DEPARTAMENT OF APPLIED SOCIAL SCIENCES

A TECHNOLOGY ASSESSMENT OF BRAIN-COMPUTER INTERFACES

BRIDGING PRESENT AND FUTURE WITH A HUMAN-CENTERED PERSPECTIVE

GABRIEL T. VELLOSO

Post-graduate in Foresight, Strategy and Innovation

Bachelor of Science in Translation

DOCTORATE PROGRAMME IN TECHNOLOGY ASSESSMENT

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A Technology Assessment of Brain-computer Interfaces

I dedicate this work to my parents, Dalci Maria dos Santos, and Edgard Luiz Teykal Velloso (In Memoriam), for all their Love and Support.

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ABSTRACT

Technology assessment is a systematic approach used to scientifically investigate the conditions and consequences of technology and technicization while determining its social evaluation. This research focuses on the evaluation of an emerging technology, Brain-Computer Interface (BCI), which enables direct communication between the brain and an external device. As an emerging technology, BCI is in its early stages of research, facing numerous challenges. To address the assessment of BCIs, a methodology combining Constructive Technology Assessment (CTA) and Foresight within the umbrella concept of Future-oriented Technology Analysis (FTA), has been developed and applied. This thesis conducts a literature review and applies both structured, open-ended interviews and a survey seeking answers to these issues. It explores various social, ethical, legal, and philosophical issues to be addressed in the field of BCIs, both in the present as well as in the future. Understanding the key challenges, developments, and potential future trajectories of this technology is essential to grasp how its applications can offer both opportunities and threats to society at large. The research addresses the concerns of both the Technology Assessment and Brain-Computer Interface communities, offering a comprehensive understanding of how these social, ethical, legal, and philosophical issues may evolve over time. Perspectives from various key stakeholders in the BCI field, as well as neurotechnologies in the context of assistive technologies, are examined, providing valuable insights for further research in this area.

Keywords: Technology Assessment; Foresight; Responsible Research and Innovation; Emerging Technologies; Assistive Technologies; Brain-Computer Interfaces.

RESUMO

A avaliação de tecnologia é uma abordagem sistemática usada para investigar cientificamente as condições e consequências da tecnologia e da tecnicização, ao mesmo tempo que determina sua avaliação social. Esta pesquisa concentra-se na avaliação de uma tecnologia emergente, a Interface Cérebro-Computador (BCI), que possibilita a comunicação direta entre o cérebro e um dispositivo externo. Como tecnologia emergente, a BCI está em seus estágios iniciais de pesquisa, enfrentando inúmeros desafios. Para abordar a avaliação das BCIs, foi desenvolvida e aplicada uma metodologia que combina a Avaliação Construtiva de Tecnologia (CTA) e a Prospectiva, dentro do conceito geral de Análise de Tecnologia Orientada para o Futuro (FTA). Esta tese realiza uma revisão de literatura e aplica tanto entrevistas estruturadas e abertas quanto um questionário na busca por respostas para estas questões. Ela explora várias questões sociais, éticas, legais e filosóficas a serem abordadas no campo das BCIs, tanto no presente como no futuro. Compreender os principais desafios, desenvolvimentos e possíveis trajetórias futuras dessa tecnologia é essencial para compreender como suas aplicações podem oferecer oportunidades e ameaças à sociedade em geral. A pesquisa aborda as preocupações das comunidades de Avaliação de Tecnologia e Interface Cérebro-Computador, oferecendo uma compreensão abrangente de como essas questões sociais, éticas, legais e filosóficas podem evoluir ao longo do tempo. Perspectivas de diversos atores-chave no campo de BCI, bem como neurotecnologias no contexto de tecnologias assistivas, são examinadas, fornecendo informações valiosas para pesquisas futuras nessa área.

Palavras-chave: Avaliação de Tecnologia; Prospectiva; Pesquisa e Inovação Responsável; Tecnologias Emergentes; Tecnologias Assistivas; Interfaces Cérebro-Computador;

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GLOSSARY

Background Noise	Brainwaves other than those that are targeted for recording by the BCI device in question.
Brain-computer Interface / Brain-machine Interface	A computer system that acquires brain signals, analyzes them, and translates them into commands that are relayed to output devices that carry out desired actions.
BCI Illiteracy	When a user cannot use any particular BCI system. BCI Illiterate.
Emerging Technologies	Science-based innovations with the potential to disrupt existing industries or create a new industry.
Electroencephalography	A non-invasive type of BCI which measures the brain's electrical activity through electrodes on the scalp, used in research and diagnostics.
Electrocorticography	An invasive type of BCI which measures the brain's electrical activity using electrodes placed directly on the brain's surface, providing high-resolution data for research and clinical applications.

Acronyms

ACARD	Advisory Council for Applied Research and Development
ALS	Amyotrophic Lateral Sclerosis
ART	Anticipating, Recommending and Transforming
BCI	Brain-Computer Interface
BMI	Brain-Machine Interface
BNCI	Brain-Neuronal Computer Interactions
BNCI H2020	Brain-Neural Computer Interaction - Horizon 2020
BTBI	Brain-to-Brain Interfacing
CICS NOVA	Interdisciplinary Center of Social Sciences at the NOVA University of Lisbon
CLIS	Complete Locked-in Syndrome
CNS	Central Nervous System
CTA	Constructive Technology Assessment
EC	European Commission
ECoG	Electrocorticographic
EEG	Electroencephalography
EPTA	European Parliamentary Technology Assessment
EU	European Union
ETAG	European Technology Assessment Group
ETICA	Ethical Issues of Emerging ICT Applications
FBNCI	Future Brain-Neural Computer Interaction
FOTA	Future-oriented Technology Assessment
FTA	Future-Oriented Technology Analysis
FCSH	NOVA School of Social Sciences and Humanities

ICT	Information and Communication Technologies
ITAS	Institute for Technology Assessment and Systems Analysis
IPTS	Institute of Prospective and Technological Studies
LIS	Locked-in Syndrome
MGI	McKinsey Global Institute
OTA	Office of Technology Assessment
OAT	Observatory of Technology Assessment
PDAT	Doctoral Programme on Technology Assessment
RRI	Responsible Research and Innovation
R&D	Research and Development
ST&I	Science, Technology and Innovation
STS	Science, Technology and Society
STIS	Science, Technology, Innovation and Society
TA	Technology Assessment
TFA	Technology Futures Analysis
TEEPSE	Technological, Economic, Environmental, Political, Social and Ethical
US	United States
WEF	World Economic Forum
WFSF	World Futures Studies Federation

1

INTRODUCTION

1.1 Background and Motivation

We live in a time where information is overwhelming. Multiple sources, countless points of view, facts and narratives in constant conflict, ghosts from the past and disruptive novelties abound. Every day, people are confronted with visionary ideas, some possessing a revolutionary potential. Several technologies are pointing to such a radical change, prospects such as genetic modification, brain manipulation, neural control of computers, the end of aging and/or death, among others. The pace and acceleration of technological processes in recent times is full of new discoveries, innovation and learning, taking place at an unprecedented rate in the history of humanity. This rapid change, coupled with a high probability for new emerging technologies to cause breakthroughs and ruptures, has increased the uncertainty that naturally permeates any debate about the present, and especially the future. According to the findings of the Making Perfect Life project, developments in bioengineering are slowly but surely blurring the limits between humans and machines, changing the concept of, for example, sickness and health. These changes have brought discomfort to society at large as they defy basic concepts which describe the understanding of the world, as well as the definition of what it means to be human (Van Est et al, 2012).

It can already be said that a technological wave is now under course to revolutionize the world we live in. The technologies that have such revolutionary potential are called emerging or disruptive. According to Dobbs et al. (2013), emerging technologies can come from any field or scientific discipline, sharing four distinct characteristics: a high rate of technology change, broad potential scope of impact, its economic value and a substantial potential for disruptive economic impact.

Research on the brain is a major topic in the beginning of this new century. The brain has been considered as fundamental piece for the process of existence, since it is responsible for defining individualities and it is also the creator of the properties that define the core concepts of humanity. Once the brain has a special status as the core of selfhood and autonomy, ethical issues urgently need to be addressed in the face of rapidly emerging brain technology and scientific research (Velloso, G.T., 2012a).

In the case of Brain-computer interfaces, besides common ethical issues such as privacy, autonomy, risks inherent to new drugs/treatments and equipment's in medical settings, some ethical issues and considerations are relatively unique to emerging neurotechnologies, such as abstract concepts related to human agency, to an increasing degree of the intimacy of technologies and what defines humanity. Emerging technologies have potential in contributing to changes in some of the central concepts and categories used by humanity to understand and observe the set of values, norms and rules that involve human moral status. So, with the blurring distinction between body and mind, man and machine, it has become more difficult to assess the limits of the human body and this raises questions concerning free will and moral responsibility, as well as distribution and attribution of responsibility (Schermer, 2009).

These issues are not limited to the present time or to immediate consequences. Society also has to consider the potential risks and consequences for future generations. Ethical considerations demand an implied knowledge of likely risks and also protection against them. Side effects on the alteration of brain activity, like mood change, memory retention alterations or personality changes that could occur in the long term are some of the issues to be considered (McCullagh et al., 2013).

In this sense, Brain-Computer Interface (BCI) or Brain-Machine Interface (BMI) is an emerging neurotechnology, still at its initial stages of development. BCIs make a direct communication pathway between the brain and an external device possible, without the use of the normal output pathways of peripheral nerves and muscles. It functions as a bridge connecting the two systems, so that the control of software and hardware systems becomes possible only through brain activity, providing new and extended ways of interaction between humans and machines. In other words, a BCI system relies solely on mental activity to control a computer on an embedded system, which then controls a certain application for communication, transportation or other needs of the user. To achieve this, BCI systems use several techniques to differentiate among different mental tasks (Lebedev & Nicolelis, 2006; Donoghue, 2002; Cabrera, 2009; Mak & Wolpaw, 2009; Nicolas-Alonso & Gomez-Gil; 2012).

Given that elements of the future will be profoundly different from those of the present, any organization concerned with its survival and growth is required to deeply understand and act upon such change, regardless of how they intend to adapt themselves. Finding and seizing opportunities for growth arising from this new strategic environment is paramount for this task to be accomplished. Likewise, stakeholders and actors involved with such emerging technologies need to be aware of this phenomenon so they can be prepared to act in face of new challenges to come. Accepting the natural inevitability of such change and its possible benefits could be the key to their goals. Exploring the uncertainties and transition areas within this new strategic environment will help to define the conditions for a logical and disciplined transformation. This is of utmost importance to avoid being overwhelmed by disruptive events, preventing a simple passive reaction to them which could mean their demise.

Having this in mind, the motivation for this research lies in the need to deeper the comprehension and realization of such disruptive technologies, in the case of this research more specifically Brain-computer Interfaces and their own revolutionary potential, encompassing the social, ethical and philosophical impacts it may bring, obtaining a clearer view of this new context, suggesting the creation of a well-structured framework to better support stakeholders of the field in the task of anticipating and handling such impacts.

1.2 Research Problem and Objectives

Emerging technologies suffer from the absence of transparent and structured relations among actors, as well as a high level of uncertainty on future paths to take (Merkerk & Smits, 2008). Theoretically, BCIs are expected to be able to allow people to control many aspects of their surroundings (Allison et al.; 2012). However, according to Allison (2012) BCI's still have not been able to offer that in an efficient. And there is no perspective for that happening in the near future. Although some researchers and research groups have begun to question whether current and future applications of BCIs do not necessarily only have beneficial consequences but may also lead to harmful consequences (Nijboer et al., 2013). BCIs could improve the quality of life and well-being of people, but they raise important ethical and philosophical questions such as consequences and impacts of potential human enhancements, changing conceptions of personhood, free will and personal responsibility, how we perceive ourselves as human beings, the possibility to learn about the origins of our thoughts, emotions and personalities (Trimper et al., 2014; Hildt, 2010; Schermer, 2009; Vlek et al., 2012). BCIs could also evolve in different directions such as neural implants that could receive and transmit information directly from the brain being used for surveillance reasons; creating/inhibiting emotional responses; or even planting memories (Jebari, 2013; Trimper et al., 2014; Schermer, 2009). The fact is that the impacts and consequences of BCIs are still not clearly understood. Ethically, philosophically or religiously speaking, many doubts have arisen concerning the potential for these technologies to change society (Nijboer et al. 2013; Hildt, 2010; Schermer, 2009).

Another alert that has arisen is that these technologies could even further emphasize and increase differences and distances already existing in the human society, creating new inequalities and more barriers between people (Velloso, G.T., 2012b). These issues are not limited to the present time or to immediate consequences. Society also has to consider the potential risks and consequences for future generations. It is also worth adding that BCIs still fall short of fulfilling promises of practical and effective usage, with no perspective for that happening in the near future (Allison et al., 2011).

BCI tools have been researched and used for more than 15 years in many different applications, by a myriad of sectors and areas such as health, nutrition, education, finance, gaming, forensics, military, human enhancement and virtual worlds, among others (Allison et al., 2011). The field is constantly evolving, and although new applications have emerged, some are still just theoretical. However, each sector has many diverse types of applications and potential users, many of which can be transformative and disruptive.

Presented on the next page are the research problems for this study, highlighting the relevance of brain-computer interface research and its advancements as well as the importance of raising public awareness about the benefits and disadvantages yielded by it. Thus, answering these questions could foster a public debate on neurotech-ethics and the philosophical and humanistic implications of such discoveries, providing choices for decision-makers before adopting such technologies.

Given this context, the questions that lead this research are:

• Considering BCI as an emerging technology, will the field overcome its scientific, technological, social and ethical challenges to meet predictions and become a critical innovation for the future?

• Can BCIs reach such an advanced state where they will overcome obstacles and offer new communication possibilities for individuals with 'Locked-in' and 'Complete Locked-in' Syndrome?

• What are the current and potential ethical, legal, social, and philosophical challenges of BCIs, and which are the main constraints and enablers in the BCI field?

• How intimate can BCIs become?

Therefore, the general objective is defined as:

> Performing an assessment of the BCI Technology, investigating its potential societal, ethical and philosophical impacts, exploring ways to address the challenges it poses for both its present and future perspectives.

The study is based upon a participatory approach involving different stakeholders in order to identify and address implications for the social, ethical and philosophical areas regarding the present and future of the technology, as well as its contributions to the scientific and technological development.

