and I see it with early generations that is finding it very hard to cope with. When I look at my children I see how quickly they understand how to, you know, to use apps, because it's like a language. They grow into and they understand it, so I am sure that what you are saying is right, that some people will not catch up or will not have the money to go, to integrate it into their life and they will be able to do less things.

21:09 I: Do you think there is anything we can do to help bridge that gap? Is there any?

E: Well, as I said, it needs, people needs a lot of assistance, especially those that are not familiar with the technology and the question is how this assistance will be, will be given, like even when I. I am also developing some biofeedback equipment for the clinics and when people, when I see huge difference between people who are 60 years old and people who are 30.

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21:43 E: People who are 30 it's very intuitive for them, all the technical aspects, and people who are 60, they have to get a lot of assistance until they are able to apply the systems in their clinics, so I think the point is, how are you going to help people who have a hard time learning.

22:08 I: Okay, let me just see here. Yeah, another thing that's being discussed a lot is how to actually create ways to develop devices and software that is actually what the users and society wants. And I was wondering if you have any ideas to how to actually incorporate that into the way you develop. If you do anything to get user feedback or anything to sort of gauge what is the society and what do they want, you said 10 years ago they didn't at least in the Asian culture they didn't want stress relief, but how do you actually engage with that debate and how do you actually figure out what people want?

23:12 E: Usually, first of all we have beta testers, always, so beta testers give us a lot of input after we have developed something. What it does to them, and how to improve. We also see that after we launch a product, we get a lot of feedback from users, we prioritize the feedback, and we try to implement some of the requests. Sometimes when we do pilot studies, we understand that, what we have developed can be used in a different way. So, we also shift the strategy like, say in another, in another product that I am developing. We wanted it for homeland security, and we planned to monitor people remotely.

24:21 E: With cameras, and put it in airports, and this was the basic product that we planned to use, but then when we did some pilot testing we understood that it can also be a polygraph. So we are now actually the first product that we will release will be a remote polygraph instead of a security system.

24:48 E: See so, when you start working with technology you can many times, you understand that it can be used for other things yeah. I: Do you see this different from how researchers work with technology?

25:12 E: Well, I think that we are more in the field, if I can say so. We take our technology outside the laboratory and that's where we learn a lot about the, how to use it in different ways.

25:31 I: Okay, let me just see here. Oh this one we already covered, okay. So in the research setting there is also a lot of concerns, because a lot of the researchers are involved in people with locked in syndrome, a lot of the literature is also concerned about how to get informed consent. And keeping user autonomy high. Is that something you think about as well?

26:06 E: No, these are extreme conditions, and we don't work with such extreme conditions, so for someone to benefit from biofeedback it needs to be intellectually intact and with the learning ability so, those people who are locked in are not possibly clients of us. They can't be clients.

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26:33 I: What about just your average customer then? is that something you worry about? whether they understand your product and what it can be used for? and do you take any measurements to make sure they actually stand what they are buying?

26:53 E: Yes, well what we explain is that there is nothing intrusive, or we are not like transmitting any electricity inside their body, we are just collecting information from their body. This is something that is very basic, and in the psychological aspect, we sometimes emphasise that it is not polygraph, but it is something to help improve wellness. So this is, they are now talking about the biofeedback device, not the I: yeah E: but the security, of course it's like big brother. You don't know you are being monitored but you are monitored, there is no question here because, this goes to security purposes.

27:53 I: Okay, so yeah, a lot of the topics we talked about ties into a concern about policy gaps and legal concerns to some extent, is that something you see as a problem as well?

E: Well we have legal advice always, you know, so we are accompanied with a lawyers, but I don't remember that we had major ethical questions that we didn't cover now.

28:33 E: We covered the main things, I don't remember something else. I: What I am thinking of is that you mentioned that for many of the neurofeedback devices there are no standard or protocol. E: Yes this I think is a problem, that is why I am not concerning myself with this field at the moment because I don't think that there is enough data on what it does. This is the first point that we discussed. This is why I am not doing any development in this area, although I thought that there is a lot of potential, I still see that you know, I am still connected to forums of therapists and I still see the questions that arise there, like for example last night I read a questions in one of the forums.

29:28 E: About someone working with neurofeedback, and someone his patient became very sensitive to noises like it's called misophonia, and because of the, after the treatment like while the process of the treatment he became more, and he was asking if anyone else had encountered this problem. So this is regarding over sensitivity, if you train someone, it can be also sensitive them instead of desensitise where you want. So you don't really know very accurately yet, what such a general training outside the skull what it does to people.

30:17 I: Yeah, do you see any changes in that sense, like are people actually working on developing protocols or how do you see that? E: Of course, people are working all the time, and they are publishing, but everyone, each one is working with a different system, with different hardware, different software, different statistics, that's why I am saying there is no unified protocol yet, that I can see, like there are names of protocols, but everyone you know, does it differently.

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30:53 I: Do you see any way, that this could actually be solved? Do you need a government body or? E: When they will have a better diagnosis, like they work on something that's called QEEG, which is good for diagnosing which brain areas are, have certain activity, but is also different, like you see it in environment of the laboratory, you don't see it outside. So outside you will have a lot of distraction and the brain works differently when you are outside and you are not in the clinic so.

31:34 E: It's a problem to generalise what you see in 15 minutes of testing in a clinic to what really happens. And I see it a lot say with post traumatic people they function differently when they feel in a safe space, or when they sit in a not safe place. And if you do the evaluation in a safe place, it doesn't mean that their brain works in the same way when they are outside. So, this is a big problem.

32:11 I: Okay, yeah, so basically my last question is kind of open ended, I basically want to hear if there are any concerns about BCIs or neurofeedback that you, we haven't discussed already, that you might want to bring up, that maybe you have discovered yourself, or some users of yours or?

32:38 E: No, not really, I am just saying the point is that where you do the evaluation, you never know what happens in a different context, so it's a, it's a problem to decide which protocol to train, when you see a person in very short time, in a specific setting. I am sure that, that the results will be different when people are in different setting.

33:19 I: I, guess a lot of the neurofeedback companies that are out there right now, are I guess that's kind of their problem is that they are trying to find a generic way to teach meditation, and doing that such a general level is what's the difficult thing here.

33:48 E: Well yes, you know, because anyone, every person needs a different path to take where they learn meditation. Some people need to first meditate on stimuli which is outside, some people can concentrate in their breathing. But for some, concentrating on the breathing will make their arousal higher, and the emotional engagement more sensitive to negative emotional aspects, when they focus into the breathing so there is a lot of. You need to work individually, and see what happens with every individual and guide them in their own pace, and it also depends on how much they train at home. And what will you give them to train.

34:39 So there is a lot of questions, because when I see programs such as MBSR which are very general, and people have to sit and meditate for 30 minutes, when you measure their reactions, they are totally different reactions, some people relax, some people don't. Some people [get to] overthinking, some people do not. So yeah, there is a lot of challenge here.

35:15 I: Okay, yeah that's basically it.



8.2.6 Consumer stakeholder 6

I: Interviewer

E: Employee

I: So my first question is really trying to set the scene a bit, so I would like if you could maybe introduce yourself in a couple of sentences?

E: Alright, so I am a professor in computer science and neuroscience at [CITY] university, currently on leave for commercialising this company [COMPANY NAME] commercialising a product based on research that I have been working at the university for several years. I have done a lot of more conventional EEG and fMRI kind of research, and I then realised that one can do a lot with just two or three electrodes.

00:59 I: Which is what I have been recently working on and now trying to commercialise. So that background is in applied mathematics.

I: Okay, okay yeah so in a sentence you are now trying to commercialise this product, could you maybe give a few sentences about what is the product and what are you trying to do and stuff like that?

01:31 E: Sure, so the product is reading brain activity of various sorts, specifically emotional cognitive [execrative] and what we call extreme emotions which would be stress and pain. As such it can be of a system in diagnosing and managing various neurological diseases. We are currently concentrating on minimal consciousness anaesthesia and epilepsy.

02:17 I: Okay, yeah so extending a bit on that, what do you hope that your users then will use your device for.

E: Let me just continue since you are interested in the consumer product. In the consumer market we are looking at attention and mood disorders, management and specifically against or other types of stimulation that can actually help in elevating these disorders.

I: mhm, okay so what you're trying to do is create a consumer device to help people who struggle with these things?

E: Yeah.

03:04 E: So imagine a computer game that after you played, using neural feedback from your brain, you actually feel happier, or more concentrated. I: Okay

03:25 I: So yeah, throughout history we have seen technology get released into the consumer market and then suddenly being used in a way that the manufacturers didn't perceive possible or didn't perceive as something that it would be used for. Is there any such use cases you're thinking might be possible with your devices?

03:47 E: Well, I mean, what we see right now, is basically an opening of a channel, that looks inside the brain. Okay, as such we can look at kind of other channels that were opened and what happened. Okay, so for example, a simple example would be the windows that we have in our apartments. You know. With windows really opened a direct channel to what is going outside, and as such they enable us to really see what is there. We enjoy doing this, and this is why we opened them. We can't imagine living without such channels. But of course, such windows, can also cause trouble so people who are walking on the other side, can actually see us in the house and that may be a problem. But just like the way we [solved it] in our home, we either have a curtain, or we can shut the window we can make it opaque, etc and we are, we have to be aware not to, [I don't know] undress or take a shower in front of the window in the case that someone else is moving, walking in the streets. Yes, just like that we need to be careful with this new opening that we are now opening into our brain.

05:31 Okay, that is nothing different, and just like in the case of a window, there may be people with some telescopes, very far, that we don't see them and they are maybe watching us, through that window. And which I don't even know if it is a crime or not but you know, because this window is very important for us. It gives us real advantage in comparison with living without windows, then we are willing to take this risk. And of course regulation has to be there to reduce the risk, to reduce the abuse of that channelling opening, that we just did.

06:21 And enable us to enjoy the benefit with minimal abuse of this channel.

06:34 I: yeah, that's actually a really good analogy I think. Actually taking that analogy a bit further, sometimes people can walk past your window and look in and maybe see some things, but they might not understand the setting, they might not understand what is going on and might misinterpret what is going on. So, I know in research that's a worry about brain data, is that the users might misinterpret or the accuracy of the data is not quite there.

Is that something you think about as well?

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07:11 E: You know, this is kind of a secondary consideration, you know, the initial consideration is that the, first I don't want, those people which I do not want to see what is going on, I don't want to see them what is going on, okay. So this is maybe why I am putting blinds, that I am not pointing towards the street, so people in the street cannot see me, etc etc.

07:44 E: The second one, is that I want those people that do see what is going on, and this may be my doctor, or my [caregiver] who is actually trying to utilise that information in order to understand whether there are some medical problems, or whether the medication is working. Of course in those cases it is extremely important that there will be no misinterpretation and that the information will be understood completely.

08:17 E: In fact, even in the consumer market if I am playing a certain game where my brain is being read as part of the game, of course you know, as a person who wants to succeed in the game, I would like that system that is actually looking into my brain to be as accurate as possible. To describe as accurately as possible what is happening in my brain so. When I concentrate or when I try to achieve something this is well understood.

08:52 E: But as we well know, from medical test and from what not, that there is a lot of noise inaccuracy in the system etc. And part of science is to improve on that, not [sub] and to make the medical tests more and more accurate, be more and more sensitive etc and of course the same goes for reading the brain.

09:18 I: Is there anything in particular that you are doing to address this sort of misinterpretation and accuracy in your device?

09:27 E: Just base the results on the most advanced scientific method, to validate, to validate that we read. And I believe that the key [today] is first of all to base the results on a lot of data. Okay so, it is well known that if you draw conclusions from very little data, from very few observations, is very dangerous. And of course the same is here. We are looking at of a very high dimension of data or very. The information is quite big, and from statistics we know that when we are looking at models from a lot of what we call high dimensional data, there is a big chance of what is called in statistics over fitting, mainly that we draw wrong conclusions from the small data set that we are looking at.

10:40 So that's the key in doing the statistics correctly, what's called validation, model selection, and deduction. That has to be, there are various tools for doing that, and there is nothing different when looking at data coming from the brain. For the same purpose.

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11:02 I: When, since your intention is to move into the consumer market do you think there is a difference between how you work with the users of your device then. Because I would assume that researchers would be fairly familiar with these kind of concepts and understanding the need for as much data as possible. But is that understood by consumers?

11:30 E: So that's a very interesting questions. So we are taking the approach of starting and validating our device, really in the medical market where, the regulation, the conditions are, the requirements are much much higher. And then, take that medically approved device, and make it very accessible to the consumer market. So what we are going to do is using machine learning, AI, and basically advanced modelling we will be producing very very simple output, very simple readable output, from the sophisticated data that we extract.

12:25 Based on the medical grade kind of analysis. So that from the viewer, the user, the consumer they will see a very simple kind of meter showing something like green, yellow and red for specific indications, without having to really know anything about what's going on so if you are talking about attention we can have a meter for attention, a meter for mood, a meter for epilepsy etc etc the meter itself will be extremely easy to understand from very young children to their parents and of course their caregivers and of course consumers playing games, etc.etc.

13:15 I: Mm, okay. So yeah, following up a bit on that, in some of the research literature there is a large concern about how the public views BCIs and neuroscience and how it's portrayed in media. Is that something you think about as well?

13:39 E: Of course, of course, but you know, I am looking at where we are going now a days, and we are trading. We are trading privacy for convenience, so each one of us carries a Gmail account and puts all our emails into that account because it's very very convenient for us. But the price that we pay is that we have the big company, one of the biggest actually read all our emails and they make a lot of conclusions from those emails.

14:22 Part of it is marketing and advertisement, but there is much much more than that. And we are willing to do it, because we kind of rely on the regulator to actually block this company from doing bad things. [INAUDIBLE] in our case we are looking at the medical regulations which are even more strict in comparison to consumer market okay, and those regulations kind of tells you what to do with medical information and when we shall later go to the consumer market we shall stay with the same kind of regulation, because frankly we feel that in the very near future every kind of data can be looked at as medical information okay. And we are seeing, we are seeing this trend to be happening I mean, apple just bought a company that is measuring sleep using their apple watch which is [suddenly] a consumer product, they are now companied Tom Insel from [INAUDIBLE] just left [INAUDIBLE]. Tom Insel was the head of NIMH, NIH in Washington and he just joined a company that is actually going to monitor, psychiatric disorders using the phone, using the time and the amount of emails that you send, the length of the emails text that you write in those

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emails, so this is all consumer information correct. Consumer information that basically google can monitor, or any operating system that is on the phone or any app that is on the phone and as you can see, this is now being converted into medical information. When it is converted to medical information and medical conclusions [INAUDIBLE] then suddenly this consumer data becomes to be falling, or maybe not now, but we believe that it should be changed, to be falling under the medical regulations of data privacy etc etc and we are taking this approach already.

16:47 I: Yeah, actually following up a bit on some of the big companies and what they are doing, have you seen the Facebook wanting to take on BCI its coverage in the media.

E: Yeah I: Any thoughts about that? E: Again, as I mentioned, we would trade off privacy for convenience. In that case I think its a little dangerous potential trade off, so I am not sure when that will happen. There was a little bit of confusion in that specific movie, because they were mainly talking about implantable devices which are down to kind of very sick people, for example the ALS person, that was shown in the movie, I do not see in the near future to say the least, anyone going to an implantable device without a reason. Without a medical reason.

17:58 E: When we talk about the non implantable devices or the kind of the attached device then of course I can take, just like I can take the watch off my wrist. I can take off the band from my hand etc so then I can control when it is that I am using the device and when it is that I am not using this. Again going back to the analogy I can close the window when I feel that I need the privacy. And I can keep the window open when I want to do that. So I believe that consumers will have to be aware of that. You have to be careful not to leave that window open when they don't want to. But as long as they are given the opportunity to shut this window, and it is absolutely at their discursion then I feel that everything is possible.

18:59 I: Okay, yeah it's one of those things that struck me as well was the inclusion of invasive BCIs and the in the explanation to people how the devices going to work and what they are doing it seemed a bit strange that they would include that, but yeah.

E: It cause confusion I: It seems to be a general thing that happens a lot in public media when they are trying to explain BCIs. Do you agree with that, that it's something that happens a lot? 19:38 E: I don't know, you know, it's, I'm not, I think this is outside of the scope of your questions. You know, sometimes there are this confusion, is being created because of people are not accurately trying to describe what it is that they want to do but, the truth of it is we don't know. The truth is that we frankly don't know, I mean there are now a days kind of grain or [fries] kind of devices that are being gently implanted under the skin for RFID for various security issues. So you know, the words invasive may become very very minor in this case, if this is just subcutaneous then it's almost non invasive where if this is what is called depth electrodes namely an electrode that is being inserted deep inside the brain, this is being done these days you know for Parkinson's patients, for even mood and bulimia disorders, but definitely not done for patients without the need for such an implant.

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20:56 I: Good, yeah so another thing that is being brought up in research is that a concern that BCI will change the concept of identity and ourselves. Is that something you can relate to or?

E: I mean the internet as a whole is changing our identity, is changing the way we communicate with people. I mean, in the past people used to meet other people you know, with various social or professional events, now suddenly there are ways to meet a huge number of people based on specific similar desire etc suddenly you can write a post on Facebook and the person that is on the other side of the ocean that you have never met or known may respond and to be interesting in that, so a lot of things are changing and I believe that BCI is just going to be another step in that direction of connecting us to the web at all times and [vanishing] is also filling sometimes the other direction of not benefitting the fact that we are connected all the time.

22:38 I: Okay yeah, so yeah you already mentioned that privacy is something you think about, so maybe instead of answering whether you are concerned about privacy, maybe talk a bit about what you then try to do to address this concern. E: [As a business] I believe that this is an example of a case where technology is happening ahead of regulation. So we assume that the regulation on this new technology will arrive at some point and will be very strict. And we are now trying, already to think about what specifically that regulation is going to be and we are already thinking of [alto-traffic] specifically there is what is called HIPAA compliance which is the regulation for storing medical information on the cloud or outside of you know the local disk that you used to give to the patient and still do. 24:40 E: And this is really the guideline of how to work in this area. I: Okay, yeah so actually this confusion about non invasive and invasive BCIs and having a tendency of lumping it all together in one category is something we see in research sometimes so one of the concerns that I have seen in some of the literature is the sort of the same concern that there is with pace makers. So that if they are not a secure they may be hacked and that might have health implications, is that something you see as well?

24:40 E: I see and I talk about it a lot. And again this is a perfect example of a non regulated area, because it is not conceivable that such a pace maker that can be hacked and can actually, one can kill remotely that patient, who is wearing the pace maker, because the pace maker now comes with a defibrillator so one can shock electrically the person until the person die, or release insulin from an insulin pump and kill the diabetes patient. So it is kind of amazing that there is no yet guidelines for how to conserve those devices and not let them be hacked, because frankly the same kind of security that we expect from our bank computers or from any other very sensitive piece of information should be applied to those little devices in our body. But of course it is a huge challenge, because in the bank, those computers are connected to an enormous amount of electricity. The pace maker runs on a battery that is supposed to last for five years, and you can imagine the difficulty in replacing the battery. So there is an enormous challenge, a new challenge to computer scientists to come up with a strong enough layer of security that runs on very low power. And that is a challenge, and the regulation will go with that, but eventually yes, because we like the vice president of the united states, the previous one may decide to disconnect their pacemaker from the internet and sacrifice something in that direction. But for the sake of maintaining their safety.

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26:56 I: Yeah, do you see this as something that's a concern for consumer BCIs as well?

E: Not sure, I am not sure, as I said I really feel that in the very near future there is going to be a strong correlation or connection between consumer and can I just hold for one second?

[Interruption to deal with incoming phone call]

28:30 E: Okay I am with you.

I: The next thing that I find the research community is that there is a lot of discussion about side effects of using BCIs. What is your take on that?

E: Well I don't know what you refer as a side effect but there is now a well discussed lets call it side effects of using ways or other [INAUDIBLE] tools that certain and very important part of the brain is actually not is actually becoming inactive and there is a huge issue about that. So if this is what you mean by side effects?

I: I mean it's a bit whatever you consider a possible concern of side effects.

E: I mean some side effects to me is not an issue, so [INAUDIBLE] our fine motor skills are being affected from typing on the computer instead of writing with hand writing, and maybe in a generation or two, people will not be doing any handwriting at all, but still people will be drawing, people will be playing musical instruments, so there will be a lot of other ways to kind of maintain this skill. And yes, if the communication method will change dramatically, yes there will be side effects, but I would prefer now a days a person that types on the keyboard very very fast without errors, in comparison to a person who writes beautiful handwriting.

30:37 So you know, that's part of the change in skills, you know in the past we had to walk for many kilometres, now a days we have to know how to drive a car, and very soon we will only need to know how to run the application to get a car to pick us.

30:55 So yeah, there is of course a lot of changes and you know, that is part of, yeah we are living in a very interesting time, where technology changes very very rapidly and there are implications. Nothing wrong with that.

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31:10 I: No, yeah, actually very much following up on that, another concern in the community seems to be the risk of leaving people behind, that some people might not have access to BCIs and if it gets incorporated in our daily life, and in our work life that some people will not be able to follow. Is that something you think about as well?

31:39 E: I agree, this is actually a huge risk, because really what is happening is that slowly but surely some people say too fast, we are seeing that the more low kind of level jobs. Are being taken by computers, by robots, I mean, you know, the taxi drivers today really needs to know how to run a navigation software and to drive as opposed to having to know by heart the whole city. You know we used to build cars by hand, we now build them by robots. So yes, it is not the scientist, the nuclear scientist that are being replaced, it is those people who are doing more routine kind of job, and that's going to be a huge huge concern, way before the BCI becomes a concern. So because if in the past that sector producing cars gave the job to a number, a huge number of families. Now a days it is going to be the owner of the factory that will own the robots that are building the cars and there will be very very small number of of workers in that factory, monitoring the robots. So what is going to happen with those families?

33:27 Because clearly those people who were able to do this routine work are not going to be able to change their profession. Those people that are more limited in their capacity to learn more advanced jobs are going to be very limited. So the whole world is going into a place where agriculture is going to be mechanised you know. Everything is going to be mechanised and it is not clear how the world will cope with this social problem. So yeah. I am aware of it, that's, I am actually curious to see what will happen, I believe it will have to change. It will have to change it will have to happen as part of the regulation of company, or I suppose countries or states. And there will be just like we have ways to access the [phone] for disabled people there will have to be regulation that will enable ways to access the [phone] for various types of disabilities.

34:39 Whether its going to be motor disabilities, cognitive disability, emotional disability etc.

34:47 I: So you see that if BCI becomes the main way to interact with your computer the internet and so forth, there needs to be some regulation, so that companies and states doesn't neglect people who can't use BCIs?

E: Exactly, just exactly in the same way we deal with the current disabilities now a days.

I: Do you think that there needs to be new regulations for BCI or do you think that E: Yes I: the current regulation already covers? E: No I mean, the regulation that says that a buss should be equipped with mechanisms to enable a person in a wheel chair to get on the buss is totally different regulation than what we would need to have for BCI, but the same concept is gonna hold.



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35:39 I: Okay, yeah, very interesting. Okay yeah, so actually moving it a bit in a different direction, so when you are developing on your BCI what sort of methods do you use to make sure that the changes you're making is something that desired not only by your users, but also by society in general?

E: What exactly do you mean?

I: Well I am just wondering whether there is any particular things you do to try and engage with the community around or the people who might be affected by the technology. Are there any ways that you are trying to get a sense of what they are getting out of it and stuff like that?

E: So of course, that's rule number one, is listen to the costumers.

36:44 And of course we are doing that, over time. The costumers may be in our case the patients, maybe the caregivers of those patients, it may be the family members of those patients. This is when talking about the medical aspects. When talking about the more life style, wellness aspects, then it's really easier to decide who the costumers are and of course they have to be [wishful] [INAUDIBLE] as well as maintaining their privacy etc. So yeah, that's really [INAUDIBLE] rule number one, talk to the costumers.

37:32 I: Do you see that discussion and back and forth feedback changing when you are moving it into a consumer setting compared to the research you are doing right now?

E: Absolutely, you know, a medical doctor that has received a lot of medical education is very different than a consumer who just wants something very very simple to work with. Otherwise it's simply, you know no one reads manuals anymore. So you have to take that into account, you have to be [inaudible] explanatory and explain what to do. But at the same time we need to maintain the sophistication that you want to maintain there.