Specific objectives are then defined as:

Specific Objectives
1. Investigate the field of BCIs, pointing out the most relevant and promising applications for clinical settings. 2. To identify and analyze perspectives and challenges in the research and development of BCIs for clinical applications. 3. To identify the main challenges and potential future technological pathways to visualize development possibilities and evolution. 4. To identify and analyze the main social, ethical and philosophical questions.

In order to perform a careful, detailed and criterious assessment, obtaining the best results, reasonable limits need to be established. The strategic focus, time horizon and scope must be defined, as well as the selection of stakeholders to be consulted.

1.3 Scope and Limitations

The Scope of the research has been chosen based on current trends of BCI research now in expansion all around the world. Relevant and important research in BCI is being conducted in the USA and Europe, among others, developing not only the hardware itself (the equipment that measures brain activity) as well as software used to operate it, in the academic and industry environments. Due to the budgetary limitations of this research, and in order to further narrow down the scope, the scope will be on the of the BCI community within the European Union; not only is this study being carried out in Europe but also there is a significant investment on the European Union part for research in BCIs and the discussion of its impacts in society as a whole, not existent in other regions where BCI research is being carried out (North America, and Asia, mainly).

Although the BCI field is large and encompasses a number of different areas of application, the main driving element for advanced research within BCI has been the medical applications area. For the purpose of this study, the focus will be on the developments and impacts of three medical application research areas of BCI: communication/control, for people unable to communicate with the outside world and have no control to perform any tasks whatsoever via other existing methods, such as in the Locked-in Syndrome cases; motor rehabilitation, for users who lost their ability to move a part of their body, but still have physical capacities to do so, and need to relearn how to do it; and motor substitution, for people who have lost the capacity to receive sensory stimuli from parts of their bodies in order to react to these feedback properly, whereas BCI comes in to substitute this original signal transduction pathway or sensory stimuli. BCIs based on EEG signals are in the most advanced state of development (Mak & Wolpaw, 2009) and have also been most widely used due to their noninvasiveness, high temporal resolution, portability and reasonable cost (Hwang et al, 2013). In addition, Milán et al., (2010) points that recent progress in BCI seems to indicate that time is ripe for developing practical technology for brain-computer interaction; it means that BCI prototypes combined with other assistive technologies will have a real impact in improving the quality of life of disabled people.

If the challenges for these three specific areas are overcome, such as faster and more accurate feedback for communication/control applications, higher degrees of freedom for prosthesis and more accuracy in moving and grasping objects, as well as more touch feedback for the patients, then new possibilities can arise for the medical area. The most benefits will come to patients/users, not only those willing to be able to communicate with the world again, after being “locked in” their own bodies, but also for those wishing to regain lost functions. There are those interested in obtaining full recovery to be placed in the workforce again. These technologies will indeed have a high impact.

Then, the strategic focus is defined as being the non-invasive type of BCI using EEG (further explained on section 3.3.1.1) for medical applications, namely Motor Substitution, Motor Recovery and Communication/Control. This combination of non-invasive and Medical Applications is the one which involves the highest number of stakeholders, and it also the one which gathers the most technologically advanced applications, even though most are still not commercially viable, at least not in a large scale. To assess real world impacts, the technology to be assessed cannot be so much in its infancy as to still be in the phase of proof of concept and yet not so mature that its development pathways are already crystallized. This will be further discussed in Chapter two.

There is still a myriad of challenges these applications will have to face and those will be discussed within this thesis. To understand the main technological challenges, what is already in development and possible prototyping already in use, and understand these technical challenges is essential to realize how can the development of these applications help the end users, and further define who they are going to be as well as the ethical, normative and political questions associated with the adoption of such technologies and applications.

The figure below shows the definition of the Strategic Focus and the Scope.

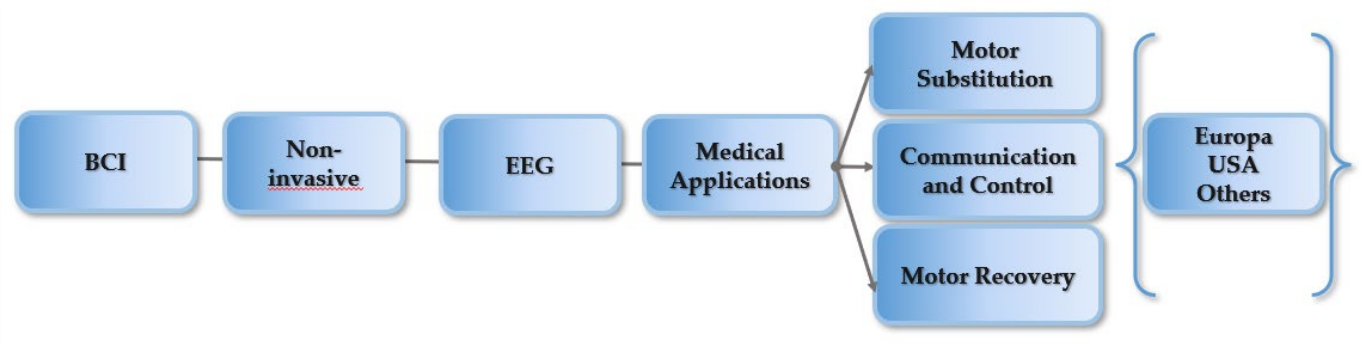

Figure 1.1 - Definition of the Strategic Focus and Scope. Source: Own elaboration.

Moreover, an important limitation of this study is the fact that the research had to be interrupted due to unforeseen circumstances from 2015 to 2022, reason why the literature review only includes references up to 2015. In order to resolve this issue, an integration of findings with an updated literature review of both the Technology Assessment and Brain-computer Interface fields was then included in the final considerations section of the research, making the connection of the findings of 2015 with the current literature, providing valuable insight into the development of the field and allowing future perspectives initially collected from the participants to be verified in reality.

1.4 Hypothesis and Approach

The present investigation has an exploratory and descriptive nature, considering the degree of novelty of the present study in a research field that still needs input and empirical studies. Such an exploratory endeavor seeks the understanding of the phenomenon under study from different perspectives, as well as points that have not yet been addressed or for which there is still no consensus. This study aims to comprehend the future of the technology's development, presenting various perspectives and pathways for the future, addressing uncertainties inherent to early-stage technologies, identifying issues that may affect the understanding of the analyzed environment as well as the decision-making process while exploring ethical, social and philosophical issues from tangible to abstract aspects such as personal data privacy concerns to a changed perception of what defines the concept of being human, emphasizing that new questions and concerns arise as technologies evolve. One particular matter of concern is the exacerbation of existing social inequalities, generating further profound negative impacts on societies (Velloso, G.T. 2012b).

That being said, the hypothesis elaborated in accordance with the research questions and to be verified over the course of this study are:

- BCI is considered an emerging technology with great potential to benefit individuals and society through its clinical applications, although it carries strong potential implications in ELSI dimensions (now and in the future).

- These ELSI dimensions may hinder or even stop the development of the technology, such as in cases related to non-obtaining informed consent from patients with CLIS (Complete Locked-in Syndrome) and LIS (Locked-in Syndrome) that may hinder or even prevent the application of the technology itself.

- The evolution of these technologies will reach a level of intimacy that significantly blurs the line between human cognition and technological augmentation, making technology an integral part of human's natural capabilities and skills, bringing profound Ethical, Legal and Social Implications.

- Stakeholder perceptions of BCIs are strongly influenced by the current state of technological development and potential future prospects, with the ELSI dimensions considered as major concerns.

Further investigation into the Technology Assessment and Foresight approaches aided in choosing the appropriate tools to assess the technology, arriving at the aim to assess the Brain-Computer Interface technology in clinical settings from the perspective of an emerging technology, focusing on its Social, Ethical and Philosophical aspects under the Responsible Research and Technology concept through a combination of the Technology Assessment, Constructive Technology Assessment and Foresight approaches.

Technology Assessment is the most common collective designation of the systematic methods used to scientifically investigate the conditions for and the consequences of technology and technicising and to denote their societal evaluation (Grunwald, 2009).

Constructive Technology Assessment – CTA, aims to produce better technology in a better society, emphasizing the early involvement of a broad array of actors to facilitate social learning about technology and potential impacts (Genus, 2006). In fact, van Merkerk & Smits (2007) discuss a process of tailoring CTA for emerging technologies and emphasize some CTA characteristics as well as interaction amongst stakeholders to assess this kind of technologies. CTA is one member of a family of recently emerging TA approaches aimed at improving the understanding, evaluation and practice of technology development in its various aspects (Genus, 2006). According to Schot and Rip (1996) one of the main characteristics of CTA is a commitment to the reduction of the costs of human trial and error learning on what concerns how society deals with modern technologies.

"Foresight is a systematic, participatory, prospective and policy-oriented process which, with the support of environmental and horizon scanning approaches, is aimed to actively engage key stakeholders into a wide range of 'activities anticipating, recommending and transforming' (ART) 'technological, economic, environmental, political, social and ethical' (TEEPSE) futures" (Georghiou, Harper, Keenan, Miles, & Popper, 2008).

And Future-Oriented Technology Analysis – FTA, an umbrella concept which encompasses Technology Forecasting, Technology Foresight and Technology Assessment (Cagnin, Keenan, 2008), represents any systematic process to produce judgments about the characteristics of emerging technologies, its development pathways, and potential future impacts. Detailed methodology will be presented in Chapter three.

Below the overview of the thesis structure is shown on figure 1.2:

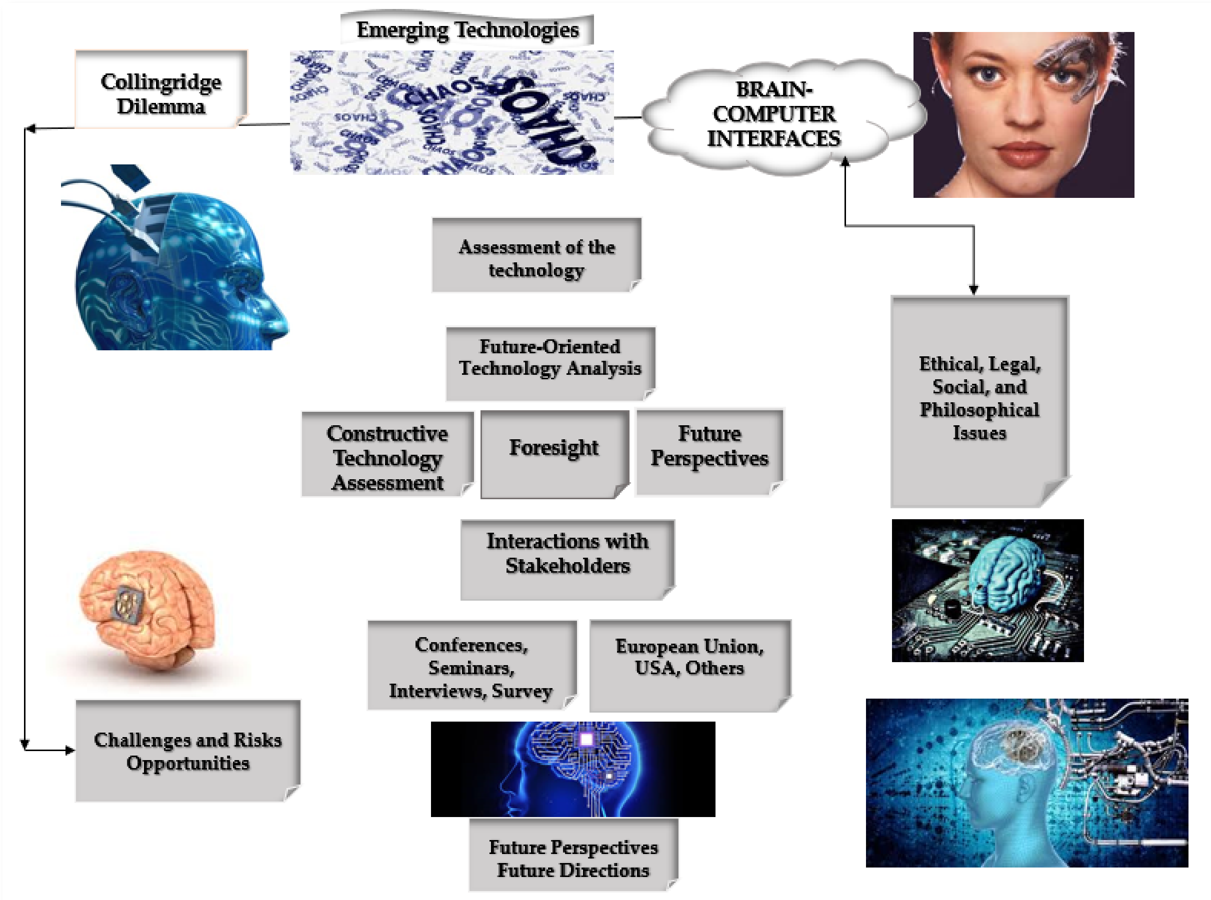

Figure 1.2 - Thesis Structure Overview. Source: Own Elaboration.

Initial efforts involved conducting a literature review and identifying key networks in the field through participation in scientific events like seminars, lectures and workshops, providing insight into the then current state of brain-computer interfaces. Understanding the field's research and development evolution and identifying key players in the scientific, technological and business sectors of the technology's ecosystem was crucial to contextualizing it, thus making it possible for the recognition of gaps and needs within the social, ethical and philosophical aspects related to the theme.

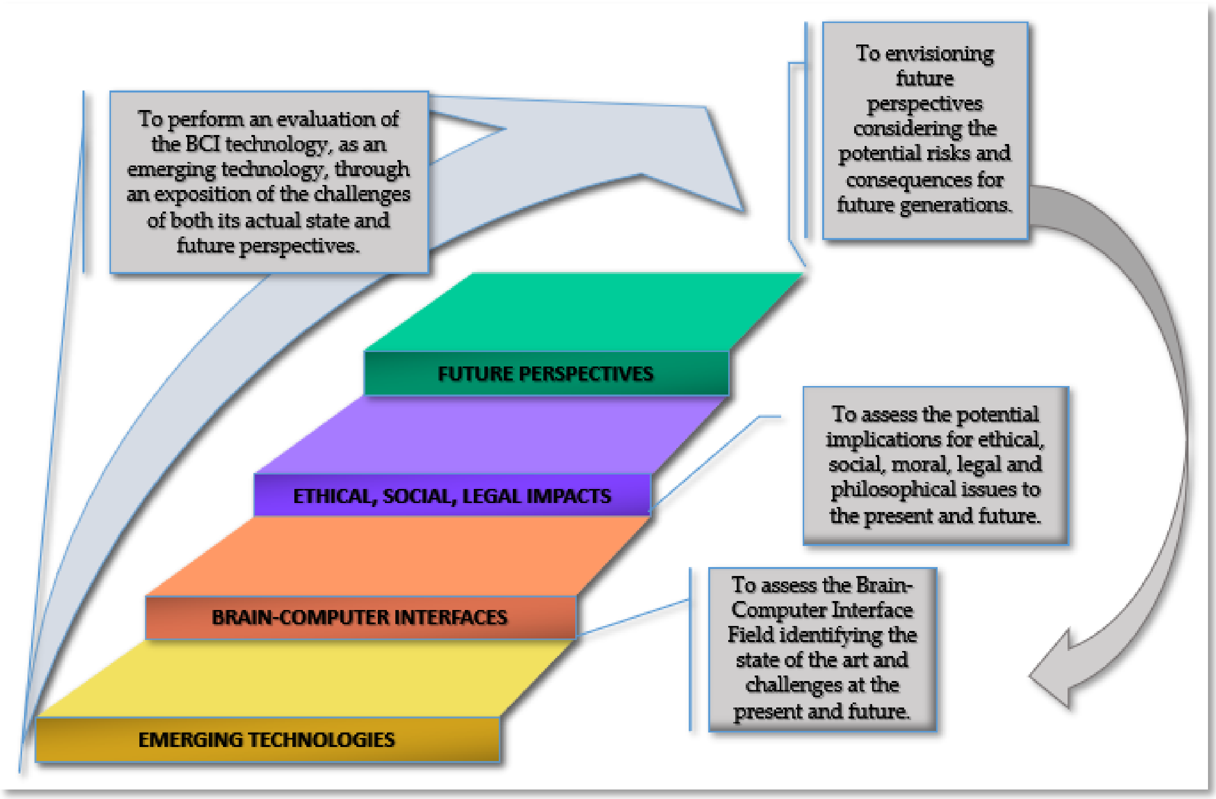

Figure 1.3 - Schematic representation of the structure of the work. Source: Own elaboration.

Each chapter is structured to give coherence to the research, as well as to introduce the main subsidies, results and conclusions of the study. Thus, each chapter presents the contents that are relevant for the understanding of the theme and the tools, approaches and methodology used, as well as for the contextualization of the research issues and conclusions found.

Figure 1.4 below presents a summary of the chapters, highlighting main points of the study's development.

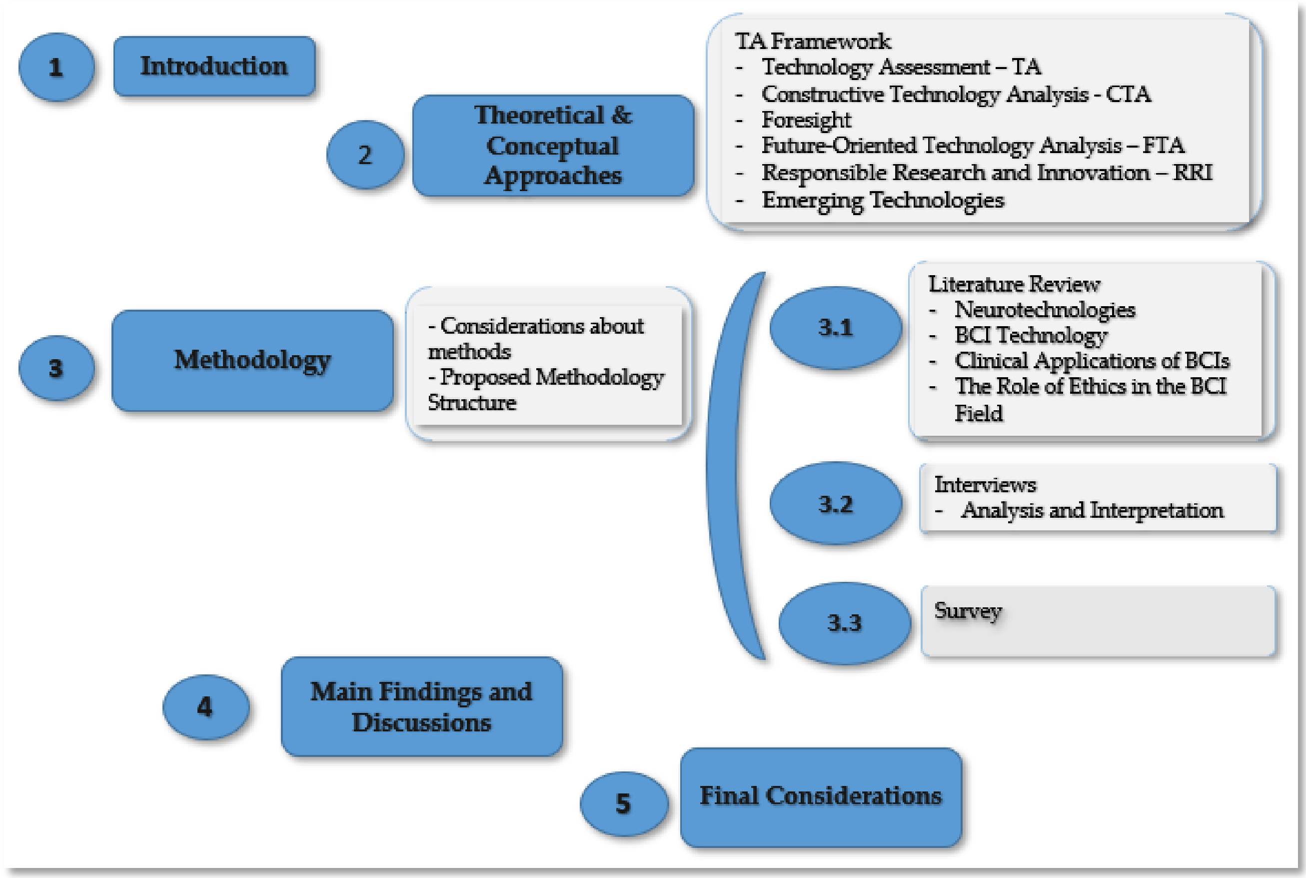

Figure 1.4 - Summary of the Chapters. Source: Own elaboration.

Chapter 1 introduces the topic, the motivation and a statement of the problems identified for the research. Objectives are presented, and the research scope and limitations are described. An outline of the thesis is provided along with considerations on the relevance of the PhD programme for Technology Assessment.

Chapter 2 provides the theoretical conceptualization of the research. The section reviews significant literature within the context of TA, CTA, Foresight, FTA, RRI and Emerging Technologies creating an understanding of the concepts and highlighting the theoretical background of the methodology, which will be presented in chapter three. It also outlines the methodology design that was utilized, explaining how tools were selected by describing them and the context of the study. The procedures for data collection and data analysis are explored in detail.

Chapter 3 presents some considerations about methods, the proposed methodology structure and each of the applied methods as well as their respective results and analysis, namely Literature Review, Interviews and a Survey. The Literature Review covers a selected number of relevant literature related to the theme, exploring the situation at the time of the gathering of information, including factors that affect the development of the technology drivers, trends and challenges that are relevant for the anticipation of the future needs or future capabilities, considering the probabilities that they occur and the likely impact, while also highlighting social, ethical and philosophical issues that are related to the technology. Then, Interviews are elaborated with results being presented and discussed. Based on the knowledge gathered in the literature review and supplemented with the interviews, the survey's questions were elaborated, and the results and discussions presented.

Chapter 4 presents the main findings, considerations and conclusions reached, as well as synthetizing and analyzing them while making a connection to the framework of the study. It includes the Social, Ethical and Philosophical aspects identified, reflections on potential future pathways and challenges for the BCI area. In addition, as mentioned on item 1.3, an updated literature review was included in this chapter, situating the research's findings with the current literature.

Chapter 5 aims to present other questions that have emerged in recent years. In addition, it points out those aspects that are deemed to deserve better investigation in the future, considering different technological paths that BCI technology may take in the future while offering suggestions for future research and recommendations for practice.

1.5 Relevance of PhD programme on technology assessment and this study

This section aims to relate the theme proposed for the present investigation with the theme of technology assessment (TA) that guides the PhD Programme on Technology Assessment (PDAT) at the Nova School of Sciences and Technology, of the Nova University of Lisbon. It is intended to emphasize the importance of the study, as well as highlight its innovative nature and contributions. The approach of technology assessment and the constructive technology assessment is particularly important because deploying a new technology in society should be a social conscious option, which means the decision about to the technology should be taken based on knowledge of the implications and possible impacts of innovation. It is important to reach a coherent vision, in which technology must always be subordinate to the global social system.

The assessment of emerging technologies requires special attention. There is a general assumption that technology is always a good thing, which comes to fulfill the needs and desires of a society, and that it has good moral consequences. However, especially in the case of emerging technologies, there are numerous possibilities of undesired effects, misuse and other negative aspects. The point is that future uncertainties regarding emerging technologies render it impossible to issue an accurate account of what will happen in the future. In the point when new technologies emerge, they bring expectations of all kinds. And with BCI technologies it is not different.

The approach of technology assessment (TA) has been widely used in the European Union to assess socio-technical challenges due to its adaptability and effectiveness to analyze innovations and their impacts, positive and/or negative. The aim is to identify the largest number possible of uncertainties, which might affect strategic decisions for organizations and governments. Thus, the role of experts in technology assessment consists of exploring the main uncertainties and transition areas within this new strategic environment will help to define the conditions for a logical and disciplined transformation (Velloso, G.T. 2012a). It is important to highlight that all the various questions regarding TA concepts, methodology and content are linked to philosophy, as there are close ethics of technology ties on what regards the normative questions that have a bearing on technological evaluation and technological design (Grunwald, 1999).

One of the main contributions of this work to the field of Technology Assessment is the actual application of this multifaceted approach combining CTA and Foresight with a future oriented perspective, while concomitantly embedding the notions and concepts of Responsible Research and Innovation within it, as it is essential to discuss and reflect on the societal, ethical and philosophical aspects of technologies.

The next chapter will present the theoretical conceptualization of the research, diving deeper into the framework of the study through a detailed description of the scientific framework for analysis and making some considerations about methods, outlining the methodology herein applied.

2

THEORETICAL & CONCEPTUAL APPROACHES

As mentioned in Chapter 1, the suggested approach for this Technology Assessment of Brain-computer Interfaces is a combination of the Constructive Technology Assessment and Foresight approaches as described under the Future-oriented Technology Analysis umbrella concept, within a Responsible Research and Innovation perspective as an inherent part of Technology Assessment itself. These concepts form the theoretical basis of the research framework, guiding the work in structuring, organizing, analyzing and discussing the results obtained. These results then could support the decision-making process by providing information about the past, present and future, near and far.

2.1 Research Framework

To design the future, one must go beyond what is known, opening the door to novel ideas and perspectives, sharing unsettling and provocative questions, and finding a perception to establish a framework that enables the construction of paths leading to the future (adapted from Santos et al, 2004). The following points present and describe the theoretical approaches which shape this research's framework.

2.1.1 Technology Assessment – TA

Technology Assessment (TA) has its origins in the late 1960s, in the USA and the Office of Technology Assessment (OTA), established in October 1972 (Coates, V.; 2019). The TA initiative was related to the US Congress efforts to establish an information collection service independent of the Administration, with the aim of increasing democratic control over scientific and technological progress, and the need of an earlier warning, an early understanding of what might be the social, economic, political and ethical consequences (among others) of the introduction of a new technology into society, as well as the substantial expansion of an existing technology. Smits further explains its origins and functions: "the creation of the Office of Technology Assessment (OTA) as a research based service and early warning mechanism of the United States Congress" (Smits et al., 2008). Without any doubt TA was conceived as a concept to assist in public policy decision-making (Grunwald, 2009; Tran & Daim, 2008). One of TA's earlier definitions comes from this time: "the systematic study of the effects on society, that may occur when a technology is introduced, extended, or modified, with emphasis on the impacts that are unintended, indirect, or delayed" (Coates, J.; 1976).

In the late 80s and 90s TA gained popularity in Europe, with the European Parliamentary Technology Assessment (EPTA) being formally established in 1990 under the patronage of the President of the European Parliament. The EPTA is a network of institutions involved in TA and specializing in advising parliamentary bodies in Europe[1], with its partners advising parliaments on the possible social, economic and environmental impact of new sciences and technologies.

There are several other European research groups/institutes working on TA, such as the portuguese initive GreAT (Study Group on Technology Assessment) and the Observatory on Technology Assessment at the Interdisciplinary Centre of Social Sciences (OAT/CICS.NOVA), an associate member of the European Parliamentary Technology Assessment (EPTA), and member of the European Technology Assessment Group (ETAG). Also the Dutch Rathenau Institute, the Institute Institute for Technology Assessment at the Austrian Academy of Sciences, and the Ger-man institute ITAS (Institute for Technology Assessment and Systems Analysis). The latter states that its objective is to contribute to realizing the potential of technical progress while minimizing its risks, looking at actors who shape scientific and technological pro-gress: politics, business and society. ITAS operates on the principle of knowledge-based policy making, providing knowledge for action and pointing out possible solutions to global challenges for the aforementioned actors.

Many of the issues that come up before European governments have a scientific or technological dimension. Both technological and scientific advances are at the core of economic growth and understanding how to support scientific and technological innovation

[1] https://eptanetwork.org/about/what-is-ta

while being proactive and responsible concerning the impact of technologies is key to a sustainable and healthy growth.

According to Grunwald (2009), "TA constitutes a scientific and societal response to problems at the interface between technology and society" - where "the term ""Technology Assessment" (TA) is the most common collective designation of the systematic methods used to scientifically investigate the conditions for and the consequences of technology and technicizing and to denote their societal evaluation". He further adds that four types of challenges have evolved for TA, namely:

- that of integrating at an early stage in decision-making processes any available knowledge on the side effects;
- that of supporting the evaluation of the value of technologies and their impact;
- that of elaborating strategies to deal with the knowledge uncertainties that inevitably arise; and;
- that of contributing to the constructive solving of societal conflicts on technology and problems concerning technological legitimization.