38:25 I: Yeah, another thing that is being discussed a lot is the neuro enhancement or cognitive enhancement and even in that topic there is large variety of things they are talking about. But is that something you thought about as well?

38:45 E: This is actually one of my main interests, so while scientists are trying to built the most advanced robot, and the most advanced computer AI algorithms that will be close to humans. We are actually trying to think how to take advantage of AI, robots, [INAUDIBLE] etc. to actually enhance human brains. We believe that [INAUDIBLE] the future enhancement in the intelligence of other species I mean robots etc as

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humans we have to take another step forward to maintain and kind of what I talked about before those [workers] that are now [robots] would [INAUDIBLE]. And this is really our main interest, that the statistics today that one out of six kids suffers from some kind of brain development disorder, that's a huge number. I: Sorry what did you say? One out of? E: Six kids suffer from one or more brain development disorders, so in [part of the statistics] that's shown the emotional issues, the attention issues, all together this becomes this huge number [inaudible] and those that will survive and will become good citizens etc, however if we can help them at an early stage with their disability, alleviate or remove the problem. This is something that we are extremely interested in.

40:44 I: Good, okay. E: And if we can do that with a consumer product, so from their perspective they will be playing a computer game or any other game. But at the same time we should be enhancing their brain, then we catch two birds, in one hand.

41:05 I: Yeah, since you are working in both fields you are probably aware of this, but informed consent is something that is a very big concern in the research and medical setting, how do you see that in a consumer setting?

41:28 E: So, as I said already a few times, I really feel that we are getting to that stage where all the information that is being collected on us from the GPS from the location of where we are, and from the emails that we send and from the voice messages and from Alexa that we speak to etc will eventually be used, can be used and therefore will be used for various source of medical application, so we actually consider the medical regulation and informed consent that requires the patient, not the patient the subject to fully understand what it is that is going to happen etc, actually this is really [feel its] going to be the only guideline.

42:31 E: And of course it will be up to the state, the legislator to regulate it because of course I will always be able to download an app, but those stores that provides me with those apps will have to adhere to those regulations.

42:54 I: And do you see any good solutions to actually make sure that there is informed consent because, in the consumer market as it is. It is very much a term of use kind of contract that people are agreeing to. But that's not really a great way to get informed consent, so how do you see that panning out?

43:19 E: I am not sure, I am not sure. It is really up to the regulator to one, make sure it happens, but two, make it easy to use. I don't want to have to go to lawyers to do that of course so. It has to really trade off between ease of use and at the same time make sure that the lay person is going to understand what is going on.

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43:46 E: And what it is that they are agreeing to. I believe that there will be a lot of consumer organisations that will be the watchdogs of consumers, making sure that you know, those who will be the most sophisticated people that will be guarding the general public.

44:12 I: Okay, yeah that actually ties very well into my two last questions. So yeah, the second last one is, many of the topics we discussed ties to some extent into the concern about policy gaps or legal concerns, besides the ones we talked about with informed consent and privacy and stuff like that. Is there any legal concerns that you are worried about?

44:42 E: Well, you know, if we are getting closer to persons brain, and actually affecting that persons brain. Clearly there may be legal issues involved. One has to be aware of that, you know, if I give you a toy that you play and you fall and you break a leg, then [INAUDIBLE] safety issues but then when we look to safety in the past, it really was kind of mechanical safety. I didn't want the paint to be toxic, I didn't want the thing to break in my hand and maybe injure me. And now we are talking about medical safety, but it's not a medical safety in the sense that the medication is toxic or dangerous, it's a medical safety in terms of providing you say for example with a neuro feedback that can cause trouble. That is a huge topic, that will unfold in the next several years, many years as technology gets into more and more fields. But we can really see where it can take you.

46:06 I: Is there anything you are specifically worried about not being addressed?

E: I think I've covered a lot of things that have to be addressed, I believe that the regulators will really have to work very very hard to think about all the possible aspects of this. To really maintain a more stable safe conditions in this new era okay? But you know, having said that. It's obvious that there will still be people that will be unplugging their freon from their ventilator from their air-condition [then they] kind of inhaling this. So you know, there will be a lot of ways to overcome as there are now for various things.

47:13 And we, I think as I mentioned those consumer organisations, those consumer groups will have to be the watchdogs, will have to be really indicating this and suggesting ways to do with it.

47:36 Maybe I'll mention one issue that is very close to what we do. There are rules now in Europe when it is that you go to the family and offer the family to have their loved one who is apparently considered to be braindead when you offer the family to donate his organs to other living human beings. And as we understand it, it's a huge problem, there is a huge list of people waiting for donations which can save their lives etc etc. So it's obvious why it's very important, but of course the huge concern that maybe you are actually going to practically kill someone that could wake up and become awake again. And there is a famous case now in France of a person called [Vincent Lamberg] where the high court of human rights, the European court of human rights, enabled his wife to become his guardian and decide to disconnect the person from the feeding tube. But he said, since that person never gave such a consent when he was

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awake, then they need the consent of doctors saying that he is suffering from irreversible damage and there is no chance or extreme high probability that he will not wake up.

49:24 And the doctors said very clearly, we don't know. So this is the state of medicine now a days. We know when the kidney is not functioning, we know when we do not produce insulin, but when we come to this very sophisticated organ, which is our brain. Currently that's the state of chaos, we don't know. You know there are some cases where it is easier to know, but in this case they said, we don't.

49:57 And you can imagine, that such a problem about 200.000 people go into coma every year in the US, so this is not a small number. You know, from car accidents, from strokes, from heart attacks, from a lot of cases where suddenly there is no oxygen arriving to the brain so. This is a huge problem and one if we can really address it in the right way, that will take into the account those people who are waiting for donation and those people who are potentially alive. That's a huge huge challenge to deal with.

50:40 I: Basically just before we stop, just whether there is anything we haven't covered, that is a concern for consumer BCIs or something just BCIs in general?

51:00 E: No, I believe we covered, we did not cover. Well I believe we covered everything.

51:07 I: Well that's it then.

### 8.2.7 Research stakeholder 1

I: Interviewer

R: Researcher

I: If you wouldn't mind, maybe first you could introduce yourself in a couple of sentences? R: Sure, my name is [NAME] I am a senior researcher at the university of [CITY], in [COUNTRY] and my research is mostly about adaptive cognitive interaction systems. That means, systems which measure, they uses state in a certain way. For example using BCI technology or other sensors and use this information to provide an adaptive system behaviour or an adaptive human computer interface which suits optimally what the system thinks the user state is.

00:51 I: Okay, so more of a passive use of the BCI to react to what the user is, what state the user is in:

R: Yeah mostly, in this active passive dichotomy we are mostly, or my research is mostly located in the passive BCI area. We are looking into certain active BCI applications as well, so for example, SSVP based control BCIs for [INAUDIBLE] reality devices or something like that. But passive BCI is more our area of active research at the moment.

01:38 I: Okay, so yeah following nicely up to that, what do you actually hope that your research will bring forth?

R: Well, my goal is always to provide smooth intuitive and efficient user experience. So my goal is always to. So I am less interested in only measuring how good can we decode certain activities or states, but in the end I am always interested in how does that help to significantly improve a user experience. Whether for example existing systems, so I am less interested in building a pure BCI system which or force BCI into everything where it could potentially be a sub-optimal replacement for established interaction components but more as a complement to measure user states and user situations to which we with other means don't have. Don't have access to.

03:01 And with that broader challenge I think we can improve the usability of many HCI systems. I: Okay so, are you then mainly thinking normal ability persons who already can interact with computers in a normal fashion and then how you can add on that or is it improving interaction for those who might not have access through normal means?

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03:30 R: So, my research is not with patients so I am usually targeting, able bodied, and healthy users and try to enhance their user experience. I mean many of the things I do would also work probably with patients I assume, but I never worked in that area.

03:58 I: Okay so yeah okay, So yeah in the literature there is a lot of discussion about the issue of misinterpretation of data and the accuracy of data, is that something you worry about as well?

04:15 R: Well you always have to care about that your, the BCI will never be very accurate. I think that is impossible, we have, we have seen large improvements in [testification] accuracy in the last decades, lets say. And I think there is a lot of potential for more improvement, but you always have to deal with that the BCI works on a very noisy channel. And it will provide misinterpretation so it can never 100% trust the output of the BCI. And you have to build systems which embrace that uncertainty so for example the systems I am building or studies that I do always take that into account.

05:11 So that means, you always have to weight the risk okay so, I know this is the result so, what if that classification was wrong in a given instance or what would be the consequences for example. Would a mistake of the BCI incur really high cost. Compare that, weighted by the confidence we have in the BCI results by the benefits if we actually used or get the correct output. Something like that, so you have to take that into account, but I'm not actually worried about that. I mean, basically all of these channels which rely to some extent on machine-learning have that attribute. So it's not very specific to BCI, I mean BCI is one of the most challenging modalities, which are regularly used in HCI at the moment. But I mean, every gesture recognition, face interpretation voice analysis software. All these systems rely on statistics and machine learning and all of these allow misinterpretation by the machine or faulty classification results.

06:43 You have to come up with a scheme for HCI which erases this, and I think if you do that. You can cope with that.

I: Do you think that the nature of BCI has a different impact on users than for example voice recognition. It seems like some users has been sort of getting used to the fact that voice recognition is not always 100% accurate. Do users actually know that BCIs are not accurate then?

07:21 R: You mean the perceived accuracy? I: Yeah R: I think that's very hard to compare because at the moment BCIs and for example voice recognition software they work on completely different levels of maturity. So for example voice analysis software has come a really long way. So now, every smart phone you buy has really nice working voice or speech recognition software for example.

08:05 But say 15 years ago, 20 years ago nobody expected it to work that well. I mean back then you were surprised if the system actually got something right outside of a lab situation for example so. BCI is

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probably a long way to go to get to that point. Or to get to a point where there is a convergence of what people think that systems can do. And what systems can actually do. But, it's really hard to compare so of course I think expectations are different between the two, but that is probably due to the very different maturity level, of maturity and different levels of user experience.

09:02 I mean no, most, basically nobody has exposure to BCIs on a regular basis. But many of us, at least have access to voice enabled devices.

09:19 And I think that makes a huge difference. I: Okay, actually following up nicely on that, the whole expectations things is also something that is brought up in the literature as well. So do you see any concerns with the way the public is engaged with this and maybe how BCIs or neuroscience is portrayed in the media and to the public?

09:44 R: I don't have very concrete examples but I think it's, what always is difficult is when BCI is framed in something like a mind reading context. Because that is usually never the case. So a colleague of mine [NAME] is doing research on text decoding from neuro-signals which are measured by ECOG, so with implants. But so, he got, there was a lot of press and there is always questions about, okay can we, can soon somebody read my mind and try to record all my secret thoughts etc.

10:38 I think that is always, a very dangerous framing and a framing which is not accurate to the state of current BCIs and probably to all BCIs which are, which are possible in, with the technology we currently have. So that's a problem, and yeah apart from that. I mean, much other coverages in press regarding BCI is usually the more driven by I think, more on a curiosity level so it's still not about okay this will be right now super useful for my daily life. But more an okay look what we can actually decode, so they are for example locked in people who can now communicate again with their systems or they are useful approached where everyone understands that okay we wont always have an EEG cap on our head when we use our computers for example, but these are outlooks into the quite possible future and I think there is a more positive, more positive and yeah curiosity driven coverage regarding these aspects.

12:23 I: Okay, so yeah, one of the things also mentioned in the literature is that some are concerned that the fact that it gives us an insight into what is going on in our brain and the place that the brain has been given in society and our understanding in ourselves, that having that insight might change our concept of identity. Is that something you can follow as well?

12:56 R: Yes, so I think. So for me this, I also see this discussions for me, these conclusions are very far fetched. I mean, basically every BCI which we currently have, these are classifiers or regression models, and so that means, you have a clearly defined target which you try to predict. You train from labelled data which means you say or supervised learning which means you tell your BCI, okay this is the concept I like you to detect and this is the data I give you which contains this information, so the BCI, every BCI is

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specialised to model one or a small number of very specific traits, attributes, whatever. And these are I mean, we are talking about concepts like attention, vigilance, workload, confusion, something like that so these are concepts which are of course, relevant to our cognition and how we behave. I mean otherwise they would be useful to measure those. But I think there is very far away from modelling something like, or modelling very broad concepts like I mean, or yeah, our self image or our yeah, how we model our own identity. I mean these are constructs, where everyone even struggles to give a clear cut definition of what that would be or how that would, or how that could be operationalised in a BCI.

15:28 And if you don't have that, so if you can't describe in a formal way okay what is your, inner self representation. How does that look like? Where is that located in the brain? What switch, features actually modulate this etc. So if you don't have that, there is no way you can build a BCI which tackles any of these concepts. So, I don't see that there is a really tight connection there. So, not beyond anything you could do from for example external observation. So we can look at micro expressions in the face and of course decode really relevant information about cognitive processes going on. And then say something about the person you are observing. But that is still not yeah, looking at these very, very broadly very cloudily defined concepts. And as long as you don't have that very precise description of what you want to model, you won't build a BCI which does that.

16:47 I: Okay, good, yeah. So yeah, maybe a bit of an obvious one, but a lot of people talk about privacy as an issue. What are your thoughts about that?

16:59 R: Again, I don't think that most. Of course privacy is an important issue. But I think it is not BCI specific at all. I mean as soon as there are sensors involved privacy is a relevant issue and you have to make sure that you handle the data properly and yeah, don't give open access or unsecured Wi-Fi whatever. But that holds for every sensor and given that it's basically impossible to use a BCI without the user knowing that he is using a BCI. I think privacy is less an issue than for other sensors. So for example a camera or microphone that can easily be hidden or it's unclear whether it's currently capturing data or not.

18:00 For BCI you don't have that, because, I mean you put the device on when you want to use it and there is no way that somebody will secretly put EEG electrodes on your head without you noticing. And as I said, so the constructs that you measure, well of course people have to, they need a certain understanding of what the system is measuring from their brain. But as I said, for any BCI which we currently have this needs to be clearly defined for the BCI to actually work.

18:46 So that's also information which can be revealed to the user so that must. So this information must be available and if you would, if you are a reasonable supplier of a BCI would, you would give this information to your users. And I think then there would also be no [principle] privacy concerns regarding what the system is actually getting out of your. Getting out of your thoughts or your brain.



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19:19 I: Okay, but yeah, so you basically say that the whole privacy issue is not something specific for BCIs because the data is not more sensitive than what you could get from other sensors?

19:35 R: Yes, so that's. I mean so one difference you could make is regarding the raw data, so I think that at least needs to be transparent to the user whether the system is recording the raw data. Because at least in principle future analysis methods could reveal at least to a certain extent other information than what could be available right now from what you extract.

20:14 So that depends on, at least this needs to be made clear to the user whether the system is only measuring a certain specific construct and only storing or passing on that information. Or whether it's recording and storing the raw data for future processing for example.

20:37 I: Just, a thing popped into my head, I wonder if that is because of the current state of BCIs, because maybe when cameras were first developed. Maybe you would say the same thing, that you could analyse things in the future that you might not know now that you could.

21:02 R: Yeah, that's probably the case, that's probably true. I mean for, no yeah I would agree with that.

21:19 I: Okay, so yeah, in the literature there is a bit of a thing going where they tend to lump BCIs together into one thing. So you talk about BCIs you talk about invasive, non invasive, it's, everything is the same thing. So some have raised the concern that there is also a security concern, which I personally relate more to invasive BCIs, where there could be a security concern in the same way as there is with pacemakers where they could be hacked and that could have an impact on your physical health. Is that something you can see as well with BCIs?

22:11 R: Uhm, that depends on multiple factors I would say. So first, I think that doesn't really. So it depends of course on what you actually do with the BCI data, right? So if you are, if you use it to control a robot or a car or whatever so. Some of these toy examples of course there could be security issues. But for more realistic examples I think that you are mostly moving into the area of medical applications and there I think again it's not very specific to BCI. I mean sure, if you are using invasive BCI and you are, your patient is by definition of an invasive BCI very vulnerable so of course everything is a security issue basically.

23:27 And of course if you use, the BCI for example to influence active components so for example there is brain stimulation which works together with a BCI component for example or where there are other, other systems for example to suppress seizures or something like that. Or control prostheses sure, I mean, these could in principle be hacked and attacked, and that's probably in the same, in the same security level ballpark as pace makers for example are. So where patients are comparably vulnerable and there are the same venues of attack. I think BCI, so BCI as they are available currently they are highly individualised solutions.

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So I think they are probably actually fewer attack vectors because I mean, for a reasonable attack you need to know the system and know where a vulnerable, where it has its flaws and where you can attack.

24:58 And it's more of a case for mass market medical devices than it is for the very individualised BCIs, so if we consider, if we consider BCIs which are, which would have the same level of maturity I guess they would be in the same category as for example pace makers are. How you would need to make sure that, that they can't be attacked.

25:40 Yeah, I think for now that's a theoretical risk.

25:44 I: So yeah, another big thing in the literature is the concern about side effects. Do you have any thoughts about that?

26:01 R: Will you give me a little more info about what, what side effects you think, you are thinking about?  
I: I mean, there is quite a wide range about side effects in the literature, there is stuff like skin irritation which is more for the non invasive, and then there is for the invasive BCIs there is stuff like break downs and infections and stuff like that and for. And then there is even a completely side thing which is the side effect of how it might affect human beings, and society and everything. Which is sort of a whole different category of side effect so there is both, sort of the medical ones and then there is societal ones.

27:01 R: Yeah, so regarding, regarding the medical, medical side effects. So of course for invasive BCIs there will always be. Risks. I mean it's a highly, highly invasive technology. And the risk will always be there, and will always be substantial. So you would never use invasive BCIs if there is no pressuring medical implications to do so. So for example quality of life is so low without say a channel of communication or if you really need that to find out or to control seizures for example. So these, you really need a strong trade off to actually take those risks. And probably, I mean I am no doctor so, but I can talk about the how that can be mitigated or what to do. What you could do there but there will probably always be a risk remain, and you have to find that trade off and you have to make that probably individually for each patient just as. And invasive BCI that will always be administered by a medical doctor, so these will of course never be systems which you would buy or get at the store or BCI service or whatever. They will always be a hospital only [from what I can see]. Regarding the, regarding the other, so for healthy users, I say that the side effects from a medical perspective they are really minuscule so I mean. So many new devices are available or come up. You don't have to use [embrasive] gel anymore, I mean there are devices which works completely without any gel which could irritate skin for example.

29:47 Yeah, so I mean, there is [suoceptible???) to use current BCI, but the technology is moving so fast, yeah so I would say that this is really minor. And should be improving over time. And yeah, of course regarding the societal aspects, there probably is potential for side effects there, as again, I think for a [heavy] systems which on a regular basis monitor our behaviour. And that may of course change how we

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behave, how we think, how we try to control ourselves for example. I think there is a potential issue there, but that's so regarding BCI again, that's so the thing about BCI is that you can still as I said, control [really fine] when you are using it and for what purpose you are using it. So you actually have a better control about, in which situations you would be influenced by BCI. Than for example cameras which are all over the place in your, on the airport or whatever so. We're constantly monitored basically, that might of course change.

31:32 For example once your, when your boss forces you to use a BCI to monitor your workload or whatever but I mean there are plenty of other technologies which could be misused in that way. And I think that's a really large and important discussion but again BCIs plays only part in that discussion and there is many. There are many other technologies which basically go the same route or could be misused in the same way.

32:09 I: Yeah, actually that goes nicely into the next question, so in the past we have seen technology items go from being you know a research tool and even then to a work tool and then all of a sudden it's something that everyone needs to have and needs to know how to operate. Which sometimes leaves some part of the society without these tools and that leaves them at a disadvantageous situation. Is that something you see as well in the future for BCIs?

32:54 R: Again, not to an extent which is super BCI specific. So I mean of course there is, what you say, the digital divide or is that how it's called? And that's, that's potentially a really huge issue for society I mean, if you really would go mass [mar..] had a BCI application which would appeal to the mass market. And which could be useful in the mass market you would, you would be able to. I mean for the price of people are regularly paying for the new iPhone, you could build a BCI. I mean that wouldn't be the best BCI in the world probably. Of course you could always use medical grade sensor technology etc, and that would not be required for, for something that would imagine could be a mass market BCI.

34:06 So I mean, there are, if you look at these. I mean there were toys which had BCI sensors in them. They were crap but, never the less it was basically the technology in there which you would need to have a working BCI. And there are, there are other people who build research grade BCIs for ten thousands marks, there is open BCI so if you would really. If you had an application where you would imagine that you could sell millions, a million copies of you could build. And you could build something which most people in the western world could afford if that would relevant or useful to them. So in the honour of more expensive smartphones. Well if you look at a more global scale of course that changes. But that changes for all other useful applications devices as well. So, there are many many things that can enhance our lives which can, which helps us tremendously and which costs, substantial money. And there are people who can afford it and people who don't but, I think, I don't think BCI opens an, opens an area where only the richest 5% could afford it.

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35:51 I: Okay, good. Yes so, in pretty much all neuroscience or neuroethics literature there is some mentioning of brain enhancement. Is that something you see where BCIs might have a role as well?

36:16 R: So are you talking about stimulation, electric stimulation for example or trans-cranial stimulation?  
I: Again, this is where the term BCI is being applied very broadly, but yes, that is often where this discussion have found place.

R: Yeah, I mean, I mean that is the thing, BCI as it's defined is a measuring tool, so whenever you try to enhance something, and maybe the cognition itself or the mind itself, you need some sort of actuator. So and that actuator could also be inside the brain of course, and there are medical applications which tries to do that. So for example as I have already mentioned, detecting seizures and trying to counter them in certain way. And you could of course, theoretically, I am no expert in that regard, you could of course think about other applications which try to enhance your focus on an application when the BCI detects that you are distracted for example and then the, your stimulator is tuned up and you are more focused on a given task. Something like that, I am only making stuff up.

37:45 But, so at least that would be outside of what you would call BCI, so the BCI would only be the measuring aspect of that. And, yeah if you think about that, so research in that stimulation area is really, I mean, it's not as it was as what we know about, what we know about BCI I'd say. So there are certain, there are specific applications which are, where research is really, is really advanced, like for example, controlling tremors, or seizures or yeah things like that. But these acting target really broad concepts.

38:40 If you want to have a general purpose cognition enhancer basically no body knows how you would build those. So there is a lot of focused research in that area, so there are many people claiming they build a mind enhancer, and actually doesn't do a thing, or is even dangerous. Yeah, so, I, I don't think we, there is enough knowledge to give a really educated answer to that from my perspective.

39:25 So I think, most, most thinking about that is probably, from my point of view, guess work. So, people make up what you could in theory, or what you could imagine, such an enhancer could do. And then reason about whether that would be dangerous to society or individuals or whatever, but as long as we don't have a clearer picture of what is actually possible, and what are, what would be the side effects, I think it's not useful to really discuss that.

40:08 I: Okay, so yeah, 3 more questions, yeah 3 more questions. So yeah, let me see, yeah so another thing is. Informed consent, and user autonomy, have any thoughts about that?

40:32 R: Yeah, I think I already talked about that in my previous statements so yeah of course that is an important thing. I think BCIs have the. Have the characteristics that basically, you can't be forced to use. So

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BCI can't be used secretly, I think the informed consent is right now. It's not really an issue, and what is important is transparency so people, people need to have a clear understanding of what the system is measuring and what results are given to, to the application or how the information is used. And of course, the clearer this understanding is the better people can actually decide whether this is something they want or whether they don't need or want that.

41:48 I: No, and I think the reason why I personally think it is such a big issue in the literature is because it seems like a lot of the research is being done regarding ALS patients and people who can't communicate themselves so that sort of pushes the whole issue of, how do we get someone to agree that can't communicate with us and I think that is really why it's.

42:14 R: Sure, I think that's a super important issue, but I think that's an issue of this condition people have and that's, I mean for, that is true for every treatment. I mean, the BCI at least in theory would, that would increase user autonomy if it works correctly right. So of course, it may be the case that people don't want, don't want that, but giving them opportunities for communicating with us, will allow them to I mean, maybe you put, you use the BCI, the first thing that people spell is "put that thing off" or. But that would still be better than for all the other treatments people get where they don't have any chance of back-channelling what they, or give feedback what they feel about that treatment.

43:10 So if you administer medicine, they have no say at all, it's the doctor says okay we use that and, that's it so. I think if, if anything the BCI increases user autonomy, in these very very difficult cases where user autonomy is basically at the lowest point possible.

43:37 I: Okay, so yeah, this is I guess a bit more into you and what would BCIs, so I was wondering, when you are developing with BCIs, what kind of things do you actually do to try and make sure that the ones who will be using the BCI is, wants the same thing as you do, from the BCI, how do you actually engage with that figure out what you should be working on with the BCI?

44:17 R: You mean that, the developments we are looking for are things that people actually want? Is that what you are asking? I: Yeah, I mean, the thing is I am looking at both the commercial side and the researcher side, so for the commercial side this question at least make very much sense, how do you make sure that your users wants the thing you want. But can you see the same relation for a researcher?

44:54 R: Of course yes, so for me that's, that's really important because, I see my research as I introduced myself as a, as a component to improve user inter, or computer interaction. And in that regard of course you have to look at, you have to come from both sides and have an understanding of, what the BCIs, actually capable of decoding from the brain.

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45:32 But also come from the HCI perspective and see, okay, what are actually usability deficits which a BCI could improve on. And really come from both sides and find, where does these actually match. So I think, so for my research I am always, I am always looking for such situations where you could really build an application or have something which is embedded in a, in a realistic user experience setting. And then look at, yeah how could you actually improve usability there. And these usability, these HCI settings are usually of something people can connect to.

46:35 So for example the research you mentioned in your first email was about detecting when your auto correction fails, whether we can detect and help in such situations, using a BCI. And I think that this is something many people can connect to which, tries to solve an actual usability short coming of current systems. And of course that is important to do, from my perspective. So I think there is too much research in BCI, which is focused on signal processing and machine-learning and working on interesting data, which is, all of this is really important of course. But if in the end you build a BCI which no one can use because there is always technology which solves the same problem in a better way then, all your research is basically. It doesn't go anywhere, so I think it is an important thing.

47:41 I: Okay, do you have any work method that helps you get into that mode where you understand the users? R: I'd say it's well, looking from an HCI perspective in general. And I wouldn't say we have a formalised method for doing that, of course there is participatory development, which we, which we sometimes use. We haven't used that regarding BCI, but for other bio-physiological interfaces, so that would of course be a way to, to learn about that in a better way. But yeah, in general not start with a finished BCI and then see what you can do with that, but looking from an HCI perspective first, and see okay, what are usability concerns and try to work on those.

48:55 I: Okay, good. Yeah so, the last one is basically a free for all, you can raise any concerns you might have, but before that the last questions is regarding the fact many of these are tied into policy gaps or legal concerns as well. I am just wondering whether you see anyone, any specific concerns there as well?

49:24 R: ...

49:36 R: I don't think so, I mean what would be important would be again, a better representation or modelling of such, of all these intelligent sensor applications of which BCI is part of. In our current laws and regulations. I think many of these are very specific, for example only focusing on video surveillance, so this is the thing that everybody currently knows, and this is a tool which political, in politics people work with and they say, okay we need more of this or less of this and people understand that, but it's super specific to that. So, but in reality or in, in what we do there, there is so much more which you would use to decode information about people, in many many ways. So, starting from your smartphone which records so much data about you, of course to BCIs which are another way of decoding information about you, and I think, what would be needed would be a more general understanding of all these components work and not to,

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to really start from scratch again and again, and to always be behind in a next, in the next innovation which comes up and is not covered again by, by your current laws.

51:22 And that would require a better, a better understanding or abstraction of what all these intelligent sensors are capable of, of doing. How they process data and all these things. I think that would actually be important and I would of course cover the BCIs as well.

51:44 I: Okay, good yeah. Oh yeah, as I mentioned the last one is basically whether you have any concerns you stumbled upon or maybe some users you've tried with has brought up?

52:00 R: So I think, so the, one issue where we had few people who were actually concerned was actually what I mentioned before about handling of the raw data. So I think that is more, so at least in our research environment we are of course always interested in collecting raw data, and not only some abstract constructs that, from which we can't recover anything else. And there are a few people who actually were concerned, okay what's, I have no understanding of, of what's in there, and what you can get out of that. I mean, we can assure them, that we won't do anything evil with the data, or find any really deep and hidden thoughts, I think that is basically impossible from skull EEG, but still, I mean there are no, you can't give a [faulty] guarantee there, and that's. I think that is something well, which people were sometimes concerned about.

53:15 I: So the uncertainty of a new innovation and what can we actually do with it, is something that people are concerned about?

R: Yeah so, for, for tools like video and audio, I mean that's both much more mature and technology, but that's also data which can be interpreted much more easily than EEG data, basically when you look at EEG data you see nothing. And you can't explain to people what's happening in the data and what you see there, basically everything that you can get out from the data, needs to be interpreted or pre-processed very heavily and then the connection is, people basically have to trust you that these components actually do what you say that they do, and I think that, that makes it harder for people to, to trust that the system is actually decoding only what you, what you guarantee that it is decoding and nothing besides.

54:26 For a video, you can look at the video and see, okay this is what you can get out of it, what I would get as a human out of it. And if I am fine with that, I can be pretty sure that there is no hidden agenda there or anything like that. And for BCI data that is more difficult to guarantee.

54:49 I: Good, yeah, that's it.

### 8.2.8 Research stakeholder 2

I: Interviewer

R: Researcher

I: First if maybe you could just introduce yourself in a couple of sentences? R: Well I just finished my PhD on brain computer interfacing. I worked mainly on developing sort of a user centric approach to brain computer interfacing. The way I kind of viewed the field, because I come from a mixed background in psychology, math, neuroscience and engineering.

I: That's a good mix. R: Yeah, it was a useful mix, it was kind of an accident, but it was a useful mix in the end. I kind of, I looked at the field and it seemed to me that brain computer interfacing was missing the psychology side of things, a lot more than say the engineering side of thing. It does seem to be dominated by engineers for the most part. Whereas the other field, or the related field I worked in which is neurofeedback I would say has the opposite problem. It's dominated by psychologists with little to no, direction from engineering and statisticians. So for me, I think my contributions to brain computer interfacing involved more looking at how does a human successfully collaborate with a machine learning algorithm in the context of a brain computer interface.

01:31 And in the long term, what I am most interested in is how can we use brain computer interfaces to try and integrate or incorporate certain capabilities of an AI, as part of a human thought process.

01:49 I: Okay, yeah, so I guess that sort of also answers my first follow-up question which is what do you actually hope people will use BCIs for? But maybe you can extend a bit on that?

02:11 R: Sure, so what I mentioned just now is definitely a much more long term idea which I don't know how much of it could be realised within my lifetime. I hope brain computer interfacing I think within my lifetime becomes useful as a way of I think improving peoples ability to reason about issues. As a way of, I guess making certain task easier in a productive way. So helping people work productively and think productively so for example, you're looking at I guess you are comparing say different what should I say, retirement plans for yourself.

03:07 Having a brain computer interface which allows you to kind of glimpse at these plans and allow you to calculate very efficiently or calculate for you maybe, say, because you ask yourself when looking at these plans. If I invest 5000 [CURRENCY] a year to this plan versus 5000 [CURRENCY] a year to that plan, how much, what will be the better plan for me?



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03:33 Having a brain computer interface that maybe allows you to in a more automated way go through those computations like a computer would that in a way that a human can't really do. So that becomes a seamless integration between how a human thinks about problems and how a computer is able to compute solutions to things.

03:54 I: So yeah, through history we have seen technology sometimes be used in a way that wasn't intended in the first place. Is there any such things that you worry about regarding brain computer interfaces?

04:08 R: Uh, yeah a lot of things. I think, I think brain computer interfacing has a lot of potential to improve peoples life, but developing brain computer interfacing in the type of society we have, which is very keen to exploit for capital gain worries me a lot. So. Obviously targeted advertising based on peoples brain activity, the possibility that we will be able to stimulate peoples brain remotely. Having those systems hacked, by people who want to say, read your credit card information or what have you. It's more corporate entities I think that I am worried about the most.

05:04 And the military of course, so the possibility of us, of people. Reading for example when a soldier behaves, is behaving empathetically towards someone who the military doesn't care about and then, using that as a way to retrain in some psychologically sense that soldier so that they don't behave empathetically as much in the future, is a real possibility I think. More so in the nearer term because it's much easier to read thought processes or gross emotions like, this person is feeling empathetically right now, or is conflicted emotionally versus then, in the future being able to directly stimulate networks in the brain to kind of kill that emotion right away for example so.

06:03 There is a lot of ways that brain computer interfacing can and I think will be used against people.

06:10 I: Okay, uhm, do you see any way to maybe prevent some of this?

06:16 R: It's a difficult question like a lot of things, the more people are aware about possibility and how it would work, can allow people to guard against it. The way I look at it is people with more like, I guess I can say nefarious goals, will develop these technologies with or without people who have more positive goals in mind. And so I think it will take people with, who care about the wellbeing of people, more than exploiting people to be able to understand the technologies well enough to point out how and when, and why and where they are being used. Misused.

07:07 And obviously having that kind of knowledge and being able to disseminate it is only a first step, the rest of it, or a lot of it is then political and social.

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07:25 I: Okay, uhm, so yeah, a lot of the following questions will be sort of the topics that are presented in the literature as concerns, so just want to hear your take on some of them.

07:38 So in the literature there is a lot about misinterpretation and the accuracy of data, is that something you concern yourself with as well?

07:48 R: Uhm, yeah, I think especially when brain computer interfacing enters commercial use. I think we have seen for example in court rooms how people misunderstand ideas like false positives and false negatives, we, I mean you can give, have a test that has very high false positive rate and people will still often convict on that basis without understanding the implications of having a very high false positive rate so I can see that down the line being an issue in brain computer interfacing, for example, you'll probably, you'll have, I am sure you will have companies kind of going after this self-diagnosis market, of people who are addicted to websites like WebMD and diagnose themselves with different form of cancer every week.

08:49 Uhm, and you might have a system that somewhat accurately or you can say it has a 99% accuracy in detecting whether you have say, whether you're dephressed, depressed sorry, and need an SSRI, but then they don't tell you that there is a 60% false positive rate, that's part of that, and even if they tell you that in the fine print I think, my sense is that a majority of people are not aware of how to incorporate that into their interpretation of the results. So that's potentially troubling I think.

09:28 I: Okay, uhm, so yeah this sort of ties into that, there is also in the literature a concern about public awareness and how brain computer interfaces but also neuroscience in general is portrayed in the media, is that something you worry about as well?

09:49 R: Well, if we are talking about sort of like, pop culture, and websites like I don't know, the wired or extreme tech or those kind of websites, yeah I think it's not so uncommon that you'll see really sensationalised article which in the first paragraph directly contradicts the abstract of the article they are citing. Which is frustrating and brain computer interfacing, I, I mean there are examples of how it has been hyped in popular media when in reality what we can do with BCIs right now is extremely limited and rudimentary so. I think that trend will continue. I don't really have an answer to that. To how we can address that, because it's all about click bait and money at the end.

10:44 I: Okay, uhm, let me just see here. Yeah, so some of the them also talk about this improvement in our knowledge of the brain and how our mind works, might change the way we see our selves and our own identity. Is that something you see as well?

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11:16 R: You mean in the context of pro, proliferation or brain computer interfacing in society. I: Uhm, both that, but also just the, sort of the side effects of BCI and science in general increasing our knowledge about how our and our mind works.

11:38 R: Yeah, I think, I think that has been happening for centuries, [I mean] science has gradually and often profoundly changed the way we think about ourselves. Some people are more resistant to incorporating that than others. I think brain computer interfacing is in a way, fundamentally different in that. There is a real possibility that it will change us. Uhm, especially going back to the beginning talking about the long term possibility of integrating AI into our brain. I think that does fundamentally change us. Or potentially at least it depends on how well and how much it's possible to actually integrate those two things.

12:25 Uhm, that I think, by definition is something that we can't really understand because it would, right, the sum of human and AI is probably greater than either of those individually put together so, I don't think that we could really even speculate about what that would mean, if it gets to that point. But, so yes to your original question, and also I think that there is a real chance that we'll, we'll actually change us at a fairly fundamental level in terms of how we think and how we perceive things.

13:07 I: And what then about those who are concerned about that?

R: Uhm, it's a difficult question, it depends on their concerns as well. Obviously I don't know what it's like in the UK, I think the UK, you are in the UK right now right? I think it's fairly similar to [COUNTRY] but obviously we see in the [COUNTRY] there is a lot more religious fundamentalism. Obviously they would be part of the group that is concerned about these technologies but I am not sure that their concerns are founded in a realistic view of the world. And what these technologies are in the first place. However there are people who have I think, realistic concerns that we need to take into account.

14:00 And so at some point we are going to need more than just BCI researchers thinking about these problems, which is why it's a good thing that you're thinking about these problems.

14:18 I think that's going to be very difficult to address. The way things have gone traditionally is that progress has kind of made despite the concerns of people, and society has to, is forced to adapt. I don't think there is a stopping or slowing down the development of these technologies in a real sense. I don't see that, that is really a possibility. Aside from you know, even war on a global scale may not greatly slow it down because perhaps militaries will then take over in a greater sense the development of those technologies which would be terrifying.

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15:08 R: So, I think the best we can do is kind of be conscious of those concerns and address them. Incorporate those concerns somehow in the development of the technology, because some of those will be very legitimate and real concerns, that maybe we will only understand why they are important after the fact. It's better to try and integrate those concerns and understand them before these technologies are deployed wide scale. That's the best I can say on that. I think it's, it's a very political thing that needs to happen in that sense as well.

15:49 I: Yeah, I mean I'll actually get back to the political part later so you'll have a chance at that as well. So yeah, maybe a bit obvious, but privacy has been raised as a concern. How do you see that?

16:10 R: That again is a product of the type of society we have, which is seemingly more and more authoritarian I would say. I mean, as everyone knows now, we have, we have lost a lot of privacy on the internet. I think of the US they have probably lost a lot of privacy, in more ways than that. So, I think, when we are developing these technologies, both the developers and the users needs to be aware that someone is watching.

16:48 I think you just have to start with the assumption that, whether it's true or not, that someone is recording this brain activity and monitoring what I am doing with the system. Particularly if the system is connected to the internet in any way. And then to kind of proceed in terms of using and developing the system that way. Do we want to have systems that, where your BCI is also, used in terms of logging into your bank account. Is that a safe thing to do? Is that a wise thing to do?

17:20 I am not so sure, although obviously it's a possibility. We could technically develop a system like that. Is it just a smart thing to develop? Right. And then of course, monitoring your emotions, monitoring your, your reactions to different stimuli. So you, someone is, can see you are watching a youtube video about how the American military has attacked some new country for some unknown reason, of course to spread freedom, I guess that is the reason. Then, and if they are using a brain computer interface for maybe, maybe for some other reason, but then their brain activity is recorded, analysed by some machine-learning algorithm on I don't know, some government server, and then it says this person, has say a negative reaction to our, military efforts in this other place.

18:19 I don't how that could, that COULD be done, and it could be, could go back and bite that person later. The other things that we really have to take seriously when we are developing these systems.

18:30 I: Do you see, the solution to that being, a technical one, or a political one or both? or? How do you see that? R: I would say both. I don't know enough about computer security to offer technical solution, but I would have, I would be interested in whether it would be possible to somehow prevent or encrypt the data in such a way that your brain activity couldn't be just sent off to some other server without you knowing, and analysed in ways that you weren't intending for it to be analysed.

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19:09 That could be a technical solution to some extent, although of course then we would see, I think, efforts to collaborate with the companies who sell these systems to create backdoors as we see with cell phones now right.

19:27 So there is a, having a technical solutions is obviously not enough. The political solution I think is very similar to whatever the political solution is to regaining some sense of privacy on the internet and on your cell phone and things like that which seems like it has not been figured out yet.

19:46 I think because we live in what seems to be increasingly authoritarian, in increasingly authoritarian political atmosphere. I don't know if it is true that it is increasingly authoritarian or that as I become more aware of politics I notice more authoritarian elements to it.

20:04 I: So yeah, in the literature there sometimes is a bit of a clash between what they talk about when they talk about BCIs so they don't always distinguish between invasive BCIs and non-invasive BCIs, which is why even though I am looking more on the non-invasive side, this has been an issue that has been raised, which is some have raised the issue that, when using invasive-BCIs they might face a similar security risk as with pace makers that they might be able to be hacked and in that way be able to manipulate or hurt the person who are, who has the invasive-BCI. Is that something you see as well?

21:01 R: Uh, yes, I guess I would say the only difference between an invasive and a non-invasive BCI in that sense is that you can take off the non-invasive BCI. So if the user has some kind of off switch that can't be overwritten, for an invasive BCI, that might be a technical solution to that. Although I don't know again to what extend it's possible to, to prevent someone else from turning it on.

21:32 I would guess that there is a way to do that but.

21:36 I: Okay, uhm, so yeah. Another concern is the concern about side effects, is that something you have come across as well?

21:55 R: Well I think there are multiple levels of that. So, first of course in terms of an invasive BCI there are potentially some biological side effects of having some, piece of technology directly interfacing with the brain in some way. I would suspect that there is, there are side effects related to that. In terms of using a BCI, yeah I could see, like if BCIs become more and more useful and you rely on them for certain tasks. I could see it come to the point where say a child who grows up using a BCI from near birth to adulthood, would not really be able to function very well without one.

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22:45 I would suspect that, well, even us who were, who grew up maybe without cell phones for half of our lives, wouldn't really function too well without a cell phone now. Right? We become reliant on these things. The difference for the BCI I guess, I think it were, [it] depend on the type of BCI and the application, but potentially more dramatically effects the way we think. And the way we interact with the world.

23:16 For example if you have, say you are someone who suffers from anxiety and panic attacks, and you have been using a BCI for years which detects early on whether your anxiety levels are rising in a pathologically way. And I guess initiate some kind of like, meditation program, or calm down program, or maybe even stimulates your brain activity directly. I assume it would become very distressing for that person to not have the BCI, at some point.

23:53 If that was taken away from them. Even just the sense of security that might be associated with that. And then as I, have alluded to a few times, BCIs in the future which perhaps will be able to augment our cognition in some way, if we get used to having those and that is taken away from us. It would probably to some extent feel like we had been lobotomized. And I assume that would be very psychologically distressing as well. So I guess there are a few layers to how, what kind of side effects we might experience.

24:32 I: Yeah, since we are already on the topic, obviously neuroenhancement and stuff like that is something is something that people have raised concerns about as well. Is that anything you are concerned about or? It seems a bit that you are maybe even hoping for them.

24:51 R: Yeah, well the way, the way I kind of view technology in general is that, having. I do see that as a positive application of brain computer interfacing, the issue is the divide between people who can afford it and people who can't afford it. This is kind of a way I view most technologies.

25:17 It's not, to me it's not, the problem is not the technology the problem is us. Because we would allow people to go without. It's sort of, it's the same with my response to when people bring up the concern that robots or AI will take over a lot of peoples jobs. And people will be homeless. You know say 20, we will have 30% unemployment or something like that. The problem is not the AI the problem is that we are people who collectively would allow those people to die on the streets without doing anything to stop it. That's the problem.

25:54 So same with, to me it's the same with brain computer interfacing with neuroenhancement. That I think, will cause a serious problem with our society. Because that is almost, potentially, depends how advanced this technology becomes. That potentially could become almost like a species divide among humans And I don't see, I mean, clearly the potential for humans to have neuroenhancement can be enormously positive. Right, we could advance our society and ourselves, perhaps much more quickly than before. And in some sense maybe it's kind of inevitable. The problem I see, is that we apparently as a group

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lack the empathy to not allow people to become destitute to go without, that we don't see them. That we will stop seeing them as people.

26:52 Because they don't have the enhancements that other people have. So, I still see it as the problem is us, not the technology. Perhaps if we can enhance our brains with increased ability to empathize with other people. Maybe that would be a better start than improving cognition.

27:11 I: Okay, yeah this leads right into the next one, which is the whole digital divide concern. So yeah, in the literature there seems to also be the angle of it being the issue when BCIs becomes something you use in the work place, like the computer. Is that something you see as well?

27:47 R: Yeah potentially. It really depends on how, how the technology develops. [I mean] right now we are not at the point like, where it's a useful tool in the workplace. I do hope that one day it will be. Because I think that, you know, making, allowing us to work more efficiently to solve maybe more complicated problems that we wouldn't be able to solve, or wouldn't be able to solve as quickly is ultimately a good thing.

28:19 One of the nice things about the workplace is that your work place provides you with your computer, I would hope. And so the workplace should provide you with the BCI. One issue is that someone who can afford BCIs outside of work, will also have an advantage at work. Because they might be more effective at using BCIs, but it's a similar issue that we have now. People who, who spend more time on computers, and can afford more modern computer technology are just better at using computers I guess on average.

29:00 That I think would function again, how our society is structured, so.

29:08 I: Okay, so yeah, in a lot of the literature they, they also deal a lot with people with locked in syndrome, who are, and stuff like that so, the topic of informed consent and user autonomy is quite a big concern in that type of literature, but it's also in the other parts of BCI literature, is that something you think about as well?

29:38 R: Yeah, I mean, we actually just started a project in that area, for people who are locked in or nearly locked in. [Well] I guess for us, we restrict ourselves to people who have spouse or close family members who are able to give consent on their behalf.

30:01 Which is, I guess a next best thing. And we are using non-invasive technologies right now. So, that's a little bit safer. I think it depends on the country in a lot of ways too. I know for example our university is fairly strict about consent. I mean right now we are actually only able to experiment with people who are

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not completely locked in, so they can actually themselves give consent. And perhaps down the line the hospitals, if this is a successful system, will use it as a way to provide some communication ability to people who are unable to give consent. Who need a family member to give consent.

30:51 I think, a big question that is part of that is whether this BCI, whether you are experimenting with a BCI because you want to then later use it for some commercial application or if this is meant to improve the lives of patients like these down the line.

31:14 Which if you are saying, well the point of experimenting with this BCI on this test group who cannot by themselves give consent, is because we want to develop a system which will actually allow them communicate for the first time in years maybe. Then perhaps it's worth taking the risk that they wouldn't want to be part of this experiment and that their caregiver has incorrectly identified them as someone who would consent.

31:42 Which, you know, once they, if it's a non-invasive BCI hopefully in that case then they would be able to type out with their p300 speller, please take the system off of me. And then you would have your answer. It's a complicated issue though because, you know as you kind of allude to, often they can't give consent by themselves.

32:08 So, we try to be strict at our university so, I can't comment on other places.

32:15 I: So yeah, actually tying a bit into that, so when you are working with BCIs and doing research and stuff like that. What are some of the ways you try to make sure that what you are doing with the BCI is actually what your users want and society wants?

32:35 R: Well so far I have worked mainly on very abstract concepts. So developing, just kind of developing the tools further. And so a lot of my work is on kind of bringing the user into the picture, in a deeper way. Perhaps that, I don't know, alleviates that issue a little bit. Although my work is more on say, here is what the system does interact with it freely in a way that makes sense to you, rather than saying, here is the brain activity you need to learn how to modulate in order to control the system.

33:17 But... in terms of developing applications that people would actually want, I think it is more of an issue of what kind of brain activity or cognitive processes or emotional states can we actually successfully detect in real time and then, what array of applications can we develop from that. So it is less here is an application that we want to develop, and have we interacted with the community to say, to determine that this is an application that people want. Because I think that you will always be able to find a sample of people who are, who will approve of that application and a sample of people who don't approve of that application.



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34:07 For me it is more, what are the possible, given what we can actually detect or read about the brain, what are the possible applications out of this. And then, what can we identify, I agree ideally in collaboration with the public, is the best or most positive application out of this set. That we think we can create. And trying to take it that way. Because right now I think we are at stage where, what we can detect about the brain is very limited and that is what limits the kinds of applications we can actually develop.

34:44 I: Okay, so yeah, all of these issues as you have alluded to a few times as well ties into a concern about both policy gaps, but also legal concerns. Is there anything you have in mind there?