The author also points out that TA has as key characteristic "the combination of knowledge production, the evaluation of this knowledge from a societal perspective, and the recommendations made to politics and society". According to him, "TA has emerged against the background of various experiences pertaining to the unintended and often undesirable side effects of science, technology and technicization – adding that "those side effects can assume extreme proportions".

For instance, Sarewitz (2005) proposes that Technology Assessment should reflect four realities: i) that human choices are responsible for the directions and the development rates of advanced knowledge and applications; ii) that the directions and pace of technoscience is a reflection of the interests, values, motives and perspectives of decision makers; iii) that all decisions are made within a complex social setting, including a diverse range of socioeconomic, cultural and political components; and, iv) that this complex social setting interacts with the results of technoscientific advance to create social outcomes. The setting, the science, and the outcomes mutually evolve over time.

In fact, Banta (2009) says that, in the early years of TA studies, "technology assessment has been defined as a form of policy research that examines short- and long-term consequences (societal, economic, ethical, legal, etc) of the application of technology." The EPTA brings another perspective, stating that "Technology Assessment is a concept which embraces different forms of policy analysis on the relation between science and technology on one hand, and policy, society and the individual on the other hand".

All the various questions regarding TA concepts, methodology and content are linked to philosophy. On what concerns the normative questions that have a bearing on technological evaluation and technological design, there are close ethics of technology ties (Grunwald, 1999).

2.1.1.1 Constructive Technology Assessment – CTA

Technology assessment and constructive technology assessment are approaches used to better understand and deal with advances in research and development in any area of knowledge. It involves the early identification and analysis of scientific and technological trends, as well as emerging technologies and corresponding social developments, providing recommendations to guide decision-making in matters related to science, technology and innovation (Weinberger et al., 2013).

Constructive technology assessment (CTA) is a member of the family of technology assessment approaches, developed in particular in the Netherlands and Denmark, in the mid-1980s. CTA shifts the focus away from assessing impacts of new technologies to broadening design, development, and implementation processes, and has concentrated on dialogue among and early interaction with new actors (Schot & Rip, 1997). The proposal of CTA is to anticipate potential impacts and provide feedback (insights) into decision makers and stakeholders' strategies. CTA is viewed as "an active, positive form of shaping technological development in reaction to the original 'early warning' approach" (Eijnhoven, 1997). Schot and Rip (1997) show that one of the main characteristics of CTA is a commitment to the reduction of the costs of human trial and error learning on what concerns how society deals with new technologies. Genus (2006) points out the main characteristics, considering the opinions of several authors. According to this author, the main characteristics of CTA are:

- integration of anticipation of the future effects of technology into the promotion and introduction of technology, meaning ‘that actors involved in control activities should actively participate in the technology design and development practices';
- inclusion of more social actors and aspects of technology during the development and introduction of the technology ‘in order to improve the quality of technology society’;
- that modulation (‘change’) processes should have certain qualities; the ongoing anticipation of impacts due to the irreducible uncertainties at certain stages, for all actors to learn about the possible new linkages between the design options and the demands and preferences of the envisaged users. The learning should include aspects of the political and social articulation of acceptability of technology in development and its linkages to broader cultural values in society (Rip, 2002); and,
- actors should be ‘reflexive’ about the processes of co-evolution of technology and society, of technology and its impacts'.

Genus (2006) also states that "CTA aims to produce better technology in a better society”, and emphasises the early involvement of a broad array of actors to facilitate social learning about technology and potential impacts.” Given the high level of uncertainties related to emerging technologies, van Merkerk and van Lente (2005) reinforce the importance of understanding the technological dynamics necessary to appreciate and influence technological evolution. Thus, for the CTA approach, the main issue is to understand technological dynamics through the eyes of the main actors, while identifying important issues and challenges that may stimulate or constrain research in one field or another. Furthermore, van Merkerk & Smits (2007) discussed a process of tailoring CTA for emerging technologies and emphasize some CTA characteristics as well as interaction amongst stakeholders in order to assess this kind of technologies.

CTA aims at increasing reflexivity in technology development and engineering by addressing the level of concrete products, systems and services, going for a “better technology in a better society” (Schot & Rip, 1996; Grunwald, 2014).

CTA is considered the best approach to face the so-called dilemma of control, or Collingridge dilemma. This dilemma fundamentally states that controlling the direction of the technology's development is hard; when the technology is at its initial stages of development, anticipating their social impacts is difficult, but the direction of development can be easily changed. On the other hand, when technology becomes part of the economic system, social impacts can be easily observed. However, changing or controlling their technological development becomes extremely difficult (Collingridge, 1980; van Merkerk & van Lente, 2005). This dilemma can be faced by changing the relationship patterns between the players involved in the innovation process, as well as promoting the expansion of their visions and expectations, providing new perspectives of social and technical dynamics. Then the main actors involved can have a broader view of the innovation process itself, along with a new vision of its consequences and develop a better understanding of how these innovations will be (van Merkerk & Smits, 2008).

This interplay between the players involved proposed by CTA is the key that fosters the implementation of shared responsibilities amongst stakeholders, seeking to steer the development of the technology into a desired common pathway towards a more humanistic future, dependant only on the actual interests and values of the stakeholders themselves.

2.1.2 Foresight

Within the realm of science, technology, and innovation (ST&I) systems, Foresight has been considered essential for promoting the creation of the capacity to organize innovation systems that respond to society's interests. Thinking, debating, and seeking to shape the future are activities as old as humanity's existence itself (Santos et al., 2004).

The concept of "Foresight" in the context of science, technology and innovation hails from the Foresight Project, carried out by Martin's group (2010), within the SPRU (Department of Research in Policy for Science, University of Sussex, in the United Kingdom) in 1983. This group was established by the Advisory Council for Applied Research and Development (ACARD) of the Cabinet Office, part of the UK Government, and they adopted foresight as a convenient form to define "the techniques, mechanisms and procedures for attempting to identify areas of basic research beginning to exhibit strategic potential" (Martin, 2010).

One of the first definitions, albeit still a valid one, was written by Martin and states that foresight is "the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits”.

However, Miles (2010) emphasizes that the first definition of Foresight was elaborated by Joseph Coates in 1985, as follows: “Foresight is a process by which one comes to a fuller understanding of the forces shaping the long-term future which should be taken into account in policy formulation, planning and decision making. Foresight includes qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when directly linked to the analysis of policy implications. Foresight prepares us to meet the needs and opportunities of the future. Foresight in government cannot define policy, but it can help condition policies to be more appropriate, more flexible, and more robust in their implementation, as times and circumstances change... It is not planning – merely a step in planning” (Coates, 1985).

Broadly speaking, the foresight approach can be defined and/or explained as an open and collective process of purposeful, future oriented exploration, involving deliberation between heterogeneous actors in science and technology arenas with a goal of formulating and sharing visions and strategies that take better account of future opportunities and threats, obeying six essential principles: orientation towards the future and towards action; participation; evidence; multidisciplinarity; and, coordination (ForeIntegra, 2007).

The historical reference that also influenced the development of foresight is the French school of "“*La Prospective*”," initiated by Gaston Berger and Bertrand de Jouvenel. Gaston Berger (1896-1960), an industrialist and statesman, is considered the father of the discipline in France. He used a highly appropriate metaphor: the faster you drive, the further ahead your headlights should shine. Berger said that the attitude of “*La Prospective*” is based on five principles: seeing broadly, seeing far, seeing deeply, considering the human factor, and taking risks (Godet, 2012). “*La Prospective*” acts as a spotlight designed not to predict the future, but to illuminate actions to be taken now, in the present. Meanwhile, Jouvenel, who wrote "L’Art de la conjecture” in 1972, was the founder of the Futuribles Project and one of the founders of the World Futures Studies Federation (WFSF). As a pioneer of “*La Prospective*”, he viewed the future as an arena of freedom and power, consistently emphasizing the need to distinguish between the notions of a controllable future and a dominating future, and to have a global, long-term vision in decision-making. Currently, Michel Godet is considered the main reference of the school.

Currently the concepts of foresight and "*La Prospective*" are considered quite similar, including by the authors themselves. Michel Godet, for instance, who at first proposed the term strategic foresight as the correct term in English for "*La Prospective*", stated that despite cultural differences, the concepts of Foresight and '"*La Prospective*"' are very similar (Godet (2010). Martin (2010) highlights that the concepts of '"*La Prospective*"' and Foresight are not totally synonymous, but rather that they have substantial conceptual and philosophical similarities.

According to Miles, Saritas & Sokolov (2016), Foresight has become the standard description of activities related to futures in recent decades. The creation and evolution of the applications of the terms Foresight and "*La Prospective*", as well as the difficulties arising from this, are explained by Miles (2010), Martin (2010) and Godet (2010).

For Baena (2012), in a context of Foresight where the future is for everyone, the literature is directed towards a social vision in which new actors are incorporated into the strategic debate, including the participation of all in building the future and opening the doors for governance.

In the context of the United States, Mexico and few other countries Southeast Asia, the term Future Studies is still used. In Latin America, the terms Prospective, Strategic Prospective, Foresight, Strategic Foresight, Prospecção (only in Brazil), and Future Studies are used interchangeably to define and conceptualize Foresight activity, which in Latin America is collectively referred to as Prospective Studies, always focused on seeking priorities and recommendations to guide science, technology, and innovation systems. This is because, in Latin American countries, it is uncommon to have such studies aimed at private organizations and companies, so they are almost always related to science, technology, and innovation activities.

The fact is that Foresight methods are widely used and considered valuable tools for anticipatory planning and strengthening innovation systems. These methods deepen understanding of the dynamics of innovation systems, illuminate specificities of different fields, raise relevant issues, identify important actors, and explore the limits of predictability of innovations. Foresight studies identify future opportunities and needs, acting based on planned interventions in these innovation systems, recognizing that scientific and technological developments are the result of a complex interaction between different factors, evolving technological trajectories, various social actors, social needs, and economic constraints, among others.

2.1.3 Future-oriented Technology Analysis – FTA

The publication of the article "Technology Futures Analysis: Toward integration of the field and new methods" by Porter, Cuhls, et. al (2004) resulted from the work of the Technology Futures Analysis Methods Working Group. This article presented a novelty called Technology Future Analysis (TFA), an umbrella concept that encompasses methods and practices from the broad approaches of Technology Foresight and Technology Assessment in the public sector, and the approaches of Technology Forecasting and intelligence studies of private industry. TFA was a concept representing any systematic process that produces judgments about characteristics of emerging technologies, development paths, and potential impacts of a technology in the future.

This 2004 article led to the organization of the First International Seminar on Future Oriented Technology Analysis (FTA) at the Institute of Prospective and Technological Studies (IPTS) in Seville, Spain, in the same year. The seminar focused on impacts on policy and decision-making, and its main objective was to analyze possible overlapping fields of practice between Technological Foresight, Forecasting, intelligence, roadmapping and Technology Assessment. The origin of the term "future-oriented analysis" can be traced to the planning for the IPTS seminar "New Horizons and Challenges for Future-oriented Technology Analysis: New Technology Foresight, Forecasting and Assessment Methods" also held in Seville in May of 2004.

It was at this event that Technology Future Analysis (TFA) became Future Oriented Technology Analysis (FTA). This shift indicated that the focus of the seminar would clearly be on the future and on ways to develop useful information to shape the future. The essence of this change was "technology-oriented" giving way to "future-oriented" – in line with the umbrella concept created that united Technology Foresight, Technology Assessment and Technology Forecasting as the foundations of FTA (Johnston, 2008; Scapolo, 2005).

According to Haegeman et al. (2013) "future-oriented technology" is a common term that names a collection of different tools that can be used to study and understand the future of technologies from different methodological perspectives. On the other hand, Halicka (2016) proposes another definition for FTA based on the argument that the existing definitions are generic and do not reflect the nature of the approach. Thus, for this author, FTA is a process whose main objective is to predict the future of technology through a detailed assessment and analysis of the current state of technology and the identification of strategic factors for its future development. For this author, designing a methodological process for FTA is a difficult task, with multiple stages, which provide relevant information about the evaluated technologies at each stage. Such information can be related to the technology per se, but also to the factors that can affect this technology and its development, that is, the impacts of the environment on the technology, as well as the impacts of technology on the environment.

Thus, considering that all the approaches mentioned above (Technology Assessment, Constructive Technology Assessment, Responsible Research and Innovation, Foresight, and FTA) use the same toolbox, thus, the same set of methods can be used by any of the approaches. These approaches under discussion, to a greater or lesser extent, are approaches that allow the use of one or more decision tools, but they are not disciplines with solid theoretical foundations, on the contrary, they are a set of methods and techniques that, in an organized way, shares some views and differs in others. Thus, when building a methodology, it is necessary to observe the consistency between these tools in order to guarantee that the methodology meets the proposed objective (Cagnin et al., 2013).

2.1.1 Responsible Research and Innovation – RRI

Grunwald (2011) states that the terms responsible development, responsible research and responsible innovation have increasingly been used in recent times, covering issues of engineering ethics, participation, technology assessment, anticipatory governance and science ethics. These highly integrative terms include an added reflexivity to technology development and design (Grunwald, 2011; Voss et al., 2006). Grunwald also reinforces this concept when stating that responsible innovation adds explicit ethical reflection to technology assessment and science, technology and society studies and includes all of them into integrative approaches to shaping technology and innovation. In another work, Grunwald states that "Responsible innovation adds explicit ethical reflection to Technology Assessment (TA) and science, technology and society (STS) studies and includes all of them into integrative approaches to shaping technology and innovation. Responsible innovation brings together TA with its experiences on assessment procedures, actor involvement, foresight and evaluation with ethics, in particular under the framework of responsibility, and also builds on the body of knowledge about R&D and innovation processes provided by STS and STIS studies (science, technology, innovation and society)" (Grunwald, 2011).

In this regard, responsible development and innovation may serve as a fresh, umbrella term (von Schomberg, 2012) with novel nuances that can be distinguished by engaging ethical and societal concerns more directly in the innovation process through integrative approaches to development and innovation; closing the distance between innovative practices, engineering ethics, technology assessment, governance research and social sciences (particularly in the realm of Science, Technology, and Society (STS)); and especially fostering maximum transparency in the allocation of responsibility among the participating actors/stakeholders (Grunwald, 2011), among others. The author also states that both engineering ethics and TA are the origins of Responsible Innovation, with the concept of shaping technology according to social values bringing the hope that problems of rejection or conflict would no longer occur at all.