35:02 R: Well, I, I assume that politicians for the most part, will not be well informed about what brain computer interfaces are, and what they can do. And that is going to be a barrier at all times. It's really going to depend on the country as well, I mean, as you might have guessed I don't have much hope for the US these days. The degree to which they seem to be ignoring science lately I think worries me quite a bit.

35:44 At least here in [COUNTRY] I think there is much more of an effort to understand where scientists are a little bit more involved lately with politics. Maybe that is a good thing. But I have to assume that politicians will be mostly ignorant about how brain computer interfaces [actually work] and what they can do. So the kinds of political decisions they make about them I think will be poorly informed. And I am not sure what the solution to that is.

36:15 Because I don't think there is much of an interest on the part of politicians to become well informed.

36:20 I: Okay, is there any of the other concerns in particularly there is a need for some political movement?

36:38 R: For me the big one is the digital divide as you mentioned. I do think, [although] of course that could be wrong, that at some point we will have brain computer interfaces which give, a real and clear advantage to people who are able to use them and afford them.

37:01 Particularly if we have sort of, invasive technologies become mainstream in some way. Having a divide there where some people and some people can't I think, would be disastrous for a society. All sense of equality to the extent that it still exists I think is lost at that point. That I think is the biggest, in my mind that's the biggest concern that requires a political answer.

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37:37 Requires us to say, certain things are a public good, like I believe the internet now should be considered a public good. And the infrastructure for internet should be available everywhere just like we have telephone lines and roads in most places.

37:57 If brain computer interfaces do get to the point where there is a clear advantage in using them. In, you know, the work place and education and things like that, having a divide there I think will be just terrible for society.

38:13 I: Good, so yeah, the final question is sort of a free form one, and basically just is there any concerns that you have stumbled upon or maybe some of the people you have interacted with have talked about regarding BCIs that we haven't talked about so far?

38:33 R: Let's see. I think I have gone over all of the major ones for me. I think we haven't, we haven't really touched on some of the social sense. Some of the positive things that BCI can do. One of the people I work with, is well known for having developed a system which can detect whether someone in a coma, who is apparently in a vegetative state is actually conscious or not conscious. Which of course effects dramatically how we treat those patients. He has told me before how, prior to this it was not uncommon for hospitals to harvest organs from people, who are fully conscious but in a coma.

39:29 Because there is no way to tell the difference, and so they didn't really care to tell the difference, and often times they would do this, without anesthetizing the person. And the comment he got, once he delivered this system and was able to show, hey we can tell now which person is conscious and which is not. He, he was kind of, people were a little bit upset because now it was harder to, there was an extra step involved in deciding whether we could collect organs from these people or not.

40:03 And they didn't want to have to do that. They were [INAUDIBLE], it was more financial advantageous to the hospital of course to just harvest the organs.

40:13 Brain computer interfacing can take that a step further and say. And perhaps in someone who is in a coma, but actually conscious. If you can perhaps give them the ability to tell us what they want, and what they need, and how they feel and how to understand people in that situation a little bit better. So that we can make better decisions about how to treat them. How to provide for them. Things like that.

40:46 So in a social sense there is of course I think a lot of positive things that can come out of BCI that we should try to work towards. While keeping in mind, the major concerns which we have talked about so far.

41:04 Guess that is my final point on that.

41:06 I: Yeah, good, yeah, thank you.

### 8.2.9 Research stakeholder 3

I: Interviewer

R: Researcher

00:06 So yeah, maybe first you could introduce yourself in a couple of sentences?

R: Alright, so I am, my name is [NAME], and I, I created a paper, a thesis, [NAME OF THESIS], a simple game or something along those lines. And I, I work with some BCI [INAUDIBLE] on a number [INAUDIBLE] participants and I created a study about this.

00:46 I: Good, so yeah maybe you could explain what your ideas for the thesis on the paper was? What were you trying to do?

00:57 R: Alright so, it is common with motor imagery that you use small number of participants usually and you do multiple training sessions and so, basically you do your study on, throughout the long, longer period of time to have your, to have the participants actually be somewhat good at, [at the MI]. And what we did was, kind of the opposite, we were trying to see if the MI can be used with, like without prior experience so much. So that was part of it, and there were other parts to it, but basically we just wanted try MI based BCI in a different environment.

02:00 I: Okay, and yeah so, what do you actually hope that people will use BCIs for? And what you have done? R: Ideally like, everyday life. I mean, it would be tremendously [INAUDIBLE] if artificial limbs could be, can be controlled totally by mind, but that's years ahead so. Yeah, but ideally you want the technology to be used all the time.

02:30 I: Okay, is there any like, you mentioned artificial limbs, but is there any other use cases you hope that it will be used for? R: Definitely, there is, there is commercial, there is always, if it turns out to be engaging towards the audience it's gonna have plenty of commercial uses I imagine, entertainment and stuff. But I mean, to, as a, to progress as a human race I see that, that medical uses will be the most important.

03:05 I: Okay, yeah, so throughout history we have seen that technology sometimes gets used in ways that wasn't intended. Is that anything you see as a concern for BCI as well?

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03:20 R: Uhm, sure, I mean but it kind of is, every tool can be, can be used to harm, someone else. That is true for probably everything, so I don't think the concern should be, that [hard]. You can do plenty of stuff with it but for now, the technology is so imperfect that the, I think the worrying needs to come, like it doesn't need to come right away. But. No, I guess yeah, you can always use good stuff for bad stuff so. I don't think there should be much concern about that to be honest with you.

04:11 I: No, so it's more that's in line with the general concern rather than there is something specific for BCIs that's a concern. R: Yeah. I: Okay, so yeah, in the literature there is a lot of concerns about misinterpretation and the accuracy of data by users. Is that something you see as well?

04:32 R: For my research the like, we had some pretty rough data, like the accuracy wasn't top notch, no where near it. But that's like, that's the reason why MI based BCI takes usually multiple training sessions and such. I mean, everything can be, [INAUDIBLE] misunderstood or misconstrued but. You mean the concern for, for the like the, for the research community?

05:14 I: It's a bit of both, there is both the "How do we make sure users understand the feedback we are giving them", but there is also the concern of "how can make sure that, if we detect consciousness or if we detect attention span, that that is accurate". So it is a bit of both.

05:40 R: mhh, oh I think that, that, like the data itself is kind of hard to balance because some people, it depends a lot on the state of mind of the person. If someone is trying way too hard it is going to be ba[d], it is not going to have a good results and if they are trying, if they are not trying hard enough the results wont be good either so.

06:11 Ugh, it's, I [can't think of an instance] it's misunderstood, but we should strive for the best possible results. I mean, you try to make the environment good enough so that the, basically the, the experiment goes well, but I mean, in a natural way. You don't use bad data to create good results.

06:45 I: So you mentioned you would try and setup a good environment, what sort of things did you do to try and do that?

R: And I have tried to talk to the people, like to express, like what they should do, what they should [INAUDIBLE]. And there are certain things that, that can basically like, you eat. The EEG signals right so, there are things that, can have bigger impact because like, the stuff like swallowing and tongue movement and eye movement is way stronger because it's closer to brain than, moving my thumbs or something.

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07:42 And like some general advice and also just trying to share my experiences with them Like, but I mean everyone is different so I would just try and to try different things, don't like, don't expect too much. Because like, you know, if people expect too much and it doesn't go their way, it can be discouraging.

08:14 Basically I just try and to mentally prepare them for what is coming and not to be extremely sad about, if it doesn't go their way or don't like, just because it works from my experience, it works the best when you are calm. So ,so yeah things like that.

08:38 I: Okay, yeah, actually following very nicely up on that, like, peoples expectations and the way BCIs and neuroscience is portrayed in the media is actually also a big concern in the literature. Did you find a lot of that? that you had to basically reconstruct peoples image of BCIs and what they could do?

09:01 R: Well often times the people like, they have heard of the BCIs but they didn't really, it's not a subject issue here, it's too often on the news just some stuff. It's usually like, I think that most people realise that if there is some, like if they actually know what a BCI is then, then they realise that it's in the baby steps, it's in the you know, in the cradle like they don't expect it to, to work too well right now.

09:39 But if it, if they do I try to somehow show them how it works and also like encourage their positive thinking of it like, with this we can in the future do this and this and that so.

09:53 I feel that, the motivation, is usually good for people, to actually try [harder] but too much motivation is bad so yeah. Try to keep it, somewhere in the middle.

10:10 I: Okay, yeah so another concern in the literature is the concern about privacy, was this something you thought about or your users mentioned?

10:25 R: No, not at all. Like, I actually have not, with the technology I used there is basically nothing that, that would concern me myself as of to, like, the privacy.

10:45 I: Okay, let me just see here. Yeah so, in the literature sometimes they talk about BCIs in a general sense, so it might not apply to the technology you have been using, but some people are concerned about a security risk with the devices which seems to be sort of related to the same issue that pace makers has seen, where they could be hacked and that would then have an influence on, on your health basically. Is that something you see as well for BCIs?

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11:25 R: Uhm, I think that's a concern that's, uhm, that can be true for most of the future. Like, the more into the future we get the more like the computers they go huge, like bigger parts of our lives so. Of course it would apply to BCI as well but again, right now sure yeah. Concerns are for the future, so yeah it is a concern but I feel that as we go forwards, usually the lawmakers try to make, to prevent this stuff. And research stuff. Like I imagine your work also is trying to, bring the concerns into the seat, to or to us. So we can see and we can learn how to do stuff. Prevent it.

12:36 I: Yeah so, yeah, following up a bit on, maybe it's, it's definitely more of a future concern, but some people are concerned that the fact that BCI will change our understanding of our mind and our consciousness and stuff like that, that it might change our concept of identity. Is that something you see as well?

13:03 R: Somewhat, maybe. I mean. I feel like, to certain degree, the, perhaps, even literature does the same thing. It challenges your mind, of course there is this kind of technology requires you to think differently, so basically everything that challenges your mind or perspectives probably changes your, your worldview and your view of yourself so. In that sense math does the same thing, writing does the same thing, and like religion. So, yeah sure. It's a concern, but, I mean probably, not I am not sure if a concern is a right thing. Like the right word but it's a thing that, probably will happen and like, I don't see, anything wrong with it.

14:07 It feels to me kind of natural for it to happen. Because this has been happening for the past like you know, however long we are here and have been developing ourselves so.

14:20 I: So yeah, another concern the literature has brought up is a concern about side effects. Do you see any side effects from using BCIs and if yes, what are your concerns about those?

14:38 R: I had this dude who did really well like immensely well with the accuracy and, and it happened to me as well because I practiced [INAUDIBLE] my self like before the trials and I did multiple runs so I actually got better results as time went on. And what happened to me was that basically I had a simple game where you control right or left.

15:16 And at a certain degree, or like a certain point of your accuracy being good you reach a stage, like you reach a point where you kind of have to change your way of thinking. You no longer need to think like after I go right, I will go left, because the moment you think I will go left, you think in the future, but the game like represents it or the technology represents it right away. So you kind of have to think, in the moment. And that kind of thinking, like it kind of changes the way you think.

16:01 So, I am not sure if you have heard that, because I had some that, I hit the cable.

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16:09 I: Oh, that's fine. R: It kind of changes the way you think in a, in a, like, I can imagine that if you were to, if you were hooked to this kind of thing, all your life and it will, it could drastically change your, your way of thinking. Like your future thinking could be crippled by it. And I don't know, maybe you could cope, I am not sure. The technology could also certainly grow, and account for this, let's hope. But, I haven't seen like, I haven't experienced myself too many, too many things that I could imagine, could cripple, me or someone.

16:59 Could you give an example maybe?

17:02 I: I mean, one of the more, smaller and I guess this also ties into the time where a lot of the BCIs used gels to make a connection, but a lot of people were talking about skin irritation.

17:18 R: Well, yeah sure, like, it's a chemistry so you can, you can damage your cells with it, but then again there is also technology that uses, it doesn't use gel, like you just, it just sticks, kind of like [patterns] or something. So that's, that's just technology like, I wouldn't worry too much about it because, if the concerns comes up, and it's like, it is dangerous, then technology will just change like. That's just natural, I mean, sure if there is something that, that could damage people, then yeah but it should be regulated, it should be changed and stuff.

18:06 I: But you didn't experience any skin irritation and stuff like that yourself with the non-gel. R: No, no one told me anything like that. I didn't [INAUDIBLE].

18:18 I: That's good to hear, that's sort of a solved problem. R: I would, it would be kind of sucky for me to hear that, from my participants. I: Yeah, of course.

18:31 I: Yeah so, another concern people have is, if BCIs at some point becomes this household item such as laptops and computers. That there might be a problem with some people being left behind, so you have an A and a B team, where some is good at them and some might not even have experienced them before. Is that something you see as well as a concern in the future?

19:00 R: mhm... Not really, I think that, like, it's a way of thinking and it can be kind of [INAUDIBLE], in my opinion you can program a person to think in a way. That's what the upbringing is, I didn't. In the nature vs nurture argument I am on the nurture side so.

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19:22 I think, I think that people can learn and if not, the technology can be better. And like, I mean it's also kind of natural like, you can have musical instruments in your house and there are people who can't play it and there are people who will never be able to play. It's, of course the music might not be as big part of your life as this BCI if everything moves to BCI but, I, there are people born with no limbs and... And, I don't know, that's, I don't see it as much of a concern myself. Like, it's gonna happen probably, but like I don't, I wouldn't worry about it too much. I think, [the picture] will change if that comes to, to happen [pretty soon].

20:16 I: Okay, let me just see where I got to in my questions. Yeah, so another one is, enhancement, cognitive enhancement and stuff like that. Some people are worried about that, is that something you think about as well?

20:45 R: I think it should be researched, and the side effects should be researched very well and like, it is always kind of a concern when you, when you start [picking] someone's mind, be it psychology or be it like medical stuff. And it is a concern but in the end like, as long as it benefits, the human kind. Sure why not? But the side effects should be, like we should all, there are areas where people should always proceed with caution. I: And do you see this as one of those areas?

21:30 R: Yeah, I mean, yeah. It should be researched but I think that, if, if it proves to be all good and well and all just fluffy bunnies and stuff, yeah sure.

21:44 I: Okay, So yeah, when developing on the BCI and everything what are some of the methods you use to make sure that what you were trying to do was actually something that other users would want as well?

22:02 R: I wasn't really something that I was [meant] for commercial use like I, you know, I had, it would be a hard sell. I was making more of the lines of how to make it, how to hook people to the reality of the, [be]cause for the [INAUDIBLE] work you need some things to happen like, you should have the person hooked to the, to the [present] like. And stuff. And like give them, like for now, the [INAUDIBLE] works best if there is two options like. Usually right and left hand.

22:45 So I would kind of tailor my, my [INAUDIBLE] towards that purpose. If I wasn't [INAUDIBLE] trying to sell it so, I'm not sure what I would do to, to make it like, competitive for the market place.

23:14 I don't fancy myself too much of a market side. A salesman so. I don't know.

23:21 I: But am I right in the assumption that you were working with the idea that anyone would be, would be interested in seeing people with less mobility increase their mobility by having access to R: Yes. I: Okay



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23:44 So, another concern in the literature is about informed consent and making sure that, user autonomy is kept at a good level. Is that something you thought about as well?

24:01 R: I think people should be, should be welcome [INAUDIBLE], what's the word? Well informed? About everything they do. That's the downside of many of the things that are happening right now. That people are not informed, so I think in general people should be always well informed before making decisions.

24:25 I mean, this is one of the parts, like this is one of the things that should be, should be [INAUDIBLE] to.

24:37 I: Did you do anything to try and make sure that your users, well you mentioned you tried to set them in a state of mind before the experiments, but did you do anything else?

24:44 R: Oh, I mean I had the usual consent form, I told them what would happen and stuff like that. Basically explain like, what would happen, what will happen, what, what would the data be used for and stuff. And, like they had the usual you know. The consent form was needed so I, I guess normal right. Nothing extreme to, like nothing beyond that too much. Just the usual.

25:23 I: Yeah, so a lot of these topics have to some degree been tied into issues about policy gaps and legal concerns. Is there anything you see as well there?

25:38 R: You mean, let's not make people into robots too early so they can rise up against us?

25:49 I: Uhm, I mean if that's a concern you have then possibly, but I'm more thinking about the reg, like policy gaps that you see right now. Where the current legislation might not cover some of the issues that BCI might bring?

26:08 R: I am sure there are some. I don't see many of them. I think that, if you given [INAUDIBLE] that lost his limb the, a stronger artificial limb to run with. I mean that happened couple of years back where an [olympician] wanted to compete with. In the normal Olympics. And well, that was the [INAUDIBLE] of that. But, yeah like, obviously there is, there is some rules that's gonna have to either be, more, rough in some areas and some that should be softened a little bit.

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26:56 To allow people with these things to, to [apply their selves] as well. Yeah, I, it will probably be changing, obviously, how much I am not a law maker to be able to say that. But yeah it's. I think it's going to happen.

27:18 I: Do you think this is something particularly to brain computer interfaces or do you think this is just general technology moving forward and we have to always update our legislation?

27:32 R: Yeah, I, we, I think it's a, yeah as we go forward we should always update our legislation. We do not, like, we do not burn women for adultery anymore so.

27:49 I: Okay, so yeah, the last question is basically free for all, so maybe you can talk about your concern about people turning into robots, but yeah do you have any concerns that you thought about or stumbled upon during this research?

28:09 R: My biggest concern were just the, well the how bad is this going to be, and will it actually work, at the time and stuff like that. But nothing too extreme, I am, I fancy myself an optimist so I believe that as the technology will go on, so will the mindsets of people and legislation, regulation, and all that stuff so, as long as there is a rational mind behind it, that drives it and we don't do anything too extreme then I think we are gucci.

28:52 I: Okay, good, then that's it.

8.2.10 Research stakeholder 4

I: Interviewer

R1: Researcher 1

R2: Researcher 2

00:28 I: So yeah, first maybe you could introduce yourself in a couple of sentences?

00:31 R1: Yeah okay, I will. So my, the domain that I'm in is industrial design engineering, I am a trained industrial designer and also, industrial engineer. Both, so the discipline I'm already started working in I think in, 80, 90, 80 or maybe a little earlier. But I have been working in industry for a long time. And also then after that I was completely fed up with design and industrial design in everything. For a societal point of view, and then I quit, quit everything, I. I had a rest for about, a sabbatical about for two years then and I've then I started working in a university in [COUNTRY], technical university. We have about 3 here or 4 sometimes, and I have done that since 2003\ . So, and it's in the faculty of engineering and technology. Whatever that means. But, my main interest is in the interaction between humans and computers and especially in the product creation processes, and then in the area of the early phase process. Where ideation and ideas start to, you know, become externalised and so much of that research is, is done always focusing on [INAUDIBLE] as well as an integration in a very pleasant and effective way as a supportive tool for, in computers, for processes like that. And, this is basically the focus of the research also in my educational approach, so yeah. That's what I am doing now.

02:50 I: And maybe [NAME] can introduce himself in a couple of sentences?

02:51 R2: Yeah so, I did a bachelor at, with [NAME OF R1], and then afterwards, afterward doing a bachelor in industry design I shifted to, it's called human media interaction, and the focus there, yeah, lies more also in this human computer interaction and in other ways like social robotics and, so yeah, I am also in the, in the interaction side of things. Yeah so it's [INAUDIBLE].

03:27 I: Okay, yeah and.

03:29 R1: And he finished his master just now. So he is going on probably to PhD. But we have to find the right university for that.

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03:40 I: Yeah, that's always one of the big issues is finding a place. So yeah, you already sort of went into it, but maybe you could explain a bit about your research a bit further?

03:57 R1: Mine? Yeah, alright, well so yeah, my main concern was that since you have as a designer like, I am of course trained in an area where computers were not there yet I mean, there were but they were mostly big buildings with lots of shit in it. That couldn't be moved. So when the PC came out I was an early adapter so I. In the early 80s I already got my first laptop, which was, you know, real real small with very very, I mean you couldn't basically only do some typewriting on it. Program, some basic stuff. Basic [INAUDIBLE] and, but then, that always got my interest because that [INAUDIBLE]. But at the same time I got also frustrated by the thing that you couldn't do. Anything on a more intuitive level that all your capabilities your skills and facilities you have as a, as a person, could be integrated fluently, in computational systems.

05:10 So, and you know, I always tend to say at that particular point, it came really from anger. So, frustration and anger with the impossibilities of computer interfaces and the, we call that a wimp structure, probably heard about it, windows, icons, and menus and pointers. And so, from that I, I sort of slowly started researching into how you could make a better fit. For humans interacting with computers because I, I think they are very important and could have a very dominant role, and they do, but not in a way they are right now.

05:53 And so, that got me interested in of course interaction design, in usability studies and, and cognition and in the psychological effects. You name it, all kinds of, undercurrents that sort of, but for me in that particular time. Looked at as of all separate domains and it still are, most of it. While I try to make some kinds of transgression or then combine all kinds of, currents to become one flow. And from that I, I started my research on [INAUDIBLE] towards direction like, you know setting up a framework which, makes possible, the full integration of physical and virtual. Interaction but also experiences. And so, over, over the years since, really since 2009, I started publishing all this. And we did many many experimentations I think we are up to, to 20 experiments over the years, that, with large numbers of users, participants basically.

07:15 And of course by integration of technologies because of the push I just mentioned that, the push is also, something that I was kind of afraid of, and still am. Because it doesn't, it doesn't really apply to people, it's only applying to business models that have to sell a lot of shit to the consumers. So, exploring all kinds of stuff that came out, I mean, you probably heard of Kinect, you heard of, well any kind of gadget, but also systems. We try to incorporate and maybe hack to our own specifications in order to become better tools, but none of it really works. So even in that we got frustrated. And what is, what is the interesting is that, at one point [NAME OF R2] came into the picture I think it was in 2012? 2011? Was your bachelor? R2: 15 R1: Oh sorry, he came, he came in 2015 and, and he was also interested in the framework of what we call "raw shaping technology".

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08:37 You probably read a little bit about it, but, and he said, why don't we start using a brain computer interface or something like that? And, because there we might, you know, create some interaction, modalities that we didn't use yet. And, so that was basically our, our, you know I've used them before, but not in, in my own experiments or, or tools so. That was quite interesting so I said, yeah let's do that, let's make an assignment for your bachelor to you know, figure out how we can use a BCI, but [NAME OF R2] can also, you know, give you that story.

09:19 I: Okay, yeah, maybe you can few sentences towards that?

09:27 R2: Yeah I guess when I started with the search for a bachelor assignment, well I was already exploring further the area of, what's possible in human computer interaction and well I came across the, yeah the brain computer interface and of course we only hear a lot of fancy stories, and you see a lot of, kind of, make believe ideas floating around what is possible with it, and in the future of course. So, well that was kind of putting it out to the test, to see if, if it's really something that could be useful to combine in a, in a better interaction.

10:22 So yeah, that was starting point, and in the other faculty so, where I am now, they have like, they have different kinds of a consumer products already, [INAUDIBLE] for yeah, to do research. And, so I could use one of these devices, and well then, started a lot of annoyance I guess about. You, you it is pushed already like into the market, but well it's really still in the, yeah, baby shoes or how you call that like of the development, so. Yeah this was, that was a real, big eye opener I guess, to see like, okay it's, it's really unpractical at the moment to use, it's, what it should do it doesn't really do it so. And, and that everything, because also yeah what [NAME OF R1] said I guess. That when you want to, well, do your own kind of experiments with it, it's all like, well. Nicely coded so, you can't get to the raw data so that you need to have a license of, like an academic license for [INAUDIBLE] into, euros. So and I guess at that point we said, okay maybe, well. If we are to, [INAUDIBLE] with raw data why don't we just continue to try make something ourselves.