The concept of Responsible Research and Innovation – RRI then "may be defined as a transparent, interactive process by which societal actors and innovators become mutually responsive with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products in order to allow a proper embedding of scientific and technological advances in our society" (von Schomberg, 2012).

It is true that the use of the term suggests that over the past decades, innovation was not all that responsible; the negative impact of innovations on individuals, societies and eco-systems were largely neglected in favor of economic growth and creating shareholder value. The emergence of responsible innovation must be understood, then, as a fresh approach towards innovation, in which social and ethical aspects are explicitly taken into account and economic, socio-cultural and environmental aspects are balanced (Blok & Lemmens, 2015). In fact, the concept of RRI deals with a novel approach to reinforce interactions between science and society, applied to issues related to education, open access, ethics, social engagement and gender equality. This notion implies a commitment to develop and use technology to help meet the most pressing human and social needs, while making every reasonable effort to anticipate and mitigate adverse implications or unintended consequences. Responsible innovation is often not about innovation but about development of S&T (Rip, 2011). In this sense, it can be highlighted that ethical, social, legal and philosophical issues and analyses that anticipate future developments can be valuable in identifying relevant considerations during the developmental phase of technologies, and about the capabilities and future evolution of the technologies (Ryan, Blok, 2023).

In short, Responsible Research and Innovation adds reflexivity to technology development and design (see also Voss et al. 2006), forming a umbrella term (von Schomberg, 2012) characterized by involving ethical and social issues more directly in the innovation process by integrative approaches to development and innovation, bridging the gap between innovation practice, engineering ethics, technology assessment, governance research and social sciences (STS), giving new shape to innovation processes and to technology governance, making the distribution of responsibility among the involved actors as transparent as possible, and finally supporting "constructive paths" of the co-evolution of technology and the regulative frameworks of society.

2.1.2 Emerging Technologies

Once the concept of emerging technologies is crucial for this framework and approach, some points and definitions are considered here. Emerging technologies and disruptive technologies are closely related concepts and both are relevant to the study of technological change, as well as important for the understanding of science, technology and society changes. They share common theoretical roots and analyze similar empirical phenomena. Both might profoundly modify the context and the way of doing things. Although it is observed that there is still not a consensus definition for emerging technologies (König et al, 2021), (Greaves et al, 2023), some definitions have been extensively used.

A general definition for emerging technologies is presented as science-based innovations with the potential to create a new industry or transform an existing one (Srinivasan, 2008). Additionally, the ETICA Project (Ethical Issues of Emerging ICT Applications - European Commission) defines emerging technologies as technologies that have the potential to gain social relevance within the next 10 to 15 years (Stahl, 2011). According to the McKinsey Global Institute (MGI) (Dobbs et al., 2013) "economically disruptive technologies transform the way we live and work, enable new business models, and provide an opening for new players to upset the established order".

For some authors, not all the emerging technologies have the potential to change or to impact society and the economy, even though some have the potential to revolutionize sets of values and principles of a society, as well as effectively changing the way people live and work. Emerging technologies might cause disruptions in an entire industry or segment in particular, while not affecting others. To Merkerk and van Lente (2005) for technological development, the notion of emerging technologies relates to the initial stages of technological development, where there is a high level of uncertainty and the options for the future are unclear.

On the other hand, Harper (2010) described emerging technologies as ones that:

- arise from new knowledge, or the innovative application of existing knowledge;
- lead to the rapid development of new capabilities;
- are projected to have significant systemic and long-lasting economic, social and political impacts;
- create new opportunities for and challenges to addressing global issues; and,
- have the potential to disrupt or create entire industries.

According to Halaweh (2013) little research has been done in defining emerging technology and specifying its characteristics, even though the term is often used. He argues that a technology can be considered emerging in a context, even though the same technology is already established in another field. This means technology is labeled as emerging in a particular context, which could be a domain, place or an application. Moreover, he states that a technology can be considered emerging if it is not already widely available to the market. To Halaweh, a "time horizon" is another misconception, which means an emerging technology does not need to have a limited or fixed lifetime; "technology is defined as emerging when it causes a radical change to business, industry or society". So, from this point of view, both the 'emerging' and 'disrupting' terms have the same meaning. The uncertainties associated with emerging technologies take on a myriad of forms and shapes with unpredictable values and outcomes; the social impacts are unseen, unknown and unexpected before the technology's adoption or at an early stage of development.

Moreover, Rotolo et al (2015) states that Emerging Technology is “a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous”.

With those definitions and concepts in mind, the application of the methods is presented alongside their collected data, analysis and interpretation in the next chapter. A brief introduction to methods introduces it.

3

METHODOLOGY

3.1 Considerations about Methods

Reflecting on the different approaches, methods, and techniques should be seen as a means to improve activities that aim to look into the future to adequately respond to inquiries about it, at various levels and interests. Thus, in general, when quantitative methods are combined with qualitative methods, explicit knowledge is added to tacit knowledge in the pursuit of complementarity or differentiated perspectives (Santos et al, 2004).

Analyses have been conducted with the objective of mapping and classifying the methods that have been used by the approaches, in particular those that are useful for FTA. The first initiative was with the Technology Futures Analysis Methods Working Group (2004) which identified some methods and divided it into classes. Following this initiative, Scapolo & Porter (2008) gathered and systematized FTA methods, designating fifty-three methods, classified into thirteen classes. These authors were able to cover an extensive group of different methods and techniques for technology analysis in the fields of Technology Foresight, Technology Forecasting and Technology Assessment (Cagnin et al, 2008). However, according to Halicka (2016), Scapolo and Porter's classification does not cover all the possible and necessary tools for a thorough technology analysis. For the author, the set of methods selected lack the tools enabling the identification and assessment of the factors that influence the development of technology, also stating that there are no tools to evaluate the state of technology, its technological maturity, and technological possibilities.

Given this situation, it is noted that it is necessary to develop a methodology for classification of FTA methods which considers a complementation of the methods catalogued by Scapolo and Porter. Then, Halicka proposes that it is necessary to evaluate and organize these methods in terms of their use for the implementation of the following functions:

- Collecting information on the purpose and scope of the analysis.
- Collecting and collating information on technologies.
- Processing information about the past of technologies.
- Processing and generating new information on the current state of technology.
- Gathering information on the impact of the environment on technology and technology on the environment.
- Transmission of the acquired information.
- Collecting information on the factors affecting the development of technology.
- Generating novel information concerning the development of a particular technology; and
- Interpreting and using the obtained information.

Thus, Halicka reviewed the existing classification of the research methods of future based on literature review and direct observation, arriving at the number of ninety methods divided in seven classes:

- Accumulation (collection of information) with twelve methods.
- Creation (generating of new knowledge) with five methods.
- Retrospection (analysis of historical data to identify trends) with eight methods.
- Exploration (analysis of technologies from different perspectives: social, technological, economic, ecological, political, values, and legal) with eighteen methods.
- Quantification (an estimate of the costs associated to the lifecycle of technologies) with nine methods.
- Selection (identification, classification, ranking of analyzed objects – stimuli affecting the development of technology and the analyzed technologies) with twenty-two methods; and,
- Projection (presentation of the development paths of technologies, analysis of trends and potential events that may affect the trajectory of the development of technologies) with sixteen methods.

Although Halicka's propositions are important and praiseworthy, it is essential to remember that it is not always possible to present such a complete framework. Every study or research will always depend on various other factors, such as scope limitations, scale, time horizon, budget, client interests, or research objectives. Thus, it can be said that not all steps and stages suggested by the author will be feasible in a practical situation.

On the other hand, Popper (2008) points out that there is no ideal methodology, nor an ideal number of methods to be used, as everything depends on the needs and demands of the project and its characteristics. In fact, Popper states that the methodological approach used in a project of this nature must be constructed to meet the specific objectives of the project and the resources and capacities available. There are only benefits in considering all kinds of conditions and limitations before designing an adequate methodology for a particular study. Then, Popper organized a simple proposal that is clearer and easier to use, through the so-called "Foresight diamond," as shown on the next page:

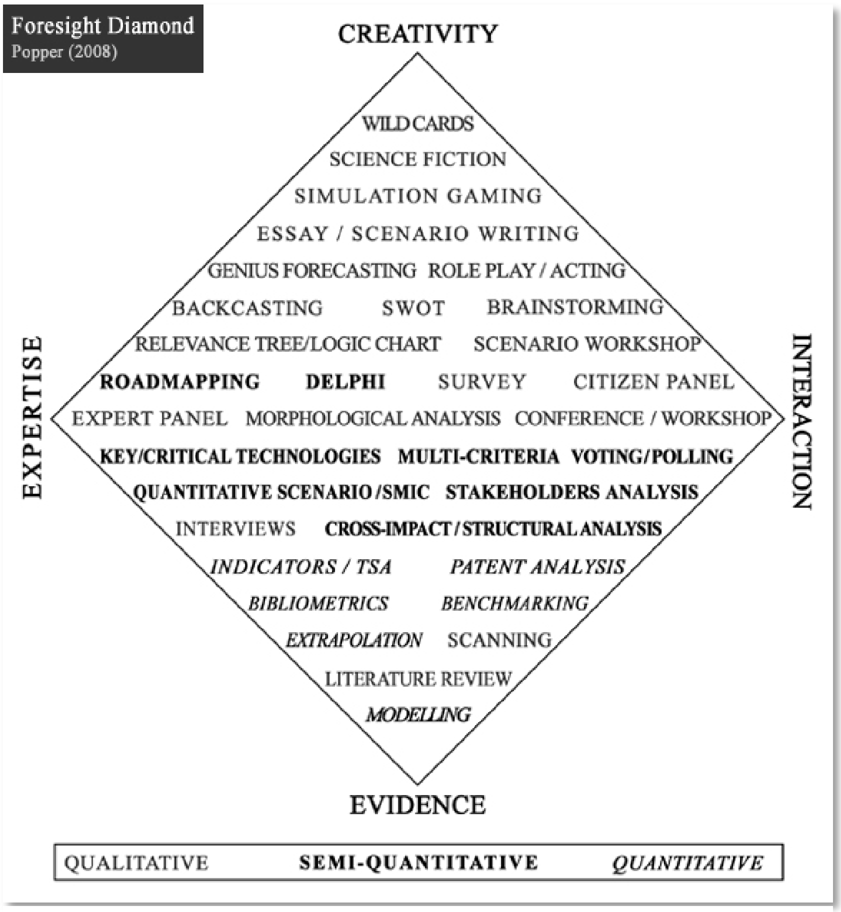

Figure 3.1 - Foresight Diamond. Source: Popper, 2008.

This Foresight Diamond presents a proposal that positions the methods based on the main and most relevant type of information source in each quadrant, that is, methods can be based on creativity, specialization, interaction and evidence, considering that these groups are not entirely independent of each other.

- **Creativity** related methods require a mix of original and imaginative thinking, such as brainstorming, science fiction, and wild cards, for example.

- **Expertise-based** methods depend on the skill and knowledge of individuals in a specific area or particular subject, such as expert panels, the Delphi method, roadmapping, morphological analyzes and key technologies.

- **Evidence-based methods** try to explain and/or predict a certain phenomenon with the support of reliable documentation and means of analysis, being particularly useful for understanding the real state of development of the research question. Some good examples are benchmarking, bibliometrics, data mining and indicators, as they are supported by statistical data, or other types of indicators.

- **Interactive and participatory methods** encourage action, sharing and joint learning, allowing the involvement of different actors.

3.2 Proposed Methodology Structure

3.2.1 Selected Methodology

The main feature of the methodology is the promotion of an interactive and participatory approach, to democratize information, to promote channels of communication between selected groups and to include new social actors and aspects related to the future development of the technology and its impacts. In any case, it is good to keep in mind that the methodology should only be defined when the objectives have been defined and the selection of methods can be affected by costs, budgets, availability of specialists, political and technological support, physical infrastructure and time. It all depends on the scope of the study, the scale and the results to be achieved.

The main sources of gathering information to obtain a view of the context, and also details of the topic or branch that one wishes to know in more depth that allows an assessment of the theme were the methods of literature review, interviews, and the elaboration and application of a structured questionnaire – a survey.

There is a general assumption that all technology is always made up of artifacts that meet society's desires and needs and that always have good moral consequences. However, in the case of emerging technologies, there are always numerous possibilities for unwanted effects, misuse and other negative aspects. The point is that the great uncertainty of these technologies, in their early stages of development, makes it impossible to predict what might happen, so as neuroscience advances, ethical issues at the interface between science, technology and society need to be addressed. In the end, it is expected that this research will be able to add a more coherent view of the challenges and opportunities of the theme, pointing out aspects that deserve further investigation, as well as what are the future paths that are being considered.

The use of these methods and techniques presupposes the circulation of information among all those involved and the collective internalization of the problems and potentialities of the issue under analysis, which is expected to generate an effective participation capable of producing individual and group behavioral changes. They are useful to facilitate dialogue, moderate conflicts, so that, from the identification of the problems presented, it is possible to find solutions that meet the interests of the community. In general, the aim is to consider the opinion of all invited or involved participants without excluding the cultural and individual realities of the different actors.

This research is based on a number of steps, where each step will provide a set of different groups of information that will pave the way to the next step, so that, in the end, it will be possible to obtain an integrated view of the subject, thus enabling a coherent and consistent assessment of the technology under review.

The proposed structure for the thesis is as follows:

- To undertake a literature review of the theme to further understand the actual situation and its perspectives as well as to map the technological possibilities on the horizon.

- To structure and characterize the technology, identifying which are the main issues associated with it, the aspects not fully understood at the moment, as well as structuring the collection of the opinion of different stakeholders, identifying also ethical, social and philosophical concerns related to the theme, drawing from the elements in the literature review.

- To undertake interviews and to list the remaining information collection activities, systematizing the collected information and structuring the findings.

- To elaborate and apply a survey eliciting perspectives and views of stakeholders from different areas of the BCI community, with the aim of understanding their relations, points of view and expectations for the future of the field.

- Discussing and integrating the results to offer a comprehensive understanding of the potential social, ethical, legal and philosophical impacts, as well as possible development pathways.