12:07 I: Good, yeah. R1: We are never very enthusiastic about stuff anyway. Like we always come from a very, I will, almost would say, cynical way of looking at technology because the promise as [NAME OF R2] also explained, is always higher, than the real. Or an expectation are always higher than the real benefits of it. So we always come across real big interaction problems that, that is, first of the encumberedness in the setup, it takes forever, the calibration, and it's with any kind of product that comes out, you know. And these companies are just churn it out too fast, because they don't want to wait because they invest lot of money. And then they want these silly consumers to buy it or silly scientists. We spend a lot of money in gadgetry but we have boxes full of shit that will never be used anymore any longer, so that is part of our whole, I think, this is a big issue. Because of course you can get maybe great data, but it never, never anything is, is accessible because of the [fender locking] right. So, [fender locking] makes everything very cumbersome and even though we have some very good let's say developers and die-hard hackers in our team. At one point you, you know, let's say if you go work with apple system, like when IOS or [a]OS, everything is hidden. So this obfuscation of, of what you really want to go at. To use for example a video, a

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simple example of, to use a video camera or the camera in, in apple is almost, it's almost impossible or basically impossible to hack.

14:06 Because it it's just, you know, not, you need to know everything security and everything so it's possible. It just show you that you buying this shit, [in system], but you don't have any real, means to work with. So now that is what I think, one of the you know strongest argument to build all the stuff yourself. And this is what [NAME OF R2] also explains that, we basically. Emotive I got I think?

14:36R2: Yeah R1: So we could get our hands on a second hand emotive headset right? R2: Yeah, it's just a R1: And they said, you can hack it the way you want, and that's what we did so, you can explain a little what

14:52 I: Uhm, before that, I'll try and move through some of my questions because R1: Yeah, go ahead I: so that, because you are already answering some of them, but I wanna make sure that. R1: That you have them all cover. I: Yes.

15:07 I: So yeah, maybe quickly you can explain to me what you hope that people will actually then use BCIs for? Since you clearly seem to have a goal with using them.

15:25 R1: Well yeah, because we, our research is that you have your hands free, and you can interact with your computer. You have your mouth, so you can speak and interact with the computer. You have your faculties, you have your extremities, right, your hand, your arms, your legs, your toes. Basically your whole body can be used to interact with the computer.

15:51 This is our philosophy. You know, before, before you, you actually can do something you have to, you have to strap on all kinds of contraptions and, like an exoskeleton or, or a BCI headset or google glasses or a MIYO or whatever you have and that. Right away has major implications on the naturalness of your interaction. Because it's not, it doesn't feel natural because it's designed by lousy engineers. And terrible designers, so it will never give you the full benefit of your regular physical embodiment, because it's an add-on.

16:33 I: So, yeah so, you goal was to hopefully find a more natural way to interact with, with computers? R1: Yes, yes I, let's say, to use a BCI let's stick to that subject because that is interesting. I said to [NAME OF R2] let's use this thing, as is. And [NAME OF R2] said okay, but then, we need some test persons, and I said, okay we will find some, so we found some test person, but then we had to prepare the BCI headset, because you had to have some cline fluid, in order to, you know, to make contact with the sensors, then you had to ask the participant, can we you know, wet your hair, can we wet you at all? You know, because we have to make contact with the sensors. Now this is stupid right? I mean this is a big drawback. You just don't want that, now of course that is my, maybe the type of BCI we had at that particular time. But most,

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most research, at that particular moment was done the way that I just explained. Always with cline, kind of fluid, in order to make the contacts, to the sensor, the best.

17:50 I: Yeah, because, that's definitely one thing I know, a lot of the consumer grade BCIs are working on, is having non-gel and yeah.

18:03 R1: So it's a big mess basically. Then, okay then you setup, you need to calibrate, then the data is sometimes, completely not what you expect, because there is so much noise in the data, that you have no clue where to look at. So, that is all the hardware shit right?

18:22 So, you have maybe something to add to that? R2: Well yeah it's. I guess yeah for a natural interaction you just want, don't want to focus on, on your preparation of any kind of test of course so. So yeah, that's, no parts, you just want to, put somebody, something on their head and just say: go play. And if it is, yeah getting their consent or yeah, you just want to, to let people play with it. Without them to fear, fear anything about, like, I didn't find any people that had like any issues with it, at all. Like this is looking into my brain or whatever, so that's already, sort of interesting to see I guess about, well how, adaptive, how people adapt it. Like, nobody sees, sees as their, if you can read their brainwaves, that, that is well. Strange. Because it's a random pattern and you can't see anything in it, but yeah. The idea is of course that you can see something in it.

19:52 I: Yeah, it, following up on that a bit, do you think that this, lack of concern is because users don't understand what can be read into those data or is it something else that's making them willing to, just accept the device.

20:14 R2: Yeah, I guess. So, I recently was also at a. Workshop, and it was about, yeah intimacy in technology and there were also some, artists, researchers doing some work with this BCI and well yeah. Some intimacy, some intimacy studies, yeah like, bringing to the world, intimate moments, something like that. And because it was like this vague kind of translation, that you can't interpret, rawly interpreted by yourself. People were accepting it, kind of just to put it on and have an intimate moment with somebody else. It was quite fascinating to see like, it was about people just kissing each other with such a headset on. And, so that it also, it was quite interesting to see that you can just put somebody's headset on and just say: Okay now, kiss each other, because then, well, some music will play because we can read your, brain signals. And then people are like, that sounds pretty cool. But, so I guess it's about that, like, that's cool so, I am willing to just share an intimate moment because there are some technology on my head. And that's, it's also part of their research of course so that was pretty, pretty interesting to see. That, while you can, evoke that with, with the technology actually. And that people, blindly follow it.

22:04 R1: Yeah, the thing is, that what [NAME OF R2] is saying is really interesting because, I have been a member of a special interest group that called itself [NAME OF INTEREST GROUP]. And we closed it down

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basically, so we started a new interest group because. The whole thing is, like if you focus the direction, like in, on emotions of people. I mean that is so, it's so instant, it's so futile basically. An emotion can be evoked anytime, anywhere, in any grade of complexity. So what do you want to do with the data? Like what do you want to make visible right? So it's always a sort thing that emotions all of a sudden become hyped because industry can use emotions in order to target consumers more to buy more. And it's not really research, it's more, you know, in a sense driven to understand more of the psychology, but also how to, basically influence the behaviour of people to buy more into the, into the capitalist consumer society. And I think that is a very bad way of doing business.

23:29 And researchers, are prone to get more an understanding of the tool, because they, they just hide it in a way, I think, I speak personally here, that you put somebody, you know, or you fit a BCI to the head of a person, a test person and you want to find out if there is an interaction possible. And then they hide it into something, like the obfuscation is really big. Because, yeah we need people that are sort of disabled or have a certain condition or, and then frame it like that. But we just are exploring what people are all about. This is what I think, and I think this is highly ethical, this has moral implications as well.

24:23 How much can you do, and how much do we need? And of course it's interesting to see what happens when I kiss a, somebody, that might of course there are emotions and you can probably measure them and then translate the measurements, the data into some kind of, what [NAME OF R2] just explained, to music or colour or light, or what you have. But, what is the real use of it, you know? Like, do I interact better or what do we? And it's all because we want to go into robotics and we want to have like robots that will be assistive in future, and this is another dire situation that we are creating. That need to assist us in our lives. But we don't even get our own physical life in order yet. And we are already starting to fuck around with computers. Sorry for the French word. You know. So this is basically what we, what we found out, and [NAME OF R2] explains perfectly that, many people you know, where also wondering why we used a BCI.

25:32 You know, and they had all kinds of remarks on it. Are you gonna suck my brains now with the data and so yeah, there is also a lot of, let's say, misinformation, also stuff that, are, is not known and that is, what I said earlier like, that is hidden, because there are, there are different agendas at play I think. And that makes it, of course very interesting to research in, from the ethical perspective, what you are doing. I find very interesting, but also, industry doesn't have any morals. And I always say that design and, especially industrial design and designers. They have no ethics, what they do. And that is one of the biggest problems we have, I find, currently, also already for, for the large decades but especially right now because of all the technology push that's been going on lately. And, on and on, because we don't, understand it anymore. What it really does to us.

26:45 And you can see it already, the implication with, with social media have on, on society. It fragments society, gigantically and it's, a big big problem. And it's going to be an even bigger problem in the coming years. And so, lot's of things to address, but I am not sure if we are answering your questions.



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27:11 I: You are, it's just not in the order I have it, but that's fine.

27:17 R2: We are really never very structured. But we always touch everything. I: That's perfectly fine.

27:21 I: So, actually following up nicely on that, in the literature there is a lot of concerns about public awareness and how BCIs but also neuroscience in general is portrayed in the media, is that something you think about as well?

27:41 R2: Well, you see, more and more sensors come out right. Let's go back to the sensors because, sensorial stuff is interesting because it can measure some kind of emotive response. Anywhere. And so, if you look at the toy industry for example, they came out with all kinds of speaking dolls, video taping dolls, recording dolls, everything. It's. This is a robot basically, in a doll, hidden in a doll, for kids. Basically they are spying on kids, to see, how kids play and interact so they can get a better vision on, on data for their next generation of dolls that become robots.

28:32 I mean, this is highly unethical. You cannot do that. And there are no regulations, it's just that it, the consumers all of a sudden or some researcher see is happen. They pick the products from the market place and they hacked it. And they see what is happening, they see that the data streams are going directly to the toy company, the production company and they, they acquire it in order to get more data on play.

29:03 I think this is a really big problem, and this is only for toys. And now we go to other, you know, other articles that are you know, let's say smartphones, same thing. You have to do a lot of hacking, in order to make the phone, the phone that you want to have. The tool you want to have. But nobody does that. So everybody is open, and everything that you do is shared, even if you don't know it, and it's captured, even if you don't know [or want] it. Nobody asked you, if you really want it?

29:36 I: No yeah, I completely understand that but, just trying to pull it back on the specific question, it's more whether you see the way specifically BCIs are portrayed as a problematic thing. You mentioned the high expectations that people have for the devices and stuff like that. Do you see this coming from the media or where does this come from?

30:07 R1: Yeah well, you know, the brain in such, is the most, currently the most, [INAUDIBLE] over the years, the most explored and exploited, lets say, call it the thing. The brain, okay, just now for arguments sake. And it will be a going, because if we don't, like, this is where all the research is heading. We have to understand how the brain works, how all the synapses function, and have, all the, let's say the interactions in the brain are working, so we can make an artificial brain. That's basically what we need to know, that's why contraptions like the BCI shit is being made by industry. So to put it forward in order to get more researchers to go into the research because it will fill their bank account, but it's you know, we have.

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30:58 R2: Yeah, no that's also. I guess, an annoying part when you have like, this licences and all this stuff. So it's, give you kind of a, well, feeling of course, that you are, well exploring this realm of, well BCI and, on yeah, an academic license, but of course you are not. So, well you, it's just like a, a layer on top of it to say okay, well this gives you, your freedom to, to yeah be the boss of your research but yeah it's still not, really the case. So, so that's a, it's kind of strange yeah because, of course this stuff is sponsored. Well, the researchers like to receive these presents of course, and well then they let all the students play around with it and well, eventually they produce some new nice research, which you can, well go back of course to the original company so. That's with the, yeah, that's a bit of maybe an issue there.

32:18 R1: But I can also have a positive notion on the BCI because as I said before. We always like to get natural user interaction right. So, we thought, okay if you have nothing, you know, in your hands or on your body except maybe something on your head. Like a hat, that can be a small device. And you can facilitate some, interaction with the computer, that would be nice. So, that is also the reason why we said okay, now you have your hands free, you can still, let's say make a design interaction, with your hands free. And you can also, at the same time, give some, commands to a system, in order to, you know, do something at the same time, simultaneously with the computer, and your let's say physical interactions, right. So in that sense we thought, maybe this BCI apparatus would give us a very handy interface, a tool, to have command structures being exploited, but also, being part of the process, right. And so, this is also basically what [NAME OF R2] tried to find out, if that was at all possible. So, he did some testing with the available software from Emotive, from the emotive company. And he showed that, some of these things, if you really concentrated and focused on a particularly task on the screen, you could enlarge and resize and you know, these things right.

34:04 But, that was basically very lame in, in an interaction way, because you really had to focus on something really hard to get something going, but that has not to do with, that say, sketching a product or sketching some ideas, you know. So, there is, there is just no correlation between how the interaction was facilitated by the company and what is really needed for us to become, that so that the tool becomes a very useful entity. So you know. There is something of a, a constraint there, but there are also many trade-offs because, the developers don't think of these things. You cannot change them to your, to your specs, because you cannot go all the way into the system to change the direction of the tool so.

34:54 R2: I guess it's just about, okay, we have a sensor and we can get a lot of data. And then try to figure out, oh, is there some kind of interaction possible. Not like, because yeah, of course the sensors have the limitation of yeah, in this case, only a [picture], mesh of brainwaves and, well so there is not a clear. There is not a lot of clear thoughts visible but for direct interaction, so. So that's I guess where it comes from. Okay, we have a sensor and well, let's just put in our heads. Let's fake some kind of interactions, and hype it in some ways that, well you can use it in games or whatever, but, I guess nobody, or a lot of people who bought that stuff, yeah, will not still use it because yeah it's. R1: Redundant R2: Yeah it's, it's more okay you are, able to do some interactions, but yeah.

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36:08 R1: Interactions. Within our domain, you know, it is not really feasible so, and of course you always use tools, that are, would be fitting, your domain right? Like, in our, in our domain, our discipline there are certain ways of doing things. Tools have to fit that particular process or alter the process in a very elegant fluid manner. It can be completely different, but if it works, it works. That is for sure. But with the BCI, you know, we came upon many many constrains that, I mean apart from the, from the ethical issues. It's also the hardware, software, yeah the way they developed this is, just not how you should do it I think.

36:59 I: Okay, yeah, moving on a bit, a lot of people are concerned about privacy concerns, was that something you thought about as well?

37:11 R1: We, see in , in research you don't care about privacy because you say, okay we won't, we will do everything anonymous, and your, your user number, whatever is not known to anybody, and we call it X or something. Or number 1, and that's it. So that kind of privacy and the kind of experiment we do are let's say. To me, are like very simplistic. Just to show, if we could use some of the, thoughts, brainwaves, you have. In a particular, you know, if we put you in as a participant in a particular design task, we want you to do, to facili[tate], you know, we want you to do some actions and the actions you can do either with a computer mouse or with a BCI. You know what I am saying, something like that. Simple, and we want to see, how effective both modalities are. And, but the funny thing was that at some point [NAME OF R2] got so fed up because it didn't work, he sort. Cut apart a complete BCI headset, hacked everything to pieces and then used the pieces in a different way, you know, basically using the sensors in a different kind of setup. And that all of a sudden, that became a very interesting way for using some of your. It's not really brain waves, it's more the electric currents in your muscles right? R2: Yeah, it's the R1: So we, we came from brain waves to muscle. Energy R2: Spasms R1: And that is less intrusive.

39:07 I: Yeah, okay. R1: You know, you have to make some kind of decisions at one point in, in the research approach though. I: True, so yeah. R1: But that doesn't answer your question. I: No, that's perfectly fine. So.

39:26 I: Also in literature some people have raised concern about side effects. Were there any of such concerns for you?

39:34 R1: No, we, I don't think we had side effects, did you? R2: Uhm, well, I, thought maybe I had some side effects myself because, well, because I hacked all of this stuff, so sometimes when I was wearing, well my hacked version a bit too long. I was, well feeling kind of nauseous sometimes. So, but that's, that's my own fault I guess. But. I am not sure. I guess what I know about it is that there is also similar kind of approaches to, well of course there is this area of deep brain stimulation and whatever you, well. Actually well trying to help some kind, dis - formations or whatever in the brain. So I don't really see that there are a lot of concerns actually about well this, just capturing kind of way. Yeah just, just that, well, you have this kind of gel of course that you need to use, or well, not anymore but what people dislike. But it's [INAUDIBLE]. feel dirty, but.

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41:09 R1: We had more complains with, when we used the oculus rift.

41:13 I: Okay R1: Yeah. There is a lot of side effects there, as you can see. Dislocation and disorientation, that's.

41:24 I: yeah, that's definitely one of the key concerns with the virtual reality stuff.

41:32 I: Okay, so yeah another concern is, some people have a concern that this increased knowledge of our mind and our brain, how that works, might change the way, we see the concept of our identity and stuff like that. Is that something you thought about as well?

41:52 R1: Well, definitely will have implications, you can see that, that when the computers, came into existence, and especially when they became personal. They already had a big implications on individuality and also in identity. So yeah, and that will go on, and on. Like this is something that we call progress. If that is really true I [wonder]. But, yeah it's a very, very. It's a very interesting topic, it's also, necessary to watch, and to, question all the time. Because especially in the young, and younger, and young generation. These are people that are born basically with the smartphone in their hands. I think that has major implications on, on our current knowledge, but also on their knowledge.

43:01 And how they are gonna move around in, in the world. So, yeah. Does that matter? For my point of view, yeah. I think because, you cannot, you cannot stop it either. Because, there is just no way to stop it. I mean, we are people and we everything. You know, just throw them some food, and they will eat it, so.

43:30 R2: I guess it's also about, if it feels like, if it's like a choice. Like I guess also, now you are saying, talking about smartphones and like social media. Like younger people I know that they are so used to always being online on Facebook whatever. So it's not, some kind of ignorance of course. This is just life, so. Well of course with BCI, if it's a choice, this kind of personal or [INAUDIBLE] about that will not. [A big impact] but, when it's like, well it is a future scenarios also when everybody is walking with their google glasses or whatever. Yeah. There needs to be an extra layer of, from ignorance I guess, and so yeah. That is a bit my view I guess on.

44:39 I: But following up on that, do you see that, somewhere in the future for BCIs that, maybe someday everyone will have it and we will have people who are good at using the BCI and those who aren't and maybe even those who can afford it and those who can't. Do you see that as a problem in the future?

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45:00 R1: Yeah, it will come, like, when the oculus rift came out there were instantly companies that sell smartphones that. And they came included with a goggle. Just to fill, fill the market, fill them up with goggles. There was no content whatsoever, useful content. So BCIs will flood the market as well, once there is some kind of easy PC setup and that. Yeah that will be, that will definitely be part of our. Our world yeah. That's how industry work, because it's all, it's all for the good of consumerism so, yeah, and that's a highly ethical problem.

45:53 You know, because there is nothing to regulate because there are no rules for that. And, and at one day if we need them, like, I hope like what happened to google glass that, the same will happen to BCI that it will just be a defunct project and product.

46:15 I: Okay, yeah, let me just check my questions here. Yeah, so when you were working with the BCI, what sort of thing did you do to try and make sure that the BCI were changed or used in a way that users actually desired?

46:44 R1: Because the BCI we got, the emotive, I don't remember the type but I think it was number 2 or so Epoc. R2: Epoc 1 R1: one okay, was a very simplistic not fully functional little gadget. And after a couple of trials and experiments we sort of got fed up with it and so we didn't give it a second thought anymore but just then, that we took out the sensors and started playing with the sensors in our own sort of way.

47:29 I think that is the best anyway to do with any kind of product that comes from industry, just take it apart and reassemble it they way you want it. And I hope that, basically, and this is a vision, that I have. That anybody in the world like, in any level of knowledge, or schooling, what do you have. That is able to make their own products. So, that this, you know, that you can fix it to your own liking. As we have been doing with our environments our little homes. Everybody does it their own way. You know, everybody has some kind of an interior which consist of a table and chairs to sit in the kitchen and lazy chairs in the living room but, everybody does it in their own way and taste and liking [INAUDIBLE]. And that's the same with computers, but they are so dominant, technology has been made so dominant, that we think that is the ticket to ride. And I think we should curb that. We should really curb it and say no, it's just another rotten piece of furniture, you know, and at one point, don't consider it too much of importance. I mean, we should start concentrating again on society and face to face interaction.

48:58 And [turn] off all the gadgets. R2: But also, to [INAUDIBLE] the question it's. It's also again the part of the, well ignorance and if, well the user, the people you are taking into the experiments for whatever purpose. Yeah you can explain them what you are going to do, but yeah, how far do you need to go, you know? Like, on which level do you have to inform them and if they say, if you just ask them, I would put this on your head, are you fine with that, and we will just do an experiment, so a lot of people already say yes or alright because they feel it's their well, it's their free will to control, what is, being [taped] to them, whatever. But of course. R1: It's a discussion R2: it's an illusion, it's illusion of, that you think, okay I've now

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control of, I will. R1: It's a discussion R2: I give consent so it's alright. And it doesn't really, then it doesn't even matter if we, well, take all of their data or not, so. That's yeah the ignorance part I guess.

50:22 R1: But you can take basically all the signals right, you can see if they become aroused when they, when you show them some pictures that are highly elusive and, you know. Do you want that, you know? This is the whole thing, I mean. There is a big big issue, if you don't tell them in advance, like what [NAME OF R2] says. I think that's not fair, because we, with more and more increasing precision of the BCI systems, you can basically see, I think at one point, any emotion.

50:58 That comes from within. And you can tap off even waves that, that you don't tell the participants, like what google does to us, happens also with potential, very intrusive applications like BCIs. Because we are always more, like, people are from, from, you know from the, the basics, they are curious and always interested in the otherness. And the otherness is basically driven from the curiosity and explorative drifts of persons. And you want to find out if your neighbour has the same ideas about your wife as that you have, or you know what I mean? Like it's really, scary so where do you say stop it. Where? You know, this is a major thing, and even in experimentation, if you can use it for people maybe that have some, let's say a specific condition it's been helped, fit them out with a specifically designed, on target, fit to function apparatus, yeah. No worries there, no worries. That's like, if you miss your arm, we fit an exoskeleton and all of a sudden you become more mobile again, fine, no worries. But with the current state of the technology, I think it's, it is [INAUDIBLE] of course to stress the ethical issues more and more, and target it also, and also, make aware all the implications that where you are testing and experimenting with, let's say innocent harmless people, you know. That is you know, it's a dominant there, it's really dominant to, get that out there and get the understanding. Because you know, we are very gullible, we look at all the commercials and everything that is spammed on a daily basis and, on your phone. I mean it's, it's ridiculous really. Right, it's really come to a point and just say, well what are we doing as a society?

53:16 I: Yeah, another, one concern that's basically like, I problem I think it's all through neuroscience. But there is always a concern about enhancement and cognitive enhancement and stuff like that. And what ethical concerns that might bring about, is that something you thought about as well regarding BCIs?

53:42 R1: I think the best cognitive enhancement is in, is in drugs. In hallucinates. And if you really wanna have some more, let's say, if you want to up people a little, you could have, do that in very micro doses with hallucinates instead of using. Technology like BCI. Because I don't believe that a BCI could enhance you cognitively. I: Okay R1: Because I think it [sits] them from within. It [sits] them from, let's say, some motivational drift and intentional drift. This is my personal opinion, I am not sure how [NAME OF R2] thinks about that but, you know.

54:30 R2: Well yeah I've never even thought about enhancement with such a tool, so yeah. That's I guess I am on the same level.

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54:44 I: Yeah

54:43 R1: Can you, can you see it? I am wondering. Can you see it?

54:45 I: Uhm, it's. From my point of view it's a bit like, calling a bicycle an enhancement tool for getting fit. So yeah. R2: Yeah.

I: So yeah, for me it's a bit of a stretch, but I can also see, I think it's more of a combinational thing. Once you start combining it with other tools and drugs and everything, then maybe it can be sort of a catalyst for enhancement problems. But whether BCIs in itself is a problem, that's definitely something that's debatable.

55:37 R2: Can I add something to that? because in the sense, when you talk about enhancement. That of course there is some work, done with, well, people that are somehow restricted or whatever, and I also think well that's and they should, because well, they are able to. Or they need some kind of care and this is actually a kind of care, this can provide some extra care. But, in terms of well, I think, I have seen some products also with a, platform, where you can then analyse, [well] your mood of the day, or whatever.

56:28 But, when you are already, wanting to, well, reflect on yourself, you don't need this [INAUDIBLE], so it's like. If you are already, just like when you track, when you run all the time. You have to run the whole time so, you are already like, it's just an extra layer to well, so it's not an enhancement, if you are just, some kind of extra gadget you can, [INAUDIBLE] your time with, with a Fitbit. But it's not, it's not, the actual enhancement because that needs to come from yourself. To say, okay I am going to run, and. Every day or whatever.