The main question is: how to anticipate better? The understanding of the early technological dynamics is a key point, crucial to shaping future developments of technologies.

Below the thesis structure is illustrated on figure 3.2:

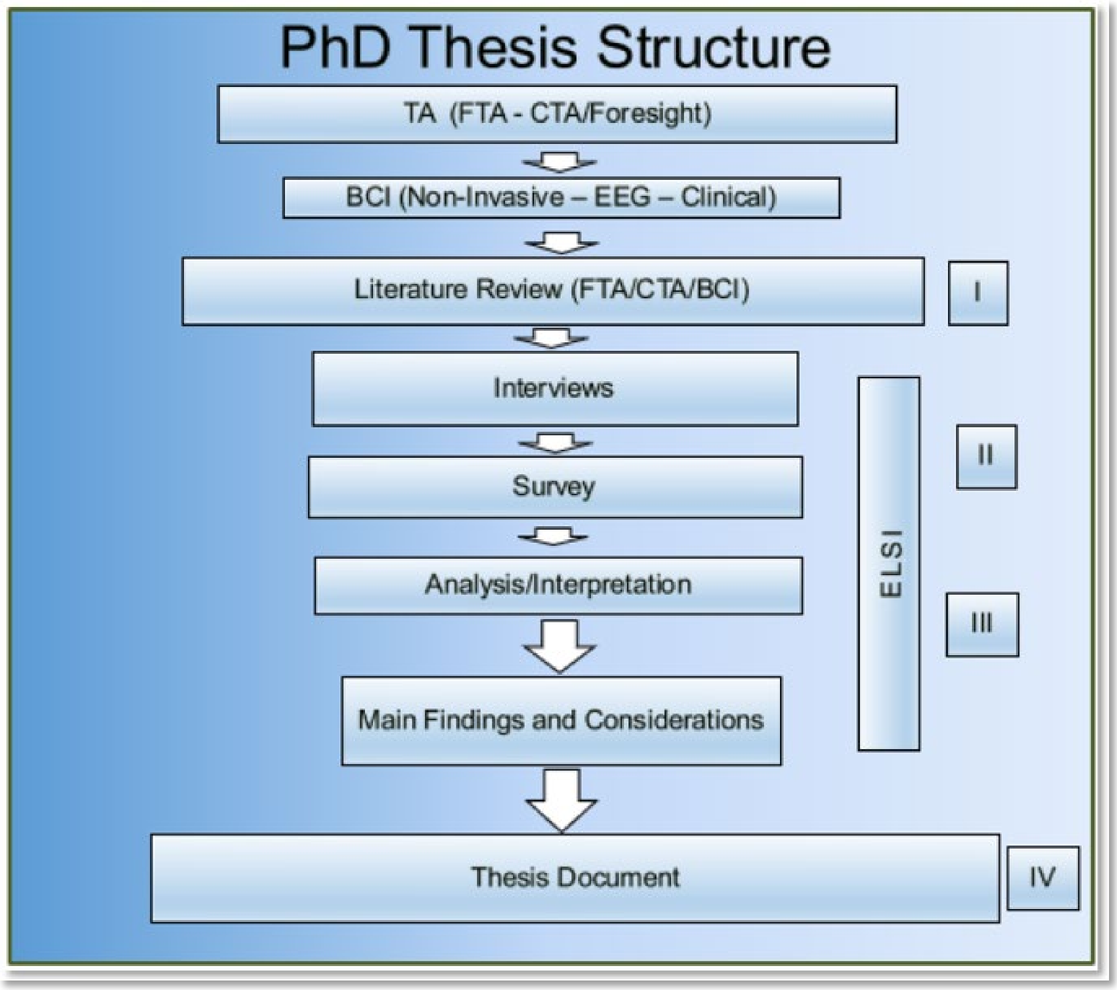

Figure 3.2 - PhD Thesis Structure. Source: Own Elaboration.

3.3 Literature Review

The foremost source of information is undoubtedly the review of existing literature. A literature review recognizes the contributions of prior researchers and establishes a context for the topic under investigation by offering an insight into its historical and contemporary developments, as well as a deeper understanding of the topic at hand. In other words, it allows researchers to learn from previous theories on the subject, recognize existing theories, findings, unanswered questions, hypotheses, and diverse perspectives within the research field. The literature review's results should encompass a substantial portion of prior work in the research area, or at the very least, the vast majority of it. Additionally, it serves as a valuable tool for justifying the research and is a member of the family of evidence-based methods.

As a result, a literature review should offer a comprehensive portrayal of the topic under investigation, encompassing the summarization and analysis of prior research and theories, identification of areas of controversy and disputed claims, as well as an endeavor to fill in any existing research gaps. Upon completing a literature review, one should be familiar with the research already conducted or ongoing and be capable of identifying unknown aspects within the topic.

3.3.1 Neurotechnologies

A foresight study from the Canadian Government called "Metascan3 Emerging Technologies" (Policy Horizons Canada, 2013) examined how four emerging technologies (digital technologies, biotechnologies and neurosciences technologies) could drive disruptive social and economic change. The report stated that within 10 to 15 years from its conception an era of transition having these four technologies as the foundation for the global economy for the next 50 years would take place. In fact, within neurotechnologies brain-computer interfaces are already in use to improve cognitive functions, assisting, augmenting, or repairing human cognitive or sensory-motor functions, and to communicate thoughts and intentions for those who cannot naturally do so. It can even provide new senses to human beings, such as the ability to sense magnetic fields, infrared or radio waves.

The World Economic Forum's Global Agenda Council on Emerging Technologies published the report "Top 10 Emerging Technologies" (WEF, 2014) that identifies key trends in technological change and highlights the most important technological breakthroughs that could reshape society in the future. BCIs are one of these ten emerging technologies that could revolutionize the world. And the neurotechnology field is growing fast.

According to a report by the Potomac Institute (2015), there is a boom in neurotechnology innovation; patents doubled since 2010 and have quadrupled since the beginning of the millennium. According to this report, in 2010, 800 relevant patents were filled and by 2014, that number increased to over 1,600. In 2015, based on new SharpBrains analysis[2], the value of neurotech patents was about $ 2B USD. There are currently over 8,000 active patents and over 1,500 pending applications, which means the product of 500% growth in 10 years, driven mostly by activity in the US and in the EU. Moreover, the distribution of neurotech ownership and licensing by entity type are: 51 % - large companies; 21 % small companies; and 15 % universities or governmental organizations. And it is important to highlight that this analysis refers only to pervasive neurotechnologies, which means, non-invasive procedures, which does not involve surgery of ingestion, and, in the near future can extend beyond hospitals or research facilities into multiple industrial and consumer fields. Research on Brain-Computer Interface (BCI) has experienced an explosive growth in the past 15 to 20 years. Wolpaw et al., (2000) points out that in 1995 there were no more than 6 active BCI groups and that in 2001 more than 20 groups could already be identified. In 2009, more than 400 research groups worldwide had been identified to be working on a multidisciplinary effort to engage a wide spectrum of research and development programs (Mak & Wolpaw; 2009).

This explosive growth has been deeply encouraged by the prospects of clinical applications of BCI's. They offer possibilities for providing new augmentative communication and control technologies to those who are paralyzed or have other severe movement deficits like amyotrophic lateral sclerosis (ALS), cerebral palsy, brainstem stroke, spinal cord injuries, muscular dystrophies, or chronical peripheral neuropathies (Wolpaw et al., 2000). According to Wolpaw & Wolpaw (2012) this is one of the main reasons for such a growth rate. Two other reasons are the recent appearance of powerful inexpensive computer hardware and software that supports complex high speed analyses of brain activity essential to real-time BCI

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[2] "Pervasive Neurotechnology: A Groundbreaking Analysis of 10,000+ Patent Filings Transforming Medicine, Health, Entertainment and Business." *SharpBrains RSS*. SharpBrains. Web.17 July 2015. http://sharpbrains.com/pervasive-neurotechnology/.

operation, and the understanding of the central nervous system (CNS) that has emerged from basic and applied research in the last 50 years.

3.3.1.1 Brain-Computer Interfaces (BCIs)

The BCI industry sector is increasing fast. In 2011, were identified 39 companies producing BCIs or related devices for diferente market sectors (Allison et al., 2011), and within the BNCI Horizon 2020 were identified more than 100 companies either directly developing BCIs or related devices, or aiming to integrate BCI-based technology into their product portfolio or upcoming market applications (Brunner et al., 2015).

Although technically Brain-computer Interface technology is still an emerging research field, at its initial stages of development, not only does the sector experiences such a massive growth, but it also comes with great potential to benefit individuals and society as a whole, especially through its clinical applications. However, it does not come without strong potential implications for ethical, moral and philosophical questions (Mak & Wolpaw, 2009; Nijboer et al., 2013).

There are still no clear guidelines on how to properly deal with ethical, legal and societal issues (Brunner et al., 2015; Mak & Wolpaw, 2009; Nicolas Alonso & Gomez-Gil, 2012; Nijboer et al., 2013; Allison et al., 2011). Nevertheless, BCI systems are improving in various ways and are gaining attention worldwide, with some of its most promising future directions having not been identified yet.

A BCI system consists of basically four elements: signal acquisition, feature extraction, feature translation and device output, which are managed through the system's operating protocol. The first characteristic, which differentiates BCIs among themselves, is the method used for signal acquisition. BCI types can be either invasive or non-invasive according to this. A variety of different neurophysiologic signals can be recorded and used in a BCI system as long as they reflect brain activity and these signals could be electrophysiological, magnetic, and metabolic (Mak & Wolpaw, 2009).

BCIs which record signals from outside the skull are called non invasive and rely mostly on Electroencephalography or EEG. Invasive recorders on the other hand use neural signals obtained from within the skull, either from the surface of the brain cortex itself or even inside the brain (Birbaumer, 2006a). On non-invasive BCIs, the neuro signals have a limited bandwith, but carry no apparent risks in its implementation and reading of brain waves. On invasive BCIs, although the neural signals have the best quality, and therefore greater potential to have better results, they carry risks associated with invasive surgical procedures (Lebedev & Nicolelis, 2006). The non-invasive methods have been successfully used in patients both partially or severely paralyzed, allowing them to have basic forms of communication and control in their interaction with the external world. However, in order to have a better motor recovery, there is a need for brain signals with better resolution. The invasive methods have greatly improved brain signal resolution, but because of its surgical procedures, brain microchip implants and significative risks associated there is still much resistance against it (Birbaumer & Cohen, 2007; Milán et al., 2010; Nicolas-Alonso & Gomez-Gil, 2012).

Success in operating the system depends on a combination or interaction of two adaptive controllers: the user, who produces specific brain signals that encode de intention and BCI system, which translates these signals into output that accomplishes the user's intent (Wolpaw et al., 2002; Mak & Wolpaw, 2009).

Although issues of terminology nature are still under discussion (Wolpaw & Wolpaw, 2012; Allison, 2011; Brunner et al., 2015) a simple definition could be define BCIs is as a device that enables communication without movement, and attend some conditions: BCIs must rely on direct measures of brain activity, provide feedback to the user, operate online, and rely on intentional control (Brunner et al., 2015).

Another definition is a system that measures and analyzes brain signals and converts them in real-time into outputs that do not depend on the normal output pathways of peripheral nerves and muscles. It should be noted that BCIs do not read minds. Systems that measure electrical activity generated by muscles do not satisfy the definition, and therefore are not BCIs. Systems that measure brain activity that depends on muscles control are not pure, or independent BCIs, but might rather be called dependent BCIs (Wolpaw et al., 2000; Mak & Wolpaw, 2009; Wolpaw & Wolpaw, 2012).

A definition by Wolpaw & Wolpaw (2012) extends the concept to state that "a BCI is a system that measures central nervous system (CNS) activity and converts it into artificial output that replaces, restores, enhances, supplements, or improve natural CNS and thereby changes the ongoing interactions between the CNS and its external or internal environment". It is relevant to highlight here that the author maintains the same definition in a later publication dated from 2020 (Wolpaw, Millán and Ramsey, 2020).

The picture below represents a BCI system.

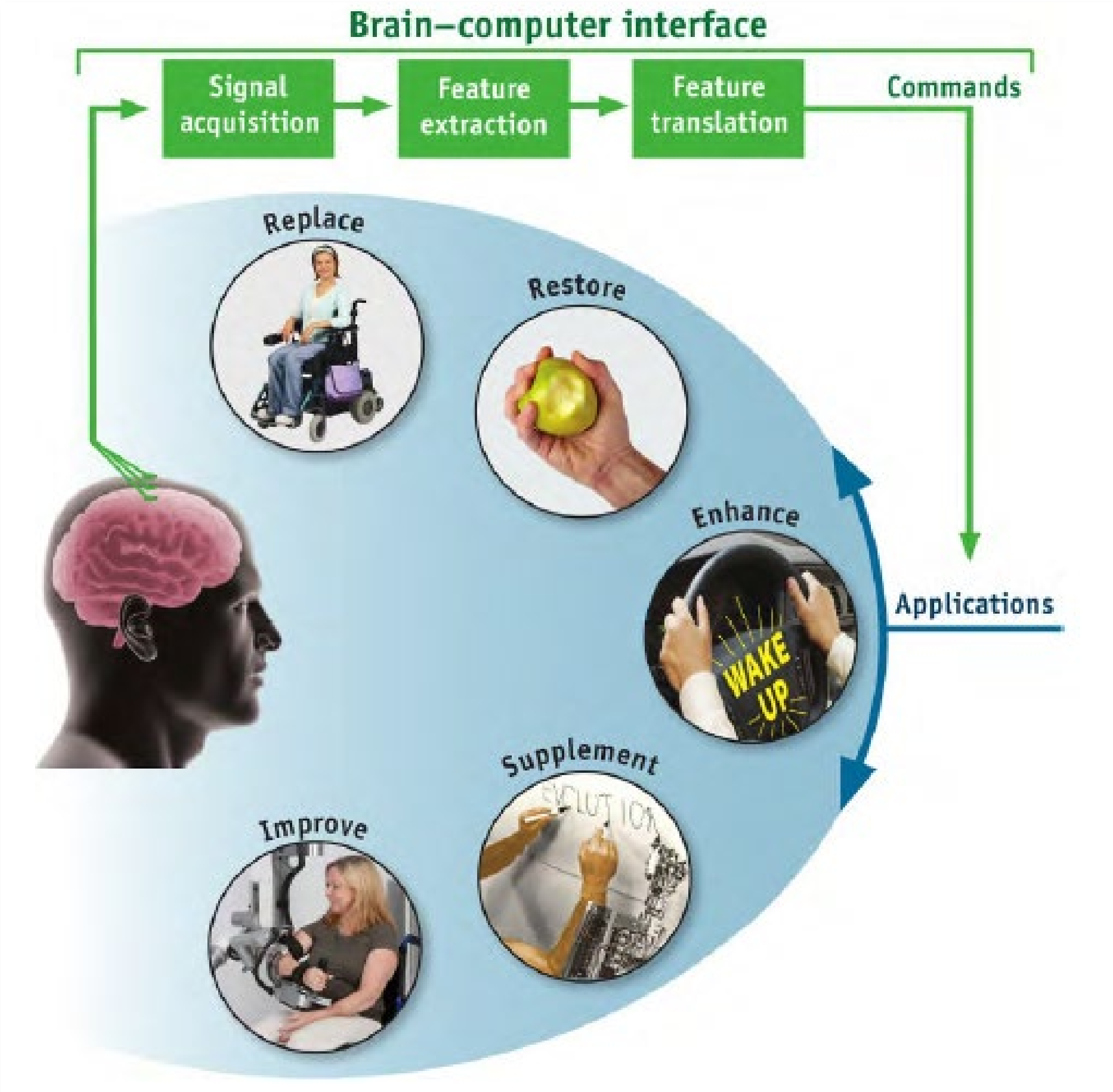

Figure 3.3 - Brain-computer Interface System. Source: Wolpaw, Wolpaw (2012).

BCIs can replace natural CNS output that has been lost as a result of injury or disease. Examples include communication and the control of a motorized wheelchair, in case of a person who has lost limb control. BCIs can restore lost natural CNS output. For example, a person who has lost bladder function due to multiple sclerosis or a person with spinal cord injury through stimulation of peripheral nerves or paralyzed muscles. BCIs can enhance natural CNS output to prevent attentional lapses of the brain and restore attention. BCIs can supplement natural CNS output. For example, to control a computer cursor or a robotic arm and hand, supplementing natural neuromuscular outputs. And finally, BCIs can improve natural CNS output. For example, stimulating muscles or controlling an orthotic device and improving arm movements. Moreover, BCIs can be used as a research tool to investigate CNS functions in clinical and non-clinical studies (Brunner et al., 2015; Wolpaw & Wolpaw, 2012).

As of the writing of this literature review, non-invasive BCI based on electrophysiological signals are the most technologically advanced, with its EEG-based approaches having resulted in a myriad of clinical applications. Individuals with neuromuscular diseases can greatly benefit from these technologies, as computers enable them to perform various tasks, such as accessing computer-based entertainment (e.g., music, movies, videos, games), communication (e.g., using the internet and speech synthesis), and effectively controlling their environments (e.g., room temperature, lights, TV). However, according to current understanding, all BCIs under development have numerous limitations, strengths, weaknesses, advantages, and disadvantages (Mak & Wolpaw, 2009).

Emerging knowledge on BCI confronts the four basic assumptions in which most of its research has been based on. The first assumption states that intended actions are fully represented in the cerebral cortex, but now it is clear that the signals recorded from a single area provide an incomplete and inconstant picture of the intended action. For the second assumption, which states that neuronal action potentials can provide the best picture of an intended action, it is still not yet clear which brain signals can best reflect an action. And the third one assumes that the best BCI is one that records action potentials and decodes them, but this question is an empirical one and it is not yet resolved. And, for the last, ongoing mutual adaptation by the BCI user and the BCI system is not very important, it has been demonstrated that BCIs allow their users to develop new skills (Wolpaw, 2010).

3.3.1.1.1 Clinical Applications of BCIs

Clinical applications offer possibilities for providing new augmentative communication and control technologies to those who are paralyzed or have other severe movement deficits like amyotrophic lateral sclerosis (ALS), cerebral palsy, brainstem stroke, spinal cord injuries, muscular dystrophies, or chronical peripheral neuropathies (Wolpaw, 2010). In fact, BCIs have been primarily conceived as a potential new therapy - as assistive technologies - to restore motor control in severely disabled patients, particularly those suffering from devastating conditions - such as the ones mentioned above, and numerous other diseases - in order to improve their communication, mobility and independence (Wolpaw et al., 2002; Lebedev & Nicolelis, 2006; Millán et al., 2010; Allison et al., 2011).

In clinical applications, primarily for communication and control, potential BCI users can be categorized into three groups: i) individuals with no detectable remaining useful muscular control, including those with Complete Locked-In Syndrome (CLIS), who may be in the terminal stage of ALS or suffer from severe cerebral palsy; ii) those who retain only very limited neuromuscular control, comprising Locked-In Syndrome (LIS) patients who are almost entirely paralyzed but possess residual voluntary movements such as eye movement, eye blinks, or lip twitches; and iii) people who still maintain substantial neuromuscular control, including able-bodied individuals and those with significant neuromuscular control, particularly regarding speech and/or hand control. As of 2010, BCIs have little to offer the first and third groups, as the former appears to be BCI-resistant, and the latter can be better assisted through alternative interfaces. Additionally, BCIs can be utilized for some individuals suffering from neurological disorders such as schizophrenia or depression (Nicolas-Alonso & Gomez-Gil, 2012; Mak & Wolpaw, 2009). According to Mak & Wolpaw (2009), only the second group—those patients who are almost entirely paralyzed and with Locked-in Syndrome, having minimal neuromuscular capacity—could benefit from BCIs, given the current state of the technology.

Communication for people who are “locked-in” still represents the most pressing area in need of intervention with BCI technology (Mak & Wolpaw, 2009; Wolpaw & Wolpaw, 2012). For Millán et al. (2010) communication functions consist in multiple tasks that involves patients using internet to sending/receiving emails, chatting, using VoIP phones and surfing the web, interacting with computers by only using their brain. BCI applications for communication deal with severe communication disabilities resulting from neurological diseases and applications encompasses a devices that typically displays a virtual keyboard on screen, where the user selects a letter from the alphabet by means of a BCI. The distinguishing element in each approach is usually the BCI and the type of control signal (Nicolas-Alonso & Gomez-Gil, 2012).

However, it is possible that such a technology will not be able to fulfill its ultimate goal of providing these people with an efficient means of communication. Recent research reports failures of completely locked-in patients who begin to learn to achieve BCI communication after becoming locked-in. A possible explanation is the hypothesis that the person with Locked-in Syndrome experiences a cessation or extinction of output-directed and goal-oriented thoughts, thus rendering impossible the operant learning and control of psychological functions. And in case this hypothesis is proven right, will it imply in BCI dropping out what once was one of its main goals? (Birbaumer, 2006b). Moreover, the question of BCI illiteracy continues to be a mjor challenge for BCI research. BCI illiteracy (when users cannot use any particular BCI system, not being able to learn how to operate a BCI) (Allison & Neuper, 2010) is a common issue. Not every person will be able to use a BCI effectively. Training may be tiring and extremely extensive, with the real possibility of the BCI not working at all.

Wolpaw & Wolpaw (2012) highlights that the success of BCI development for clinical applications will depend on new knowledge and new understandings about how the brain works, and the practical usefulness of BCIs will depend in large measure on the answers to critical questions and results of experimental investigation. Current and future perspectives also include the development of BCIs in other areas and with different purposes, such as in entertainment, and to improve human performance, as covered by the Human Enhancement Report (Coenen et al, 2009).

The European Commission (EC) project named "The Future of Brain/Neural Computer Interaction: Horizon 2020" (BNCI H2020) is one of the relevant projects that could shed some light into the BCI community. The project was not only aligned with the approach of this research, but was also the largest and most comprehensive to be funded by the EC on BCIs up until that point, and its objective was to develop "a roadmap for the next decade and beyond, encouraging discussion and collaboration within the BCI community, fostering communication with the general public, and the foundation of an international BCI Society" (Brunner et al., 2015). According to the project, as the field of BCIs rapidly expands, some challenges have to be faced in order to better organize the community and ensure that progress is not hindered by lack of infrastructure, of communication between key stakeholders, ambiguous terminologies or unclear roadmaps of the research field. The project listed some challenges for the BCI field:

- There are no major coordination efforts in place to ensure efficient coordination and collaboration among key stakeholders.
- There is no clear identification which are the relevant disciplines and stakeholders.
- The BCI community has not agreed upon a common terminology. There are no gold standards on how to evaluate BCI performance and there are no guidelines on how to properly deal with ethical, legal and societal issues.
- There is no central open database with curated benchmark data sets, which allows comparisons between signal processing and machine learning algorithms across the research of distinct groups.
- There is no adequate communication with people outside the BCI community. For example, people working in fields such as assistive technologies do not even know that BCIs exist and how relevant they can be to their fields.
- There is no clear identification about which are the most promising future directions.

In response to these concerns the BCI society[3] was created being formally established on March 13, 2015, as an international organization legally based in the Netherlands. The BCI Society is a member driven organization with 300+ members located in over 24 countries around the world, which represents the broad range of disciplines essential to BCI research and development, including neuroscience, engineering, computer science, mathematics, psychology, clinical neurology and rehabilitation, biomedical ethics, and others. Members are involved in the many potential uses of BCI technology including restoring communication and control to people who are paralyzed; improving rehabilitation for people with strokes and other neuromuscular disabilities; addressing important basic science questions about brain function; and enhancing or supplementing normal brain function. And one of the purposes of the Society is organizing meetings, collaborate with other BCI-related organizations and individuals, share research and information providing information and advice to scientific, technical, clinical organizations, governmental or regulatory entities, scientific or popular media and the general

[3] http://bcisociety.org

public. It is another crucial step for the BCI area to envision overcoming mutual challenges among stakeholders and continue on a path towards sustainable growth.

3.3.1.1.2 The Role of Social, Ethical, Legal and Philosophical Aspects in the BCI field

Scientific and technological breakthroughs are poised to transform our human identity, leading us to redefine our moral and ethical boundaries (WEF, 2016). Neuroethical debates have already identified several topics of importance to BCI research, development and dissemination. However, although some of the ethical issues related to this technology still have not been properly addressed in the field, they are well known in medical research and the medical device industry. Rules and regulations in medicine are in place for decades now, having been first influenced by the Hippocratic Oath. The four principles of biomedical ethics as outlined by Beauchamp and Childress (2013) have become the cornerstones of biomedical ethics in healthcare practice, in the modern age, as follows:

- Respect for autonomy: the patient has the right to choose or refuse the treatment.
- Beneficence: all actions (of the practitioner) should be in the best interest of the patient.
- Non-Maleficence: no harm should be caused; i.e. more benefit than harm should come out of any treatment.
- Justice: fairness and equality should be the driving forces on decisions who gets treated when health resources are scarce.

Furthermore, there is also a category of questions that are relatively unique to BCIs. Although brain–machine interfacing devices present situations which might seem new and unfamiliar, most of the ethical questions raised pose few new challenges. But what if these devices actually make changes in the brain? Melding brain and machine makes the latter an integral part of the individual. This could be considered a challenge to our notions of personhood and moral agency (Hildt, 2010; Haselager et al., 2009; Clausen, 2009).

Vlek at al, (2012) believes that, in the future, BCI has the potential to impact not only individual users but also society as a whole. Research and development of future BCI applications such as BCI computer games, neuroprostheses, online cognitive research, neuromarketing, or cognitive enhancement inevitably raise ethical and societal challenges, and a public debate on rights and restrictions is to be expected.

Haselager et al. (2009) states that BCIs may cause concern about its potential philosophical, ethical and societal consequences. They consider that neuroethics brings too many different topics that could potentially be relevant to BCI: mind-reading and privacy; mind-control and the suppression/stimulation of (un)wanted impulses; personhood and the ownership of mind; elective enhancement and social stratification, to name but a few. They also explore the difficulties involved in acquiring informed consent from locked-in patients. According to them, there are some points that have substantial impact on acquiring informed consent: sharing moral responsibility in BCI teams, and maintaining effective communication with the media.

Glannon (2014) when discussing some ethical issues of BCIs, particularly in the case of individuals with severe paralysis, in which the cognitive capacity was impaired by some lesion in the central nervous system, such individuals may have difficulties in translating their thoughts and actions or even not manage to do it. This can cause anguish and frustration in some subjects when they realize the difficulty of recovering some degree of motor control. Therefore, the management of patients' and caregivers' expectations about the recovery of motor function with the use of a BCI becomes very important, since, many times, the results may not be reasonable due to the patient's cognitive challenges in operating the system, which can cause psychological damage when the subject's desires and intentions to produce actions are not fulfilled. Furthermore, the use of a BCI for communication in neurologically compromised patients raises the question of whether their responses would be evidence of the ability to make informed decisions.

Other ethical considerations for BCI technologies are related to its contribution to change some of the central concepts and categories used by humans to understand and observe the set of values, norms and rules that involve the human moral status. The blurring distinction between body and mind, man and machine becomes increasingly difficult to assess, especially when the limits of the human body are challenged, raising questions concerning free will, moral responsibility and the actual distribution and attribution of responsibility (Schermer, 2009). Ethical considerations demand an implied knowledge of likely risks as well as protection against them. Side effects on the alteration of brain activity, like mood changes, memory retention alterations or personality changes that could occur in the long term - these are some of the issues to be considered (McCullagh et al., 2013).

Moreover, Hildt (2010) discusses about various ethical issues, such as the complicated process of obtaining informed consent from people with Locked-in and Complete Locked-in Syndrome, user control (which involves the direct cooperation and mutual dependence between a person and a technical system), situations that could result in difficulties navigating the system. Other issues that hinder the adoption of BCIs include the number of training sessions required to achieve adequate skills, when and if these skills are actually attainable for the specific person/patient (issues with neuroplasticity, the ability of the brain to adapt and BCI illiteracy, when some people are not able to use BCI despite continuous training), dysfunctions and failures that could have direct negative impact on the user, side effects that may include health problems and unforeseen modifications in physical or mental traits, questions related to privacy, autonomy, that can be easily identified. Further issues may be less obvious or concrete, as for example the aforementioned agency, or "mind reading", such as when background noise (other brain waves other than the ones inteded for a specific action) are recorded by the elctrodes and then could be used without consent and/or knowledge of the person or patient, moral and philosophical issues such as the blurring distinction between man and machine, the cyborg concept, possibilities for reinterpreting and reconceptualizing categories that humanity have used to understand life.