57:13 R1: See, that is what I said initially on the onset of the conversation. If you have to fit it to your body, apart from maybe glasses, right, spectacles. Because, once you have glasses, you right away are, you know, addressing a, a problem, with your vision. And it's also, it became an item of style and so, it doesn't really have a lot of implications like a watch for example. to tell time. But we have, other things, attached to your body I agree with [NAME OF R2] it's just an extra layer to nothing basically, which tells you, your emotions over the day, like who really cares. And it tells you how many steps you've taken over the day, who really cares. I mean, you know that you sedentary and you sit in an office the whole day, so you know that you didn't do a lot of walking.

58:10 So this is a no-brainer but people are becoming more and more brainless because while these apparatuses, so that's, that's for me a concern. At the same time, what I think is necessary is that, I wanna

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go there now instead, if you have the ability to implant sensors. You know, in order to, yeah enhance maybe some kind, or augment some kind of deficiency, that I have always kind of liked. But that is for me, similar to what I said earlier in the case of, micro doses of enhancement using psychedelics. And you can see that the whole society is slowly turning towards that idea because, we know from tribes, tribal settings that they do that already for zillions of years. So, and it makes them really come in contact with the body which they are, you know, whatever you call it soul or whatever. I am not. And it becomes, so they can become a better person, but also understand themselves emotionally and physically, but also.

59:29 R2: It's a real, outer perspective. Like when you see your data, visualised it's not an outer perspective. So, you cannot zoom out in that sense and yeah. I guess. When you use like a drug, you are in another state. You can switch perspectives actually, so.

59:49 R1: yeah I: Yeah, following up on the implanted comment you made. Some have actually raised concerns about those type of devices, in the sense that, they could be hacked just as pace makers can be hacked. Is that something you see as well?

1:00:10 R1: Well once again, yeah everything can, can be hacked you see, and that is again, has to do with how you fit it. If it is, like, if you address a certain condition, or a certain deficiency. And you are able to enhance that, let's say, to the degree that you can get back to your full 100% of [INAUDIBLE]. With a technology, or a implant. That is okay. Because you can regulate that. You can actually you know. Make sure that, that works.

1:00:54 The thing is, we never address our research to that, because why can you hack it? Because it's hackable. You know, so the instruments we implant, I, the other day I spoke to a company, or, no also a researcher from the UK who does some research on a sensor that is called a northsense, so what it means is that this sensor you sort of, plant on your body, you first have to have a surface piercing, actually 2 surface piercings. In order to place these sensor on your body. But then you will, every time you face north it will give you a little nudge, a little trigger.

1:01:43 And so that way you can always, wherever you are, in 3-dimensional, 4-dimension space you, you always know what north is. I used that sensor because I bought into it. I didn't do the in-surface piercing because, that was a little too far for me. But I found some ways to, to put it onto my body. And I used it for a couple of weeks. Not anymore now, but I said, you know, if you are able to put something in your, let's say, in your body, that has a similar function. Yeah, I would do it.

1:02:24 R2: Like a sensorial layer R1: Yeah, because I kind of like the way, I like the philosophy because we are very sedentary people right now. Everybody lives in, in high rise cities, millions of people live in high rise city. So they don't have the, nomadic perspective anymore. And I think it would be great, even if you are living in a city you would still be, made aware of that there is a north.



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1:02:51 There is a north star, there is a north pole, whatever that means. But, you know, some sense of direction like you are part of this, planetary structure you know, living on this planet, and you are just a space traveller as anybody else. And I kind of like that, so if you can have an implant, I'll do it.

1:03:09 I: Okay. R1: It has not to do with BCI though. I: Oh, it could be. R1: It could, yes. It could. You know what I mean.

1:03:22 I: So yeah, many of these topics they tie into concerns about policy gaps and legal concerns. Is there any of such concerns for you, regarding BCIs?

1:03:34 R1: Well, yeah. They should be fully transparent, they should actually be, telling the truth, if there is any truth. But, it should be fully open. And should probably be explaining what the device is doing, what kind of data it comes out, how the data is used, what can be done, if it can be hacked, what kind of hacking can be done, and so, etc etc. So yeah.

1:04:14 I: So some regulations to enforce transparency is something you would like to see.

1:04:20 R1: This is what is missing, so, in society, you know, at the moment. So, there is no transparency.

1:04:30 I: Okay, and what about you [NAME OF R2]?

1:04:36 R2: Yeah, I guess the same, and also, well there can also be an additional, i guess, an educational step, because of course we, you see this image of the BCI and your fancy interactions and whatever. And, but like I guess, 99% of the people who see that. They will never ring like a bell says like, hey, this is also maybe some downsides or. So this ignorance I was talking earlier about while you are using Facebook or whatever. So, educational wise that could also be the step, to say, hey, new technologies, yeah, be sceptical about it.

1:05:29 And I guess now we are, actually, we are like, everything is so rapidly rising out of control. That we are like, I guess as society just, well getting kind of horny of all the well new developments and just embracing it. Spot on, and without this kind of scepticism about what used to be I guess. Before my time, a bit more when [INAUDIBLE] well, could have some criticism because well, the development strides that were made were maybe, well a bit, taking more time so. So I guess yeah, this is kind of, reflective state on new technology could be well, reintegrated in a educational way.

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1:06:39 So I guess it's nice that we can [INAUDIBLE] this stuff but, yeah, what downsides.

1:06:47 R1: So different perspective right? R2: Yeah

1:06:50 I: Okay, well then the final question is basically whether there is any ethical concerns that we haven't discussed already that you want to bring up?

1:07:03 R1: Yeah, two things here, because. I am kind of, I am always a very lenient towards what we call, maybe open mindedness right? So, I, at one point, I don't know under which [hold], let's say industry or research, anything. For me that, it should be basically boundless, everything should be explored and tried to be investigated and [bla bla] that is one thing. I think that is, but if that is so, right. Then if you allow BCIs in research, as we do right now, then at the same time we should also allow the entry of hallucinates in research. And in let's say research institutions. Because for me, it's the same thing. We allow smoking, already for I don't know, ages, drinking for ages, everybody drinks to oblivion. There are sort of regulations but at the same time they are not. So I think, there is a lot of, let's say, paradox in society but especially in research. In the academic world. About, what is allowed and what is not allowed. And I think, if you allow BCI systems and all kind of other contraptions that sort of, you know, take stuff from the brain, whatever you have. Then at the same time we should be allowed to use hallucinates in research in order to see if we can counter act, some of the, the devices that we think have promise. You know, if I need enhancement in [INAUDIBLE] or creativity, I will rather use a little bit of a drug, to stimulation.

1:09:03 I am not saying here that we should use more drugs, it's just that I, that could help to facilitate some of that. In order, than to facilitate them with a BCI headset. You know what I mean? So there is a little of contradiction and there is a lot of paradoxes in things like that. So yeah, that's why I am probably on the other spectrum of it, not so open towards using this stuff.

1:09:30 Like, especially not when it becomes a consumer product like the BCIs for example, because they can be hacked and I know that all the toys that come out there are hidden agendas, there is lots of obfuscation in the. In what the actual, let's say internet of thing artefact can do. You know, and that is not being stressed, and that is not being conveyed to the public at large, and the thing that is a big problem.

1:10:06 Like if they could really tell you, what, when the moment that you go onto google or Facebook what happens with your information I know they cannot oversee it themselves there in those companies. Then, it would be a completely different story. And that is what I compare with [NAME OF R2], is that, there used to be some kind of, you know, scepticism, some, yeah, cynicism maybe, some, you know, like holdback in, adapting to new stuff. Yeah there was.

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1:10:39 And now, it seems like, how [NAME OF R2] said, everybody is horny and everybody wants the newest gadgets in order to be, you know, technology prone. You know what I mean?

1:10:52 And that is really. Why is that? That is so much, sign of these times like it's. You have to be hyper all the time, you have to be up 24/7, and all your data should be free. It's totally ridiculous if you come to think about it. And then people say "yeah but I lie on Facebook, that is not really who I am". Like what are you doing? What is this?

1:11:19 You know, like HELLO. You lie? On Facebook. "Yeah, and I lie also on tinder because that's not really who I am, I am a real fucked up bastard but I am on tinder". You know what I mean?

1:11:32 I: Yes R1: Yeah, that has ethical implications. Sure. Yeah.

1:11:38 And I am not religious you know? I am an open minded person.

1:11:42 But I have concerns. I: Yeah [NAME OF R2] do you have anything?

1:11:47 R2: Uhm R1: [NAME OF R2] is laughing. R2: No I guess, [INAUDIBLE], same for me, not religious. R1: Agnostic right? R2: Maybe. R1: But with a headset on you can't become religious. R2: Yeah, it's kind of. That's kind of, could be interesting to see that. Well it's going towards reading, of course a, yeah. Smaller boundary between what is inside and outside. So, maybe this is what is going on, we are just becoming more of a [INAUDIBLE] kind of big creature, and [individualism] will, die. But yeah, I mean yeah, if it's would do that.

1:12:50 R1: You know, what I am thinking right now because I, I read a lot about incarceration of let's say young black Americans right? And there are millions of them incarcerated because that's complete new economy, you probably know about that, but like, you know, I can see that, these Americans will fit them up with BCIs and you know, start mind control all these people, you know. It's scary, and I know for sure they already probably do it. So. Just shows you like, why are we doing this? Is it mass control? Is it? What is it?

1:13:31 R2: I guess in general, I don't know, [INAUDIBLE] was talking about it, but, if just a technology is, well portrayed in a area where it's beneficial so in healthcare or this kind of things. Then that's also the public statement, that this helps us. While when you see robotics from Boston dynamics created for, for defence, everybody is like whoa that shit is fucking dangerous so.

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1:14:09 It's also, yeah this hidden agenda for, where it's context, yeah the context, so if. That is, that is kind of scary maybe, that, when we say, oh BCI yeah we can help the autistic children to yeah, concentrate better or whatever, everybody is like oh this BCI stuff is awesome, it can help us. And [INAUDIBLE] it's adapted and then, you get stuff like.

1:14:42 R1: Let's put it on Johnny because we cannot understand why the kid is always running away from home. You know, so we then, we can track all the thoughts of Johnny so we can control him better. Because Johnny was running away because there was an [effective] problem between the parents, because the father was hitting mom and the father was always drunk. That's why Johnny run away, but now all of a sudden Johnny becomes the problem and is fitted with a BCI so we can address the problem to correct Johnny in a mental way. That's wonderful, right?

1:15:09 That's what we want to have.

1:15:14 I: Alright.

1:15:16 R1: Was that a question?

1:15:21 I: I took it as you not, you making a statement and not a question.

1:15:26 R1: Excellent. It was very opinionated.

1:15:30 I: That is, perfectly fine. But in that case, I will shut off the recording.

8.2.11 Research stakeholder 5

I: Interviewer

R: Researcher

00:00 I: First off, maybe you could introduce yourself in a couple of sentences?

00:11 R: Yes okay, my name is [NAME] I have a bachelor's degree [only] informatics engineer. And master of science on advanced systems and methods in biomedical engineer. My main research goals is on bioinformatics and BCI. Brain computer interface.

I: Yeah, okay. Yeah, do you have anything more?

00:38 R: No, I'm working as a professional systems engineer the last three years on a big. Here in [COUNTRY]. That's it.

00:49 I: Okay, so yeah, maybe you could explain some of your, some sentences about your research?

00:57 R: Yes, I have. I have done a research about how to design a brain computer interface with a commercial headset BCI, more specific the emotive EPOC.

My, what I did in my research, it was to run dedicated software application on, on the processing language is a java based language. And what I did is to invoke sudo commands to an Arduino Uno that the signal is acquired from the headset. Actually you can move a robotic claw, with your brain.

01:53 I: Okay. Okay, so yeah, what do you hope that users will use your BCI for?

02:04 R: The main goal of my BCI is to, to show, to show on the general public that with [zip] technology such as an Arduino board and some servos, several motors that you, could have in your every day life a basic robotic claw. That you can use, with your mind, with a little bit training a person will have some disabilities. He could use everyday things as brushing the [teeth] or holding a cap or something like that. That's the main goal of my research. To show the general public that with some [tip] pushing. Equipment, some simple equipment you can use a BCI.

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03:13 I: Okay. Okay, yeah so, throughout history we have seen technology been used in ways that might not have been intended by the developers. Is there any such concerns about the BCI you are developing?

03:31 R: The concerns about the BCI developing, I think is more on, from my respect. I think the general public has a, a technophobia bias, if you know what I mean. Person that doesn't have much knowledge could be afraid or something like that. So that, [INAUDIBLE] all the stakeholders in general they have to, to make a trust building marketing of the BCI from commercial use. From the research part I think, as long as the research follows the biomedical standards for ethics I am okay with it.

04:25 I: Okay, so you don't see any unintended usage of BCIs in general?

04:32 R: I can't answer that, I don't know what the big companies as google or Microsoft or whatever have in their minds, but my, my perspective, my goal is pure, it's pure for knowledge for science and stuff like that if you know what I mean.

04:55 I: Yeah, okay. Now you mentioned google and Facebook, what's your take on them looking into BCIs?

05:05 R: I think they have, what I said before, they have if they, intent to use BCI technology, they have to built it, they have to built a trust between the public and them. The marketing they should do is about building a trust, but the general public not to be afraid of BCI technology.

05:36 I: Okay. So, in the research literature there is a lot of discussion about, well and concerns about misinterpretation and the accuracy of data, is that something you, met as well?

05:53 R: Yeah, in my research, with an emotive EPOC. I faced this difficulties. The sensors couldn't have good connectivity. It's [INAUDIBLE]. There is, much of the time, the signal had to. How to say that. It's a little sensitive to noise and to [INAUDIBLE] so the. The outcome has to be done by filters. Lowpass filters, [INAUDIBLE] and stuff like that. So the biggest difficulty is the, the connectivity from the sensors, from the BCI. for the headset I mean. The second difficulties that you have to do, much much, you have to, to dedicate much time in training. So the, acquired data is not about precision than is more about the skill rating of the subject. What I mean. As much as you go through training, the outcome is more. I can't find the word, give me.

07:42 I: Yeah, so basically the more training you do with the subject the better the data accuracy becomes?

R: Yeah yeah yeah, exactly that.

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07:52 I: Okay. Yeah so, it seems like the solution to many of those problems are better AI and machine learning algorithms and not so much better hardware?

08:08 R: I think the, the problem is on the hardware. I: Oh really. R: Yeah yeah yeah, the hardware. You have better algorithm, the algorithms is something that you always do better. The hardware I think is the problem. I: Oh really. R: The emotive EPOC for example because is the BCI headset that I used. Have a 14 electrodes, electrode sensors. Two for reference point behind the ears, that the, what they actually do, they measure the potential difference on the skull [surface]. That the, your neurons create. This is, a technology that, as I said before has much problems. Big problems I mean. With the noise in the artefacts. The signal that you get is not very accurate. So I think they have to do something with the sensors. Something better with it.

09:28 I: Okay, so yeah. Let me just see here in my questions. Yeah, so also in the literature some are concerned that BCIs might change our concept of identity. And how we see ourselves. Is that something you see as well?

09:51 R: Yeah, I believe in that. What I mean. I think the BCI in the future, it will help for rehabilitation of cognitive or neurological problems. That aims [wait] people with motor [INAUDIBLE] such as ALS paralysis or stuff like that.

10:26 I think if the general public with some disabilities have access to that technology. That would change the perspective of life forever. So if a person with paralysis for example have again the ability to use everyday stuff. To not be excluded from the general public the outcome is that I with that I don't have any disabilities, I feel a better person, that I've helped that. You know what I mean.

11:09 Yeah so I think yeah, BCIs could have a good impact to everyday life. If that [would] your question. If I. I think if I understood correct. What was the impact of BCI in your everyday life question?

11:34 I: Yeah, well, yeah. Basically. It's specific, in the literature it's specifically how we see ourselves. But it, yeah I guess that ties back into how it might affect your everyday life. But I'll get more into that as well because there is a few concerns that ties into that.

12:04 So yeah. Another concern which might be obvious since it's a technology is that some people have mentioned privacy concerns. What do you think about that?

12:21 R: As I said before is in the general public, there is a technophobia bias for that. And not only for the BCI for the times in general. Like bioinformatics [the name], genetic mutations for the food or something, I.

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I think that if the neuro pattern that you acquire from a headset, from a commercial headset, not for research. Follows the bioethical rules of medicine. I am okay with that, but as long as there is technophobia bias on the general public I think, that, that would be a problem. So I think that this is a part of the interesting in general. The companies, they have to, as I said before, they have to to build a trust between their stakeholders.

13:47 I: When you developed your, your setup. Was privacy a concern you made specific changes to?

14:03 R: No, no not at all. All the subjects that do come, part of a research, they don't have any problem with, the. Actually let me explain it. They emotive EPOC has a, an option for the research, for the researcher, to have access to raw data. Here in [COUNTRY] because, we have a, economic crisis. That effects the education system as well. So in my, in my school, the university of [CITY] [INAUDIBLE] science. We don't have the money to have access to the raw data if you know what I mean. So we have to do what I did is little trick with a protocol that it use for the to the music, the synthesisers. They, is a open [INAUDIBLE] protocol. That they actually translate the signal from the brain, who open sound control protocol. And that, it was suitable for the Arduino board. So in my research there is no raw data, there is no data base, that holds the data acquired from your neurons. The privacy was not a problem.

15:46 I: Okay. Okay, yeah. Because in the literature they often put invasive BCIs and non-invasive BCIs into what they just call BCIs and talk about the concerns. Some researchers have mentioned the concern of security issues just as with pacemakers. Where if you have an implant and it gets hacked then there is security issues around your health. Is that something you see as well for BCIs or?

16:25 R: As far as I know, the commercial BCIs is strictly non-invasive so if someone has an implant in his head for BCI research, it's for research, it's non-commercial. So. As far as, my concern in the commercial BCIs. This is not a problem. For privacy or whatever. What I mean is, if an individual agrees to have a surgery for research. [INAUDIBLE] the privacy is not a problem. But what you mean, I think is in the future, if they have a invasive technology. I: Yeah R: Yeah I think that is a problem. I think that then the neuro data that have, that they will have to follow the rules of biomedical ethics. The privacy [and all that]. Maybe one solution for that is to, make new laws about a neuro data that is acquired. I think is a good solution. For people to follow the rules, follow the [numos], the law of biomedical ethics in general.

18:11 I: Yeah, okay, no yeah it makes sense. So yeah. Another thing that has been raised as a concern is side effects. Is that something you thought about as well?

18:24 R: the side effects of an invasive or non-invasive technology? For non-invasive technology I think there is no side effects. From the users of a BCI headset. The side effect that I could have in my mind right now is after a few hours of [research] the subject as is, normally, will feel some dizziness or something. As if you are in front of a computer screen for 5 hours. If you know what I mean. Now, in the invasive part of the



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research there is a, I think, there is no mine, how can I say that. I don't have the knowledge of a neurosurgery. I: No yeah R: So I can't tell you what would be the best side effects of an implant in your head. I think that it would be, if you know what I mean, yeah.

19:34 I: Okay, could you see any side effects that might not be physical ones, but maybe on society in general?

19:46 R: That's a good question. I think there would be side effects more on psychological. The, what I mean. Imagine a subject that don't have the access or the money, I mean in the future, not right now. If the commercial BCI is a thing, that is used for rehabilitation. Imagine a subject that have a disability and don't have the money to buy or don't have the technological knowledge to use a computer or a BCI or something like that.

20:40 I think the side effect it will be psychological if you know what I mean, feel left out. Yeah.

20:49 I: Yeah, do you see any ways to maybe get out of that situation? Is there something you could do to make sure that everyone has access and the knowledge to use them?

21:04 R: that's, an answer that the companies should give. If you know what I mean. The big companies have to do. The BCIs simple enough for persons with disabilities access to it. For the rehabilitation. Problems. It will all. Another thing that I can imagine right now is, if they are cheap, that they are easier to use. An old person don't have the knowledge to use a, properly. A computer system. So if the graphical user interface or the menu or something is easier to use, if you know what I mean. Yeah, I think that would be a good solution.

22:19 Easier access, cheaper access and easier to use BCIs.

22:26 I: Yeah so. Basically tying into all this, when you develop your system, did you do anything to try and make sure that the system you were developing were something that was for example easy to use and something that people wanted to use?

22:50 R: Yes. My main goal was to for my system, the setup that would be easy. One of the parts of my research is, was, was to build a graphical user interface. Very simple to use, with four button clicks. To connect it on your computer and to have the proper, give me a moment to find the exact word.

23:29 I: But yeah so also.

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23:32 R: The proper message to, give instruction to the subject to follow. So after you have connected to your computer with one click through a universal serial bus. It prompts proper message for you to follow instructions. So it was one of my main goals to be easy to use.

24:00 My setup.

24:06 I: Yeah, did you have anyone try the system? Did it work to have like only 4 buttons?

24:10 R: Yeah it has only four buttons. And system was tested on a. A. More than 30 times, to me. And one day I took my setup to the school and this is not a part that I put in the paper. I: No no, but just. R: It's off the record. So one day I took my setup to the school and have be used from several our students. Undergraduate students healthy, under 25 years old. The results was, was promising.

25:00 But the problem was that the connectors couldn't have the proper connectivity. Most possibly I think due to the morphology of the subjects skull or something. That was the biggest problem. The graphical user interface was pretty easy to use. I think everyone, even an old person could use it.

25:31 I: Yeah yeah, so that brings it back to the issue with the hardware. R: Yeah yeah yeah. I think the main issue with commercial BCIs is the hardware.

I: Okay. Let me just see where I got to.

25:46 Yeah, some have argued that BCIs will lead to neuroenhancement. Is that something you thought about as well?

26:01 R: I think yeah, and I am big fan. Of this. I think it [would] be a major advance to become neuroenhancements to, to be specific, on people with problems. What I mean that a person with a problem have to, to have a neuroenhancement. In that case, yes I think that would be a great thing, in the future.

26:45 I: Do you then see the worry that people who are normally neurologically, like then using it to be, even better? Is that, a concern you can see?

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26:54 R: Yeah, I have a concern, I have concerns about that. I think that the, the nature of human being is being a bit more aggressive. So yeah, I think people will do that.

27:18 And this is about all, I think it's a part from the companies to have it [promote] the marketing to have a if you know what I mean.

27:36 I: yeah, okay so. But yeah, that ties nicely into my next question which is about informed consent. I know in research there is, like this is a big thing and making sure that test subjects are informed about the experiment and everything. How do you see, that concern?

28:01 R: I think is a [measural] thing to have the subjects be informed properly. Of the, the, give me a moment to find the word. [INAUDIBLE] Procedure. About the procedures that would be what was the question again about?

28:28 I: Well just, how the question of getting informed consent might tie into.

28:38 R: Yeah. I think that the subjects MUST, with capitals, be informed properly. About the procedures, about the the performance of the headset, about what it will do. The techniques or whatever.

29:03 I: yeah, do you see a difference in how researchers make sure of that and how companies make sure of that?

29:13 R: Differences. This is a thing I can't answer, I don't have the knowledge to answer. I don't know what a company, how the company, a company would think of that.

29:34 I: Yeah yeah. R: From the research part, yeah I think is a duty from a research to provide proper information to the subject, about the techniques or the procedure or whatever.

29:52 I: Yeah, okay, so yeah, a lot of these topics tie into a concern about policy gaps and legal concerns. Is that something you thought about as well?

30:09 R: yeah, I think I answered that before, I think the little concerns, it, as long as the BCI technology follow the bioethical standards world wide. I think this is not. There would be no problems.

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30:27 I: Okay but, do you think that governments are good enough to keep up with the development in BCIs?

30:38 R: I think that governments do whatever bring, brings them money. As to, here in [COUNTRY] I can't tell for other countries. Here in [COUNTRY] we don't have the proper, [NATIVE WORD] I can't find exactly the words. Our government doesn't concern about education that much. So there is no programs, there is difficulty to do a PhD that you are getting a refund or something. For example I am going to give a proposal for my PhD research. In the March, and there is, it's certain that I will do it for free. With no, refund or something. So I think the [COUNTRY] government have to, to be more, I don't, I can't find the exact word.

31:51 I: More active? R: More active yeah, thank you. More active to help the, education system.

I: Yeah, okay. And, how do you think that might impact the BCI development not having the government being so proactive in helping people?

32:16 I: Will it set it back or? R: Yeah, of course it will set it back. For example, a young researcher have all the potential, all the good will, to do a research. If they don't have the, the funds or something, or the equipment or the, the place to do. The most of my research I did it in my home. Not in school. We don't have the, the proper place to. So yeah.

32:57 I: Yeah R: If you know what I mean. I: No yeah, I can definitely see that as a problem.

33:04 I: So yeah, basically my last question is sort of a free for all talk about what you find interesting about BCIs. But yeah so, is there any concerns that you might have had or people you talk to might have had that we haven't discussed so far?

33:25 R: No I think we covered everything that I have in my mind. But you, what is your last question, about?

33:35 I: Basically just whether you have anything to add, that we haven't talked about already?

33:40 R: No no no, I think we covered what I have in my mind.

33:48 I: Okay

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33:50 R: What I have to suggest for. The human computer interaction whatever. I think that, the applications should focus on the persons with autism, or ALS and this problems. What I mean is that, we don't have the need, it's good, but we don't have the need for neuro games or BCI game developing or whatever. I think that the government and the researchers have to mainly focus on rehabilitation of cognitive or neurological relations. From my perspective. I: Yeah yeah.

34:46 R: that's my main concern well.

34:52 I: yeah, how do you think that, it might be, like how do you think it might be possible to focus researchers on that rather than neurogaming and stuff like that? Should it be the government setting those directions or?

35:13 R: I, the educational system overcomes it, I think. Or have. A great impact on that. And while I think it is, yeah it's part of government. Yeah the educational system to proper educate the students for the needs or where to focus with the research.

35:41 I: Yeah, okay well then I will just stop the recording here.

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### 8.2.12 Research stakeholder 6

I: Interviewer

R: Researcher

00:22 I: Okay, so first off, maybe you could introduce yourself in a couple of sentences?

R: Okay, now? I: Yeah R: Okay, my name is [NAME] I am from [COUNTRY] I am an [electrical] engineer from [UNIVERSITY]. And I have been working with BCI for two and a half years, at least.

00:50 I: Okay, so yeah, can you maybe in a couple of sentences describe your research and your work with BCIs?

01:00 R: Okay, I have been working with [electrical synos] and, I have made, I have used some, machine learning algorithms and, I have using some. Different application, [INAUDIBLE] with [INAUDIBLE] according to the [INAUDIBLE] made. And the second was I [wrote the] [INAUDIBLE] by [districts]. I have been using neural networks and another [INAUDIBLE] for do that.

01:37 I: Okay, and so, what do you hope that people can use your BCI and your work for?

01:43 R: The idea, the main idea of the project was help with people with limit mobility. For, the robotic arm was made for. I am sorry for my English it's very rustic.

02:03 I: That's fine, it's perfectly fine. R: Okay, it was helping people to take their medications, just with the arm. Point from the medication was to [INAUDIBLE] them. [INAUDIBLE]

02:18 I: Yeah, good. So yeah, often with technology we sometimes see it being used in ways, that you might not have intended as the developer, is there any such use cases you might see with the device you, you've made?

02:32 R: Excuse me?

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02:36 I: Yeah, so throughout history we have seen technology been used in ways that wasn't intended so for example with the internet it was mainly developed for universities and military bases and stuff like that and ended up being, well, what it is now. So is there any such things you can see maybe with the BCI you developed?

03:02 R: No, for the moment no. We have only used it for that. Just.

03:09 I: Can you imagine any use cases that might be other than what you intended it to be used for?

03:14 R: Okay, so, my friend, I have some friends that are working with BCI too. And they have made some, a device you have people to with problems of speaking. So they use the BCI to, to make them [INAUDIBLE] in some way.

03:37 So I think it was a [grain], and we have been working together in that, it was, it was [INAUDIBLE].

03:49 I: Okay, so yeah, in the literature there is a lot of concern about the misinterpretation or the accuracy of data from BCIs, is that something you had issues with as well?

04:03 R: Yeah we have some issues because, the [signal] we are using, was changed according to people so, I, at the first place I have to use it, but when I test it in another person I have to change everything. Because everything change, so it was a issue we had.

04:24 I: Yeah and, how did you try to fix that? or did you try to fix that? Or was that just, how it was?

04:30 R: We tried, because it didn't work, for example for the training with the blink. With blink it, I record my blinks, and my [boyfriends] and another friends, we trained with a blink and we tried to put in the same metrics but it didn't work, it was a totally mess so. We conclu[de], we did training before use it, everybody so. It was, it was a [INAUDIBLE] time. But, at the end it worked.

05:05 I: Okay, so yeah, you found a practical solution to how to, make it work. R: Yeah.

05:10 I: Okay, so following up a bit on misinterpretation of data, and stuff like that. There is a lot in the public about, well in the literature about public awareness, and how BCIs and neuroscience is portrayed in the media. Is that something you worry about as well?

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05:30 R: No, I do not worry about because, when you share the knowledge you can, you find your boundaries so. I can't. For example I can, I cannot, I fix in some way my issue. But if someone who will practice or have experience with the [that]. Maybe he can, he can find another solution for the problems so. It was a, a collaboration.

06:03 I: And have you, had contact with anyone who had been worried about putting on a BCI or? Thought you were reading their mind or anything?

06:15 R: No. Not yet.

06:16 I: Not yet. So yeah, another thing is that, some people have speculated that BCIs might change our concept of identity and how we view ourselves. Is that something you see as well?

06:36 R: I am sorry, can you repeat the, the last part please?

06:39 I: Yeah, just basically some people have speculated that it might change how we see ourselves. Having that insight in your brain. Is that something you thought about as well?

06:56 R: No. No because I think, if people use with good purpose everything is fine. And it depends to. My, the machine is as good as the creator. So. We have to be careful, just in, with [hands] it is, but not for now. I think we are so far away from that [INAUDIBLE] to watch literally in our brains so. For now, no I am not concerned.

07:33 I: Okay, so yeah, another thing that people have raised concern about, is privacy. Is that something you thought about as well?

07:43 R: What privacy? I: Mhmm R: No, no I think, no. At least in the research, everybody gives [consents] to do that so.

07:56 I: Yeah. If I am understanding your device correctly, it didn't actually store any data as well? It was purely mechanical so you made it do something, but it didn't store any of that data right? R: Yeah



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08:17 I: Yeah, okay. Let me see here. Yeah, in the literature there is sometimes the confusion between different kinds of BCI, so sometimes they just talk about BCI in general. Which relates to my next question. Because a lot of people talk about both invasive BCIs and non-invasive BCIs as one thing. So some have raised the concern that there might be a health and security risk as there is with pace makers. Where we have seen pacemakers being hacked. And therefore causing a health concern. Can you see that be a problem for BCIs as well?

09:07 R: Yeah, because. It.

[CONNECTION ISSUES]

11:02 I: Basically the question was whether you can see any health and security concerns as we have seen with pacemakers for BCIs?

11:11 R: Yeah, so. BCI. Okay I am sorry, I don't understand the question.

11:26 I: Well basically we have seen some issues where pacemakers has been hacked before.. Yeah? And basically some researchers have said that, that might be a concern as well for BCIs, that are implanted. Is that something you see as well?

11:51 R: About. I: That they could be hacked and then cause a health risk?

12:06 R: Yeah, but I think it was, it is, I am not sure how to answer that because. Okay I was, I mean we have. Why someone would like to.

12:31 I: Hello?

12:37 [CONNECTION ISSUES]

13:33 I: Okay, okay so let me move on here.

13:38 I: Yeah so, another thing that people have been concerned about is the side effects of using a BCI. Is that something you thought about as well?

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13:51 R: Yes, I think, I think that, at the time, it will help to, [INAUDIBLE], so I think, I think we have very high expectations about the scientific, the scientific [INAUDIBLE].

14:19 R: Hello? I: Yeah? R: Yeah.

14:20 I: Okay, and so, yeah there. But you said you thought about the, the side effects of using a BCI. What kind of side effects have you thought about?

14:38 R: Side effects? What is an side effect?

14:45 I: It's actually a range of things, there is both the health stuff, so stuff like skin irritation, stuff like that, and then there is people who talked about, mental side effects, and societal side effects.

15:03 R: ah, yeah. Yeah I. No, I think this is not a problem because, for the moment there, weren't problems about it so. There is the [INAUDIBLE] in those [INAUDIBLE] so I think it's better use that. Because if there is problem, it's with the [inpassive] techniques so, it was, there are more complicated [INAUDIBLE]. Just my answer around this [thing]. So I think it's not a problem.

15:35 I: Okay, and you haven't experienced anything during your experiments that have caused you to concern, be concerned about side effects?

15:45 R: No, I don't. I: Okay, so another thing that people have talked about is if BCIs at some point becomes a household item, such as laptops and cell phones and stuff like that. That there might be a problem between those who can afford it and those can't. Is that something you've thought about as well?

16:08 R: No, no absolutely. I don't think it will be a problem, in fact. I tried to make an application with [INAUDIBLE] to try to control the [INAUDIBLE] applications. And obviously you, a person has to be, has to be careful with, when it, is using or wear. I think it's, we have this [INAUDIBLE]

16:36 I: Okay, do you think that there might be a problem with people who is able to use a BCI and those who aren't? I've heard that some have, had issues where they didn't register on BCIs as well as other people. Is that something you've encountered as well?

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16:55 R: No, no I don't.

17:00 I: Okay. Yeah so, when you have been developing your BCI, what kind of stuff did you do to make sure that the device you were making was something that, was useful for the users and worked for the users? And was something they wanted?

17:22 R: Oh, no it was, it was a project that we have with the teacher. So. I did the idea. Two months. Can you give me a minute please?

17:38 I: Yeah, no worries.

17:40 I: Good, so yeah, some have argued that BCIs might lead to enhancement, like cognitive enhancement and stuff like that, is that something you thought about as well?

17:57 R: I am sorry, can you repeat please?

17:58 I: Yeah, so some have argued that BCIs might lead to enhancement for example cognitive enhancement. Is that something you thought about as well?

18:10 R: No, absolutely I haven't, I didn't.

18:17 I: Okay, do you think, that might be a problem?

18:19 R: No, I don't think. I don't think so.

18:25 I: Okay, so yeah, another thing the literature is very involved in appears you are as well, with people who are locked in and unable to move or communicate. So there has been a lot of discussion about getting informed consent and increasing user autonomy.

18:50 I: Is that something you thought about as well?

18:51 R: Excuse me, I don't understand well. I am sorry.

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18:59 I: No worries. So, when you did your experiments and stuff like that, did you do anything in particular to make sure that the people who tried the BCI and stuff like that, were well aware of what was going on?

19:16 R: No, I didn't.

19:24 I: Okay, no worries. So, yeah. So, a lot of the topics involved with BCIs are talking about policy gaps and legal concerns. Is that something you see as well?

19:39 R: yeah I think this is a career of what you want to do. So. But for the time it's just, it's just research so. I, we are doing, is helping straightly help. So, it's something that, is not, affect affecting people now, so. I think, for the moment we police it, they are so. Are, are okay.

20:09 I: Okay, do you see then, maybe once it becomes more of a commercial thing, that there might be need for some regulations and policies, to guide it?

20:22 R: Yes, I think, if, if it will be public, it has to be. Because. Because for example we, we try to do, something with people who are brain disorders for example. But this person we are going to, to try the product on. Hasn't the, the conscious to think what they want to do so. They are not conscious of what they are doing so. Something is insured about them, they have to. Someone has to control what they are doing with the product.

21:05 I: Okay, yeah so, basically we are already at the final question, which is whether there is any concerns you have had while you were doing your research, that we haven't talked about?

21:20 R: No, no I think, I don't.

21:27 I: Okay, no worries, then that's it.

8.2.13 Research stakeholder 7

I: Interviewer

R: Researcher

00:00 I: Okay, so yeah. First of all, maybe you could introduce yourself in a couple of sentences?

00:09 R: Okay, my name is [NAME] I am student, I am right now doing a double diploma, [INAUDIBLE] between two universities. My own [UNIVERSITY NAME], and [2ND UNIVERSITY NAME]. And work a bit with both of them, about research topics the last, maybe 2 years, it was mostly in the direction of. I guess you could, could call it human computer interaction, [multi modal] communication especially. Especially with disabled populations, let's call it like this. But mostly I do quite a lot of very very different things.

00:58 I guess, that would be it, so I can not say that I have very a lot of experience or stuff. But like I did some things in this direction, and I hope I can be useful somehow.

01:11 I: Yeah, sure. Yeah so, maybe you can explain a bit about your research, and especially with BCIs and what you did?

01:20 R: The two papers you probably, you probably found me with were dealing with generation of alphabets. Alphabets that's defined as basically ways to communicate, so the main idea was to, or is a paper, use analogy of the English language, so for example the letters the English language were optimized to be written with pen and paper, but that is, they are really nicely connected to each other, but they are not really, but they are not really optimized for readability, that was not what was in mind when the system was created. And for example right now when we use mostly or partly keywords, some of the requirements are not there anymore. And the idea was that, the idea was basically such requirements change but we still keep using old alphabets old systems. And right now we have many many many more different mediums. Eye tracking, various joysticks, more exotic and different things. And there is a need to create alphabets for some, to create normal inputs, which are useful, which are short, and which do not have the limitations of for example pen and paper.

02:46 And my research right now, mostly deals about, how can we rationally create such alphabets, such symbols, based on what the medium we will be using based on what information we will be conveying etc etc etc.

03:00 I: Yeah, cool. R: So I guess that would be it. I can more deeply but the idea is this one.

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03:09 I: Yeah, no that's fine. So yeah, I assume then, you hope that people will use BCIs for communication and spelling and stuff like that?

03:18 R: I know that people will be using BCIs in general, and I know, so basically attempts is to do it as easy and simple as possible. So I mean it, for example if we are doing eye tracking and if we are controlling something which has 4 commands, we can create really nice and simple symbols. We would be for example [operational] and for example if we steal some symbols from the language and make them 1, 2, 3 and 4\.. Which would be easier to remember but would require much more movements.

03:55 So I like, I am, I hope, I know that, this will be a topic which, like creating alphabets is something that will be needed but there is no easy way to generate and estimate some, alphabets. So like [INAUDIBLE] like to create, like a general system which based on requirements and the information create something which is. Something which is rational in such case. This means, not only easy to use with the exact modality which will be used, but also for example easy to remember, so that there is easy to connect, etc etc etc etc. [id put it like this].

04:35 I: Yeah, okay. R: Okay, its like for me it was started for example when I was doing my own system of shorthand and I got a bit. Deeply, more deeply in how to create a short hand system, how many letters do you actually need. How simple does it have to be, how to say, how can you make them so that they are easy to connect to each other for example. There are letters which are, usually is need to be connected and to basically from some [I guess] generalised and so that is, could be an interesting topic, to do with joystick, [INAUDIBLE], eye tracking, etc basically.

05:16 I: Okay, yeah, so in the literature, and in general, there is, when dealing with technology there is often a concern about them being used for something that wasn't intended by the developer. Is that something you see for BCIs?

05:36 R: I'll be honest, I did not really think too much about this. So like any technology can be used in a different way. And also, one thing which history always does is that. It's not really easy to see how it will be used. So for example it was easy to see for the atomic bomb or maybe, it was clear that it could used differently. But it is not always obvious. So like, I cannot say that, so personally I have not thought in too much about it when during my research. But, and right now on my two feet I cannot think of too many, too many variance how it can be used probably. But this doesn't mean that it cannot be so.

06:26 So it will probably be used in different way, if it will be used. But it, I [INAUDIBLE] think this should be something which should this from [INAUDIBLE].

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06:39 I: Okay, so yeah, another concern people have with BCIs is the, is the topic of misinterpretation or the accuracy of data. Was that something you had to deal with as well?

06:53 R: Actually this is like, this was a big part of the research which I did. It depends. [Research] is a really fine balance between how much information you want to convey and how much. How much do you have to [INAUDIBLE]. That this, so like, I think that it is possible to do BCI, that BCIs at some point will be easy to. Or let me put it that way. It is always easy to find some kind of balance of redun, redundancy for example. If said, if it is needed. So. It depends on which, on what system you create. So if you are doing again, let's go back to the topic of atomic bombs, I don't know why. If you have to create a system which controls, which city, country you have to bomb, then it is clear that you will try to make such a system as redundant as possible. In regards to how exactly you communicate with it.

08:03 But it is not. uuuuh

08:17 To use a different analogy, it depends also on how much do we know about information [INAUDIBLE]. So if we are talking about a typical keyboard maybe a bit of a more exotic one, if we know that we will be using the English language we can still try to and if we get some input which does not make sense in the English language we can at least say that something is wrong.

08:37 If we are doing, if we are doing something different where it is not as easy to see when there is interference on when, on when the data [is wrong] then the more redundant system. But basically my main point is, most of such systems can be built with a lot of redundancy in mind. If the, if the interface we use to communicate is not, is not precise enough at the end of the day we can always say that we have to repeat each input 5-6 times so we understand that the input is right. It depends on basically what use case you have for such a system. Is that, I guess that would be all for now.

09:21 I: Okay, yeah, makes total sense. So yeah. In the literature. R: I mean, English is not my first language if something is not clear or if something does not make sense just tell me about it, I can say more about this. I: It is perfectly fine, it's, I understand everything so you're good. R: Okay. I: So, following up on this misinterpretation, there is sometimes also a misinterpretation in the public about BCIs and neuroscience is that something you noticed as well?

09:53 R: I, personally, [INAUDIBLE] last couple of years, I did not see any. Is there. Sometimes misinterpretations but they were never something which worried me, or at least not. Never something which I found wrong enough to be dangerous for the future of BCIs for example.

10:21 It's a. Well especially in regards to neuroscience for example there is this, like some people have, some people have watched too much science fiction I don't know. Sometimes it happens but I don't, at

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least in my experience it was never bad, so there is always this when there is any new technology there is always this couple of person the people who say it is much worse than it is, or could not understand it and therefore fear it. But it was, it has always been like this and it almost never stopped anyone. It is not something which I personally ever worried about. Could you give me some examples of, of such use so I understand the kind of [INAUDIBLE] basically.

11:25 I: Uhm, I think it is very, like, some of the examples that have been brought up has been pretty much all over the place. Some are very specific about here is this article that is very problematic, and some has been more in general, the fact that, because it is a new science people don't really understand it yet. And therefore they have to, like neuroscientist have to be aware of what they are telling the media and being careful not to create hype that, they can't back up basically.

12:00 R: Yes. I: So yeah I guess since you are developing these interaction system you might get in contact with users that have a, an idea that something might work magically and that's not always the case.

12:18 R: Actually, actually that's a good point about misinterpretation that it can not be only in the, in the direction that something is actually bad or evil, but also in the direction that is much more magic and working much better than it actually does at this point. So thank I did not think this. You know, in regards to neuroscience, this is not as part of my answer but still maybe could be interesting. If we are talking about pen and paper as opposed to BCIs, there is this typical human need for control. Which some people could, if I write something with pen and paper. One I know pen and I know papers so pens and papers I have used it always. I control this which I do, I can, I will not write more than I want to. I will not, I have no control over that which I use. If we are thinking about brain computer interfaces and similar things, I could assume that some people feel. That they control it and it less, and are much less confident in using it. And I would, I could imagine that some people don't like it, simply because they might feel that either [sign], might. Much more information is write from them than they want to or something in this direction. And again, we, we will not go into some really really real obscure conspiracy theories but there are people who, who have much, much more strange ideas about brain interfaces. They are reading minds like etc etc etc.

14:15 And maybe the last point about this, this is probably not what you are looking for, but there is also the topic about mental illnesses there is this, segment of the population especially in regards to schizophrenia and [INAUDIBLE] who had this point about, [in the states] this was, it was radio controlling their minds, if remember the [INAUDIBLE] generation how accusing [the radio] of hypnotism.

14:44 From the other side, before that, it was something else right now it usually is about something within your mind has always been a really really schizophrenia thing and it saddenly. I used to work a bit with similar people and I heard really nice things about the [INAUDIBLE] program about training minds. Which has been used as examples of [INAUDIBLE] but if actually such a, if such a technology ever comes around not really then minds that something which can be interpreted as reading minds. I can assume that, at least for some people, life will become much much more interesting because they will actually have a proof that



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is possible for something to read some of their minds. But this is just like a sub[INAUDIBLE] topic, so not something which I personally found in my research and not something which, which, with which I have come in contact with.

15:51 I: Okay, yeah following up on that nicely is, some have been concerned that this increased insight into our brain and how it works might change our concept of identity and stuff like that. I assume since you've already thought about the whole mental issue thing, that this might, maybe something you've thought about?'

16:16 R: Like I have contact with a lot of similar, people who suffer from [INAUDIBLE] for various reasons. So any questions on this, I can try to answer, not that I know something about it, I have no background in psychiatric.

16:29 I: No but, do you think that, this technology might change how we see ourselves and our own identity and stuff like that?

16:38 R: I think that this is possible. I think that this is possible, I can't say anything more concrete about this but. It's something which could go a bit in the direction of. Two thousand years ago the mind was more or less a black box so. Right now the more we go, the more, I would not say, easy to research, but at least it's much easier to work with the context, the contents of someone's mind. We have psychotherapy, psychoanalysis actually in this case, we have brain computer interfaces if we had, if we still had this nice black box. It would have been much easier to see it as something magic or something more religious, a soul, and stuff like that. The more we as, the more we try to divide it into pieces, analyse the pieces with cold logical rational analysis I am not saying this is bad, I am not saying this is good so. The less actually magic stays there. Like there is still quite a lot of mysteries and I personally honestly believes that it is not something which is, will ever be completely understood, like here comes to mind a quote, I do not remember who says that, but it is that. If the mind could understand itself it would be too simple to understand itself, or something in this direction. Wait. I will not, I do not remember the exact quote literal, but I will find it and send it to you. But my idea is, we will never be able to understand it fully or completely, fully completely because we still have the limits of our own mind which, which are still there but.

18:48 We are going in [this] direction the less we go in the, [INAUDIBLE] we are going in this directions, the less magic there is, the less religion there is, there is, the less soul there is. And the, I could assume that this could give some, could change a bit how is for example [INAUDIBLE] religion.

19:06 [INAUDIBLE] Religion really nicely survived the scientific progress of the last millennium so I think that it will also h[ave] survive anything we learn about our minds. But I think that it will be influenced by it.

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19:22 I: Yeah, do you think that. R: Excuse me, maybe the last on this topic. You was, there is this magazine the atlantic, there was there a really really really fascinating article about, about the intersection of neuroscience and religious experience. That is, at least some of the religion really shows epiphanies experiences, enlightments and stuff, they can be explained through neuroscience and some people still don't, are not sure about how to feel about this. I still am not sure how to feel about this.

19:58 I: Okay, do you think that, BCI, the technology is something that changes this development or is all neuroscience really changing all these aspects?

20:09 R: Uh, which development exactly?

20:11 I: Well the whole. Increased understanding on our brain and how the mind works, and stuff like that. Do you think BCIs is an essential piece to that change or? would that happen even without BCIs there?

20:28 R: I think that, personally I think it would be, it would happen even without BCI but learning more about all of this is something which is needed amongst other things for BCIs. That is, I think, I could see BCIs as, as something which helps developing more knowledge, more information about the brain. So BCI is not a cause in itself, I don't see BCIs as a, a really big factor in itself, but it is stimulation for developing more, more information more, more data but it's not by itself a big factor or so I see it.

21:20 I: Okay, good. So yeah, maybe a bit of an obvious one but people have been concerned about privacy. Is that something you've thought about as well?

21:30 R: Could you give me an example of how. Of how. Of something that which, which would happen? Like worst case scenario of BCIs and privacy?

21:46 I: I think. The worst case people have been speculating about, which I also know that a lot of neuroscientist would say, would be, ludicrous to even thing about right now, but the whole mind reading where anything you think about can be read by others. I think that's the most extreme cases. I think the more realistic and here and now issues are stuff like. Giving away unintended information which might not be something we can analyse from the brain data right now, but maybe something that in ten years is easy to read.

22:36 R: Uhm. Another area which I actually worked at. Would be information security and partly, maybe partly privacy and one thing which I can say that. Even right now, just analysing, how we browse, how we use the internet is easy to understand much much much much more about us. As some people are comfortable thinking. I. I wont touch the really extreme case about mind reading sometime in the fut. I

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think that it could be sometimes some, could be possible some day it's not something which scientists should be worrying about right now. But this is something which will come up every time when people talk about BCIs and privacy.

23:36 I: Yes R: Uhm. Again this is a new field, and so right now it is just right now humanity does not have enough experience dealing with this kind of issue. It was like this with the internet. We are only now, we are more or less learning about privacy, security not posting stuff online. So I assume that if, if privacy and mindreading will become a much bigger issue than it is right now, after some time scientist, humanity will act, develop some kind of ethical framework, ethical rule, which will be developed by themselves which will allow people to live some, somewhat normally with, with all of this.

Do you understand what I am trying to say? I: No, yeah yeah.

24:38 R: Even, okay even the internet, even, the information we have goes through a lot of servers, a lot of servers with advertisement. Which profile us, which profile us much better than with whatever like to. Even by analysing someone's language it's. It's really easy to build a profile like an example from my life, I have, I have a twitter account with maybe something like 500 tweets and an automatic system analysed it and gave me my exact [NPK] profile and personality profile which actually [INAUDIBLE] tried just based on this information. But even right now it's much easier to get more information about us than, than we would like to [INAUDIBLE] maybe than we are aware of. Brain computer interfaces will be maybe just the next step on, about it. It will give theoretically even more information about us. But this does not mean that the world will end. We will learn to live with this. We will learn to respect each other but obviously we will learn to. To survive with this. So like I, basically the first 5, 10, 15, 20, 30 years if mind reading becomes a topic or some really deeply privacy [invasion] becomes a topic. As a first 5 to 50 years will be really bad, but at the end of the day we will survive this. We have survived everything else. I do not think that it could change, it could change a lot but I don't think that it will change anything in. [Theoretically] that way.

26:24 I: Okay. So, sometimes in the literature there isn't a clear divide between talking about BCIs that are non-invasive and invasive BCIs. So some has brought up the concern about a security health risk. As has been seen with pacemakers where the, people have been implanted with stuff that had then, had a security risk that led to health risk as well. Is that something you see for BCIs as well?

27:02 R: Uhm, maybe I would. Maybe I can 30 seconds about our previous topic especially in regards to pace makers. I read recently about a court case which was where actually the [records] of the pacemaker of a person were analysed to see if he actually was working or running during a certain time. The records on the pacemaker actually told them, told the, told that he was running from time X to time epsilon and this was used as proof in court.

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27:45 So I'm, that's another example about, right about, theoretical privacy. The practice which are happening right now and actually have happened. Also I read a really nice, nice study about. I am not sure if it was about pacemakers but even, okay, even Fitbit, it actually can be hacked and information can be gotten from it. I am still not sure how I feel about this but it's just an extension of information security. Like we have more information but the rules about how do we, how do we keep this information safe are still the same. Be it emails or be it someone's pacemaker or be it someone's [INAUDIBLE]. So the ideas would still be the same. To your question about invasive and not invasive pacemakers and security risks based on connected to them.

28:43 Uhm. I do not have a, I do not have much to say about this, but most things which are like invasive pacemakers still have to be tested. And such technologies in general. I think a really interesting [INAUDIBLE] in regards to ethics would be how do we actually find people to test them on because it is much, I think it can be more dangerous than for example medicines and stuff, but again this is not my field. I cannot answer much about this.

29:24 I: Okay. No, but that's a great answer. So uhm. Another thing that has been a big topic in BCI literature has been about side effects of BCIs. Do you see any of such?

29:44 R: Uhm, not in the ones. Not in the area I personally worked with, but. There is, there is this idea that the internet in general, influences the minds of people who use it. Because we need much less operating memory, we will need much less memory now. We need much less, lets call it operating memory inside our head.

30:13 I cannot say much about side effects of BCIs in general, but it is a topic, but I can understand that it could be a really interesting topic and that there are a lot of them. [There] can be a lot of them, but I cannot say anything concrete about it. But I can [image] about. But, we do not know, like right now people warning the, there is a first generation who, so with the internet, with all this information is available. And one really interesting topic is that this is a first generation who has this, and we still have no idea how it influences the brain, if it influences the brain. I think that something similar could be also relevant to BCIs, when they actual become seamless and easy enough. If. If the ability to communicate almost directly with them. With information systems if it will somehow influence the development of the brain, especially from a really young age. So for example, the examples which I personally can find. My family, part of it, comes from, comes from a small town in western [COUNTRY]. I personally travelled also [INAUDIBLE] small towns. A couple of years ago, hitchhiking travelling [it was really fascinating] and one of the things which I noticed, especially with older people, especially in such small towns, they usually have a really really nice memory for names and really nice memory for dates.

32:09 As they usually remember much much more than much more than I would expect. They have, they have every single detail in their heads. They can, they find such things easier to memorise. Because they actually need to do this. More or less my generation relies much less on memory. Because information is

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available if I need to find something I do not need to go to the library, find the book, write this information down and know that I can get an information, I need in a couple of seconds. That means that, I have much less stimulation to develop my memory.

32:51 So, still no idea how it influences people in general, but I would assume that in regards, so I cannot say much about the topic but one, which, is not so easy to estimate would be how, really really seamless BCIs would influence memory, someone's memory. [INAUDIBLE] brain development, especially where it's talking about using BCIs from a really really really young age. Let's say, I don't know. Three to ten years old. It would be a really interesting topic to study. I think that there could be really really big changes but again we just don't have enough information about this.

33:31 I: Good, so yeah. Actually quite, at least in my mind related to that. Some people have been concerned about what might happen if BCIs becomes a household items such as laptops and cellphones are these days. That there might be created an A and a B team, so a divide between those that have the device and those who doesn't. Is that a concern you see as well?

34:04 R: Sorry what is the question again? I follow you up to the point, A group who has them and B group who does not have them. And what next?

34:16 I: Well basically some people are concerned that, that might happen that we have some people who has it and some people who doesn't. Do you see that as a problem?

34:27 R: That some people will have BCIs as household items and some wont?

On which, like why is there sold, the question about being able to afford them, or is this a question about people being ethically opposed against them?

34:51 R: Or is this a question about unfair advantages of people who has the BCI or has not, haves them not.

35:01 I: it's a bit of all three basically, but I think they tie sort of into each other. R: Yes I: There is definitely both a con, because you could say that if, if there wasn't any advantages to having them, then it didn't matter whether only some people had them. But I think it ties into the debate about some people having it and some people not having it. These, the idea or sense that it will give an advantage to those people.

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35:33 R: Okay. Five years ago I had a really long summer, and I decided to learn touch typing, and that [work] keyboard layout. I have learned it, now I type a bit faster than usually, the question is if this gives me an advantage. I could say the same about, about various [nootropic] drugs for example. I am thinking in the direction of [INAUDIBLE] Ritalin, [what I think] if it is an unfair, if it is an unfair advantage or not. So in this view I don't think that it will be much different than, than the general philosophical about, so I am not familiar about the discussion about this, what exists, but I know that quite a lot has been written about, about those topics, being it with [nootropics] or be it with various [INAUDIBLE] advantages. I think that most of what has been said about the topic would still apply to BCIs as household items.

36:49 It would be interesting to think about this in the direction of the general, of. Of information retrieval and. In [LANGUAGE] that would be [NATIVE PHRASE], one moment, how do you say it in English. Working with information. But if we are talking about people who actually make a living from it. We are talking about people with whom it is a difference how fast, and how effective they can do it. Then it would actually make a difference to have, to be able to do this without having another layer, like a keyboard between them.

37:33 And if we think about a future society when your ability to do this will influence how much money you earn, how many others BCIs can you get? Then it will be [INAUDIBLE] the situational. The rich getting richer and the poor staying poor.

37:55 But I cannot think, I cannot think of any, any BCI specific things about it.

38:02 I: Okay. R: And I, I could imagine that unless it becomes a really big part of society it, in some areas it could almost be something like even a lifestyle or a conscious choice.

38:18 And I think that actually it will be like this, even for the next 50 years or so. So maybe later BCIs will become a real indispensable part of, of living in our society like, like it happened for example with computer. But before this I don't, I do not think that anything too bad or too different will happen. Right now we have those, I don't want to say subcultures, but people who are really into it who talk about it, who build their own, who research it. Sometime, maybe I think in the next 10,15,20 years it will become much more widely adopted but, I would not say lifechanging.

39:10 I: Good. R: I would say nothing to worry about in this topic for the next couple of, for the next 10, 20, 30 years. After this, it will probably become a household item. Okay you know, I can, I could imagine that after some time, it would become even a religious thing. I can imagine that there could be people who thinks that this is somehow intrinsically wrong or something. No idea, no idea, but it is not something which I would worry about, at the moment. There were always unfair advantages, I don't see why BCIs should be treated as a particular case of them.

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39:49 I: Do you see the same with BCIs with the intend of cognitive enhancement? That the? R: [INAUDIBLE] then so what? I: Well in terms of, BCIs not being, being something of a particular interest but, rather than cognitive enhancement and stuff like that is a topic that needs to be discussed in itself but BCIs is not something that would have a, a specific. R: Particular interest? I: Yeah.

40:27 R: Ah yes, thank you, you said it better than I have. We are living, and have always lived in a society with a lot of unfair and fair advantages. We are living in a society where the family you are born into determines 90% of, usually statistically what you do, of whom you communicate with, with, we have different money, we have different families, on, of a different level of [brokenness] and abusiveness. We have different countries, different possibilities. I really do not think that BCIs will become something on a whole new level.

41:07 And against humanity, you lived really nicely with such unfair advantages forever basically. So yes, I do not think that BCIs should be treated as a particular use case in exactly, in a particular case in this, on this topic.

41:23 In this context.

41:28 I: Okay, good. So in a lot of the literature there is a concern about getting informed consent and increasing user autonomy. Is that something you dealt with as well?

41:42 R: Yes. Part of maybe, part of my research was about estimate, various verbal, but mostly not verbal alphabets. Was about their use in, in disabled and in an elder population. What has, have, what sometimes could be, could be a problem especially as it becomes more widely and widely adopted. Either you get training as someone dealing with elders or a disabling population or you are a researcher. If you are a researcher you will rarely get, you rarely know much about ethics and how it should be done.

42:25 So currently [INAUDIBLE] two different words. So for example you can see how much I know about ethics. Never [INADUIBLE] even though I technically dealt with the topic which is relevant to elders and disabled people. Where the topic of informed consent is, the [INAUDIBLE] interesting enough. I still cannot say that I know much about ethics or about any form of [INAUDIBLE] even though I know that it actually exists.

42:58 So I, this is an interesting topic, I do not have any solution or any [source] about it. But. If you have to do research with disabled people, with elder people then ethics is, not real a problem, but at least a

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question or something which should be considered. And this is not something which we usually have. It's, I mean, not a [INAUDIBLE] but actually thinking about the ethical part of it.

43:27 R: Or at least not based on my communication with, with people who deal with it. Like, the reason, the basic ethics about doing research, but when you are dealing with actually real people it becomes more interesting and again most, at least the parts of it which I have had experience with, it's mostly. In the perfect case it would be something with a degree in IT or something similar and a psychologist something similar but mostly the people who do it right now again based on my experience are more IT people.

44:09 Who not always have enough empathy to deal with people in general. And not. when we talk about elders or disabled people it becomes even worse. But I, I do not have any horror stories about this. But at least, so was my, this was my experience. And I believe that there are some universities which, where this is much better than in the, in the university which I worked, but so I see it right now.

44:49 And since it's, I would [necessarily] like it but, is not given as much emphasis as it should be.

45:00 I: Good so yeah uhm, let me just see where I got to in my questions. Yeah so, a lot of the concerns we have talked about has been dealing with, or has been related to sometimes policy gaps and legal concerns. Is that something you have thought about as well?

45:23 R: I am not sure how good [will this sound] especially after my last answer, we need more ethic training but still. In my experience and based on the information I have talking to people who do partly this research. [Only see], is not always. Is not always effective and is not always something which help. I would say that at the end of the day, if. Sometimes it happen is, this happens even with people doing, even a bit of psychology and medicine research. Let's say I work in a mental hospital, or a hospital in general, I have this really nice idea about doing a study. I have the people I need, who agrees with it, I have some person in the hospital which can, which knows a bit about the policy stuff. It is, there is this really big barrier about actually going ahead and doing this.

46:46 There is, in an incredible, sometimes I've heard people say, this is the part of the phrase which please add it to [INAUDIBLE] phrases which I will be saying but. I know person that heard people saying that the bureaucracy is a policy which actually should be directed to making it to be better research for everyone. Usually make it, makes them [INAUDIBLE] much much much harder than it should be.

47:15 We try to protect everyone and everything too much especially we try to protect ourselves too much against any possible theoretical lawsuit, lawsuits and stuff.



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47:26 Which makes it much harder to do research sometimes than it should be. So, how it is right now. The situation we have right now where I would not say that it is a bit of wild west, but it's not. But policy, bureaucracy etc, there is not too much of it as, which is specific to this field and actually thank god for this, because if you are, if you are a normal nice person, who actually wants to help and who has the ability to do so. It is, right now, it is possible. Right now there is, it's easier to get started with this, it is easier to, to try and do something which could make a difference. If I were, in some areas, actually especially in my country bureaucracy a really big bar. It's a bigger problem than it should be. And it makes the system much more complicated than it should be. It gives some people more power than they should have. It makes it objectively harder to do it. Which means we that we have less research that makes sense and so, I said before that ethics should like. People should think more about this, but as long as it does not translate into. Into too much idiotic bureaucracy as it sometimes happen.

49:04 I: Yeah, no yeah, that's a, a very typical thing when talking about policies and ethics is that, often it gets translated into a lot of yeah, bureaucracy and forms you have to fill out and yeah.

Yeah?

49:30 R: Yes. I: Uhm yeah so, actually another question following up on that, so. When you are developing and developing with BCIs what are some of the things you do to try and make sure that what you are doing is something, that your users want or society wants? Is there any particular things you do?

50:01 R: Is that, there were a couple of seconds with bad connection, when you are developing with BCIs, what are the things you do to?

50:09 I: To make sure that what you are doing is something that society wants, and that your users want?

50:19 R: Okay I understand the question. Hmm. And actually it is a good question. Personally in my case. It usually has just been observing and seeing for something is irrationally complicated and where it can be simplified. So it is not like, it's not too different as general rules about when you make for example some start-up or something. You see a problem, you know that you can actually improve it, you talk to people and then say, hey it could be really awesome if I could, I don't know. Control some mechanism with my eyes instead of my hands because I cannot use my hands. Again as, question based on my experience working with disabled people and making the alphabet. Multimodal ones to make it easier for them.

51:18 So usually it is, usually it is possible to see where something can be improved, simply because the situation as it is right now its easier to see when something it is irrationally complicated. It is easy to see when some solution which is standard right now is, standard simply because of historical reasons and limitations which are not there anymore.

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51:45 So is, this would be such a typical way to see if some, and if you know that you can improve it and you get this idea then you talk to people. As you typically to the people who would actually be using your system or whatever you are developing. If it makes sense, if you know that you can improve it. If some, if some, if your audience, target audience I don't know, thinks that this is a good idea and they personally would use it, then [INAUDIBLE] do it basically.

52:21 I am not sure if there are any, like okay. There are, there are of course much more formal ways to analyse the [INAUDIBLE]. I am not, I know that they exist, personally I am not familiar with them and it is not something which. It is not something which I personally have used.

52:36 I: Okay, but but I assume then that what inspired you to do what you did was being around people who had disabilities or problems moving?

52:48 R: Yes. Basically observing and it's actually, usually it's a bit easier to see something does just not work or is much more complicated than it should. Again most of the things which are much more complicated than they should is because they were developed or created, or evolved themselves somehow 10, 20, 100 years ago. Since then sometimes technology changed, since then there are much less limitations since then there are much more technologies but we keep using this which what we always used. Because we always did it, and it always worked. So, and this is usually easy to see. Again it needs a bit of [INAUDIBLE] thinking and creativity to find such things, and to see how they can be improved. But again, what is really interesting, it is not something which would, which would be trivial to do if you are the target population. So I assume that, it would be intuitive to say that if I was for example a disabled person I would give you 50 ideas of how this can be improved. And usually it is like this, but this is not the entire story, and usually when, if I use something for the next, for 20 years, I can't always say. Can't always give any radical new perspective responses.

54:15 So this is where it's really interesting to see from the side, to get an explanation of of the entire thing. And then you actually get, you can see it from outside and you can sometimes get inside which will, would not be trivial to see if you were actually using this for the last 20 years. So what's really nice, started with the title when in Rome, learn why romans do, what romans do, it was a bit of different light, but still, it's something which always, which I keep in mind. If you get from zero and you get an explanation of what happens, why does it happens, etc etc etc sometimes you can really actually see if it is not optimal, why it is not optimal and what's importantly how else can it be done.

55:09 Is this especially, it's not about, especially when we are talking not about some minor improvements but of more or less radical [parting] shifts or more or less radical things. Which could not evolve from themselves, by themselves based on the situation we're in. So we are talking, this is more in the direction of genetic algorithm, I can find some [INAUDIBLE] point in a certain interval, if I look at this interval but

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sometimes there is an even more optimal point but it's somewhere far far away and it's not easy to get there without changing some of the previous assumptions and developing it from a couple of steps before.

55:56 So basically number one as a actual answer to your question, number one would be talking to people, what they think they want, what they lack, how they would see it, and number two would be observing it from the side, with some more or less a clear mind and without too much knowledge about this particular area. And sometimes you can get ideas or insights which are, which would not be so obvious when, when you are someone who has [AUDIO CUTTING OUT]. Than. That would be it.

56:36 I: Okay, well that leads me to my final question which is basically whether there is any concerns which you have had about BCIs or maybe users have had about BCIs that we haven't talked about so far?

56:48 R: That's a good question, that's a good question. Hmm, if you could give me maybe 15 seconds. I: Yeah, no worries. R: Maybe I, okay.

57:11 Actually I do not think so. But thanks for this question.

57:26 I: Good, in that case I will stop the recording.

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### 8.3 Interview documents

#### 8.3.1 Interview questions

Can you please confirm that you agree to this being record?

Firstly, could you introduce yourself in a couple of sentences?

Could you please explain what your company do, in a couple of words or sentences?

1. What do you hope your users will use your BCI for?
  - a. Through history we have seen technology be used in ways that wasn't intended for example as what happened with the internet, is there any such usage of your BCI that you might have concerns about?
    - If none of such concerns, then why not? Are you actively doing something to prevent unintended usage?
    - If yes, are you doing anything to prevent these usages?
      - o If so, what?
      - o If not, why not?
  
2. Is misinterpretation/accuracy of data by the user, something you worry about?
  - If yes, are you doing anything to prevent this for example through disclaimers or technical solutions?
  - If no, why is this not something you are concerned about?
  
3. Following up on misinterpretation of data, does public awareness and how BCI or neuroscience is portrayed in the media, a concern for you?
  - If yes, how so? And what do you do to avoid these misconceptions?
  - If no, why is this something you are not concerned about?
  
4. Some are concerned that BCI will change our concept of our identity, is that something you think about or worry about?
  - If yes, how so? And what are your thoughts about this?
  - If no, why do you not think so? If someone raised this concern, how would you deal with it?
  - What about the concept of autonomy and moral responsibility?
  
5. Is privacy something your users have raised concerns about?
  - If yes, in what sense? Data protection in general, or specific concerns about the type of data? Do you implement technical or other solutions in order to keep privacy concerns at bay?
  - If it isn't, is it then something you as developers are concerned about?
  
6. Some researchers have raised concern with security and relating it to the issue of pace makers being hacked, is that a concern for you as well?
  - If yes, how so?
  - If no, why not?

### 8.3.2 Information letter

## An investigation into what changes occur to ethical concerns when Brain Computer Interfaces moves from research to commercial use.

### Participant Information Sheet

We would like to ask you to participate in the data collection for a study on Brain Computer Interfaces (BCI) conducted by De Montfort University. You will find more information about the study on the following project outline.

We hope better to understand the following issues:

- What concerns do stakeholders have about BCI?
- Are there any ethical concerns specific to research or commercial use?
- What causes the change in ethical concerns when BCI moves from research to commercial use?
- Which methods could be used to mitigate these concerns, and which are already in use?

Some of the concerns this study will explore is privacy, accessibility, misinterpretation/accuracy, change in identity, enhancement, and informed consent among others based upon concerns found in current literature in research.

Participation in this study is entirely voluntary. It will involve an interview of approximately 30 - 45 minutes in length to take place by arrangement. The initially contact with you, will be done by email, telephone, or at public events such as conferences or hackathons.

You may decide not to answer any of the interview questions if you wish. You may also decide to withdraw from this study at any time by advising the researcher interviewing you or by emailing [christian.hansen@dmu.ac.uk](mailto:christian.hansen@dmu.ac.uk) or using the contact detail at the end of this document. If you notify us of your withdrawal, all identifiable data will be destroyed. Once data has been anonymised it will be impossible to identify the origin and cannot be destroyed.

We may ask for clarification of issues raised in the interview sometime after it has taken place, but you will not be obliged in any way to clarify or participate further.

The information you provide is confidential, except that with your permission anonymised quotes may be used. If you request confidentiality, beyond anonymised quotes, information you

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provide will be treated only as a source of background information, alongside literature-based research and interviews with others.

Your name or any other personal identifying information will not appear in any publications resulting from this study; neither will there be anything to identify your place of work.

The information gained from this interview will only be used for the above objectives, will not be used for any other purpose and will not be recorded in excess of what is required for the research.

Even though the study findings will be published in international conferences and journals, only the research team will have access to the interview data itself. There are no known or anticipated risks to you as a participant in this study.

If you have any questions regarding this study or would like additional information please ask the researcher before, during, or after the interview.

Kind regards,

Christian Behrendt Juulsen Hansen

PhD student in Ethics and Technology

De Montfort University

Faculty of Technology

Department of Informatics

Centre for Computing and Social Responsibility

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### 8.3.3 Ethical approval

#### Initial approval through myresearch:

SSOCH_ETHICS	Ethical Approval Ethical Approval: GSO Audit	01/02/2015 01/02/2015	Completed 12/3/2015 Completed 12/3/2015
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#### Additional emails of approval:

12/03/2015

On 12 March 2015 at 09:07, Anne Smith <[AmSmith@dmu.ac.uk](mailto:AmSmith@dmu.ac.uk)> wrote:  
Dear Christian

**Research Ethics Application Approval: 1415/264** - *Investigation into changes to ethical concerns when brain computer interfaces move from research to commercial use*

Your application to gain ethical approval for research degree activities has been considered and APPROVED by Prof Mark Lemon.

Please be aware that changes to the project plan or unforeseen circumstances may raise ethical issues. If this is the case it is the researcher's duty to repeat the ethics approval process.

Kind regards

Anne

#### Anne Smith


Research & Innovation Coordinator  
Research & Innovation Office (4.64)  
Faculty of Technology

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04/10/2016

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 Mark Lemon <[mlemon@dmu.ac.uk](mailto:mlemon@dmu.ac.uk)>  
Fri 04-10-2016 10:45  
Trio Support <[triosupport@dmu.ac.uk](mailto:triosupport@dmu.ac.uk)>; p14029525@myemail.dmu.ac.uk; Bernd Stahl <[bstahl@dmu.ac.uk](mailto:bstahl@dmu.ac.uk)> ✉

Hi **Anne**, Christian,

Apologies for the delay – these look fine. The title wording might be better as *interfaces move from* rather than *moves from*.

All the best

Mark

Mark Lemon  
Professor of Integrated Environmental Systems  
Institute of Energy and Sustainable Development  
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[mlemon@dmu.ac.uk](mailto:mlemon@dmu.ac.uk)  
+44 (0)116 207 8492

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18/05/2017

Tue 18-05-2017 11:16

Christian Hansen; Bernd Stahl <bstahl@dmu.ac.uk> ✉

Dear Christian

**Research Ethics Application Approval: 1415/264** - *Investigation into changes to ethical concerns when brain computer interfaces move from research to commercial use*

Your application to gain ethical approval for research degree activities has been considered and APPROVED by Prof Mark Lemon.

Please be aware that changes to the project plan or unforeseen circumstances may raise ethical issues. If this is the case it is the researcher's duty to repeat the ethics approval process.

Kind regards

Anne

**Anne Smith**

Research Coordinator

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