Neural plasticity is a subject that warrants further exploration. This refers to the capacity of our nervous system to restructure its organization, functionality and connections in response to training. Neural plasticity is task-specific and highly time-sensitive, being significantly influenced by environmental factors, motivation and attention.

BCIs have already demonstrated their ability to induce neural plasticity by providing feedback on intended movements and restoring the "action-perception coupling." The process of learning to operate a BCI device relies on the presence of neural plasticity and is thought to adhere to similar principles as traditional learning processes (Daly & Wolpaw, 2008). Numerous studies have indicated that we can not only reorganize brain connections but also modulate our brain. However, it is important to note that not all plasticity is necessarily advantageous. Instances of maladaptive plasticity following a stroke can include abnormal and non-functional movements, such as syncinesia, chronic shoulder pain, or new onset epilepsy. Consequently, the objective of neurorehabilitation is to simultaneously enhance behavior by promoting adaptive changes in dysfunctional neuronal systems while avoiding maladaptive plasticity through meticulously designed exercises combined with neurofeedback.

Another important point is the concept of the intimate-technological revolution, a term coined by the Rathenau Institute, in the Netherlands. The question is “what is the impact of technology on our lives?”. Technology is becoming increasingly intimate. Intimate technology refers to the idea that technology may be colonizing our bodies, influencing our behavior and redefining our identity. Technology therefore becomes a part of our bodies and identities and when studying the human condition. It is important to consider that human beings are more and more seen as machines, which could be then taken apart for maintenance and repair – and which could also be upgraded or otherwise improved. "intimate technology" is a contradiction in terms: "intimacy represents a human sense of confidentiality and feeling of being connected, and that concept can only conflict with technology, a term that refers to lifeless devices put together with screws and bolts" (Vorstenbosch, 2014)[4]. Moreover, machines become more and more humanoid – or at least engineers have the ambition to integrate human traits, so that they are social, emotional and perhaps even moral and loving creatures, and the interactions between people change, precisely because machines are increasingly penetrating our privacy and social life.

According to Nijboer et al. (2013) the emerging neuroethical debate has identified 17 important topics. The the main points identified are:

1) obtaining informed consent from people who have difficulty communicating;
2) risk/benefit analysis;
3) shared responsibility of BCI teams;
4) the consequences of BCI technology for the quality of life of patients and their families;
5) side-effects,
6) personal responsibility and its possible constraints;
7) issues concerning personality and personhood and its possible alteration;
8) therapeutic applications, including risks of excessive use;

[4] Jan Vorstenbosch In https://nextnature.net/story/2015/intimate-technology

9) questions of research ethics that arise when progressing from animal experimentation to application in human subjects;
10) mind-reading and privacy;
11) mind-control;
12) selective enhancement and social stratification;
13) human dignity;
14) mental integrity;
15) bodily integrity;
16) regulating safety; and,
17) communication to the media.

This initiative was important to initiate bridging the gap between BCI research community and neuroethicists and to help in structuring the growing public debate in BCI. Therefore, these results actually highlight even more the importance of the ethical discussion and its introduction as a regular part of research and development in BCI.

As suggested by Nijboer et al. (2013), Hildt (2010) the results from this initial debate do not seem to be fully integrated into BCI research, and researchers not have fully yet developed well-informed opinions about ethical issues, and, on the other hand, ethicists may not have enough knowledge about neurotechnologies and had difficulties to understand the ethical issues. The fact is that the impacts and consequences of BCIs are still not clearly understood. Ethically, philosophically or morally speaking, many doubts have arisen concerning the potential for these technologies to change society. BCI comes in as a particularly interesting and relevant emerging technology given it presents ethical issues which could eventually confront and modify core concepts and values about what it means to be human. This highlights the importance of understanding how the BCI community has been conducting an assessment of the field, as well as how these ethical debates are being introduced.

This is exactly the importance of RRI for the purpose for this study as mentioned before on Chapter 2. The technology assessment of BCI technology as an emerging technology requires an integration of the social, ethical,legal and philosophical issues of the field, involving these issues directly to a proposed shaping of innovation, inviting actors to reflect with responsibility and attention on the needs of society, sharing responsibilities for the addressing of such topics. It is RRI in the contexto of TA that adds this reflexivity to the design of the technology, giving new shape to innovation processes and to technology governance, making the distribution of responsibility among the involved actors as transparent as possible, and finally supporting "constructive paths" of the co-evolution of technology and the regulative frameworks of society.

3.4 Interviews

The structured but open ended interview elaborated allowed interviewees to express their independent points of view, responding according to their own understanding of each question. This approach allows us to obtain information that can be compared and at the same time open up the possibility for useful new information about the subject we are investigating to be surfaced. The problem is that is not possible generalize or affirm that what has been stated is true for everyone. But the provided information helps detecting how a certain fact is received and sometimes even processed, which could be considered a so-called climate of opinion, or the perceived majority of opinions of a given social group at a given time (Baltatescu, 2014). This method belongs to a family of the expertise-based methods, especially because it relies on the skill and knowledge of individuals in a particular area or subject.

In addition, and as one of its greatest advantages, the interview constitutes one of the most pleasant phases of any investigation; that of discovery, of the ideas that arise and of the most enriching human contacts for the researcher. In this case, interviews were conducted with the researchers specialized in the field of research that is connected to the research topic, or privileged witnesses, which means people who, due to their position, their actions or their responsibilities, have extensive knowledge of the problem.

According to the methodology first proposed, the next step following the Literature Review, is to acquire knowledge on the topic of BCIs as well as its community, through interaction with different stakeholder groups to get to know their points of view on the topics related to the strategic focus, in order to feed the interviews. Taking into consideration budgetary constraints, as mentioned earlier, the search for a location where this interaction and further information gathering could take place would have to be focused on Europe, where the research was based at. The aforementioned BNCI H2020 project stood out as a suitable starting point for this search., having thus being considered as the best focus point for the next steps.

This led to the attendance at the projects' "Retreat" event, whose aim was to "bring together key stakeholders in the BCI field" so that they could "discuss the future of BNCI". From the information obtained and the networking done, it was then decided that the interviews would be conducted at the next main event: the 6th International Brain-Computer Interface Conference 2014: The Future of Brain-Computer Interaction: Basics, Shortcomings, Users. The conference was a BCI specific event, with worldwide international participation, related to the BNCI H2020 project and, as with the retreat, was within distance for the available budget.

In this event, interviews were carried out and reached eleven participants, classified according to four stakeholder groups within the BCI landscape, namely Hard Science, Healthcare, Social and Industry, all of which were further elaborated for the survey. Moreover, they were classified according to self-reporting levels of knowledge, namely Knowledgeble and Expert, also further developed for the survey. Each of them received and signed a consent form, available for consultation on Annex B. They represent eleven institutions, from ten countries in four continents, being three from the Healthcare group, five from the Hard Science group, two from the Industry group and one from the Social group.

These questions were chosen considering certain current and controversial points found in the literature review and the retreat event at the time. The objective here was to hear the opinions of the stakeholder group representatives individually, going beyond the questions posed in the scientific articles, to verify, in practice, what their opinions were, seeking to identify the main points to be deeper discussed in participatory arenas.

Starting from a qualitative approach, the analysis of the interviews confronted the collected responses with the knowledge from the already consolidated literature review within the thesis, seeking to identify different perspectives and potential points of consensus and dissensus amongst interviewees in order to feed the elaboration of the survey questions and collect supplemental knowledge.

The table below shows that in more detail:

Participant	Institution	Country	Classification
IT1	Fondazione Santa Lucia	Italy	Healthcare
DE1	Brain Products	Germany	Industry
IT2	University of Naples Federico II	Italy	Hard Science
NL1	University Medical Center of Utrecht	The Netherlands	Healthcare
JP1	University of Tsukuba	Japan	Hard Science
SW1	École Polytechnique Fédérale de Lausanne	Switzerland	Hard Science
BR1	Federal University of Espirito Santo	Brazil	Social
DN1	University of Aalborg	Denmark	Healthcare
SP1	Barcelona Digital Technological Center	Spain	Hard Science
OT1	G.tech Medical Engineering	Austria	Industry
USA1	Wadsworth Center / Albany Medical College	USA	Hard Science

Table 3.1 - Participants of the Interview. Source: Own Elaboration.

The questions posed for the interview are shown on table 3.2 below:

1. What is your opinion on whether all paralysed individuals should have equal opportunities to acess a BCI, even if they cannot give informed consent in a clear way?
2. In your point of view, do you believe that the growth and wider distribution of BCIs represents a threat to privacy and autonomy? Why?
3. At the present time, would you say that Complete Locked-in Syndrome (CLIS) patients unable to communicate using BCIs represent a constraint to the development of the field? Please elaborate.
4. In your opinion will non-invasive EEG BCIs for clinical applications overcome technical and ethical issues and become broadly available to ensure communication and control to those with Locked-in and Complete Locked-in Syndrome? How?

Table 3.2 - Interview's Questions. Source: Own Elaboration.

Below, excerpts of answers (without direct identification of who provided each answer) are presented for each question, with individual commentaries on the questions and posterior discussion of results found:

On question 1, concerning the topic of 'informed consent', some participants agreed that all fully or semi-paralyzed individuals should have equal opportunity to have access to BCI technology even if they are not able to give their consent.

Answers:

"I do believe that all those people should have an opportunity to have a BCI although they are not able to fully deliver informed consent."

"LIS patients should have equal opportunities to access a BCI even if in their case it is difficult to get informed consent in a clear way. So, I do believe that they should have these equal opportunities."

"Of course they should get access."

"Everybody should have access – even if they cannot give informed consent."

"Even if they don't have the capability to give informed consent, they have others who can make this decision."

"All paralyzed individuals should have equal opportunities to access a BCI independently of their wealth and country of residence. But every individual must be informed of the pros and cons of BCI. If they cannot give consent clearly they should have the chance to use a BCI."

"The individuals should have equal possibilities and their representatives caregivers, father, mother, whatever, should make their informed consent about them."

"Is needed to balance equal opportunity demands with distributive justice demands in the context of limited resources for Healthcare management (...) For this class of patients, BCI

system may represent a unique opportunity to restore some form of communication and control."

"Everybody has the right to get a BCI system if they can express their will. If a locked patient cannot express his will in a clear way he should not be provided with a BCI system (...) The patient needs to know what is going to happen to him and if he cannot be aware of things then or does not understand what is happening, he shouldn't be exposed to this because it is not in his or her benefit."

"My understanding was always that trying out BCIs with these patients would be done at an earlier stage when one still knows about their cognitive abilities or can say something about their cognitive abilities rather than having them use it at such a late stage (...) In Denmark this is specifically is very important we don't do anything without getting ethical approval and ensuring that the person can give informed consent."

"Assuming this question is concerned with BCIs that enable communication. I do not understand the question. If these individuals are presented with the opportunity to use a BCI, it is still their choice whether or not they choose to use it. Hence, my answer would be yes. A different question is whether it is ethical to use a BCI to learn about the state of a person without the person knowing or giving consent to this procedure."

For the second question, regarding the growth and distribution of BCIs representing a threat to privacy and autonomy, the opinions of respondents are also divided:

"BCIs will not represent a threath to privacy or autonomy."

"If technology is accompanied by full informative use and achievement (...) I don't think it is a threat to privacy and it is not a threat for autonomy."

"I don't think it poses a threat to privacy. And I think BCI can only increase autonomy of disabled people to the level that everybody else enjoys, so I don't see it as a restricition."

"You have to be intentional to use a BCI (...) BCI's are very difficult actually to use, all those paradigms are really tough, so, like you know, if you don't know how to use it there's no threat to privacy or autonomy."

"I don't think if we have a wider growth or wider distribution of BCI it would represent a threat to the autonomy of the patient – it should give him autonomy, so it should be helping him that he can make his own decision, communication, whatever not only being based on the help of other people."

"The growth of BCI will make the technology more practical – so far it is still much theoretical. But the investment, the research done by diferente research centers will help to improve the process for the people who need these kind of technologies – but the ones which represent some kind of a risk, autonomy, because the people involved in the world of BCIs always look to help and in this path is difficult to get lost. Privacy, the signals we acquire with BCIs don't have much content, informations on what concerns thoughts, personal things, so I don't believe there will be much problem."

"It could be a serious threat to privacy if the EEG data is stored or accessible by a third entity. It consider a violation of autonomy the use of BCI with the purpose of modifying the decision making process of individuals by recording a group of people to model the behaviour of a bigger group."

"One needs continual ethical and legal monitoring of BCI Technologies and applications from this special perspective, insofar as potential threats of this sort cannot be excluded. Potential threats to privacy are in my view more realistic."

"In terms of BCI's, there is a threat to privacy because you are recording brain activity." And with respect to the autonomy "these people that are using BCI's, these ALS patients you are talking about, I mean they are not independent and BCI's can go a certain way but they are not going to make them, question is irrelevant in the sense that they are never going to be independent, ever again."

"I don't think it is a threat to privacy and autonomy more than other technologies (...) I think the potential benefits make an important statement towards the use of this technology

for these patients that usually have, well, their ability to communicate, to express so many things that are important for an individual they are disabled."

"I do not see a concern for widespread use if BCIs are only used for communication. There will be substantial concerns to privacy and autonomy if BCIs can learn about the state of many people."

In the third question, the respondents were asked to express their opinions about the assumption whether patients with CLIS (Complete Locked-in Syndrome) who are unable to communicate using BCI's could represent a limitation for the development of the BCI field:

"I don't think so, because they appear to be unable to communicate based on actual, current BCI systems, not those that could be developed in the future, specially if you think about intracranial, or invasive, implantable recordable systems."

"CLIS patients don't constrain the development of the field. They are part of the challenge. BCI has much more applications than interfacing with CLIS patients."

"Yes, insofar as BCIs are potentially unique as enabling technology for this class of patients. Other sorts of paralyzed patients, who are still able to move some parts of their bodies, may take advantage of alternative assistive technologies for communication and control."

"I do not think it is a constraint or an obstruction in any way. I think we can already envision a way of communicating with the patient through a MRI scanner or in the future maybe another device which is not necessarily a BCI device but it is a device that allows a person to express his or her will or wish so in that way I'm confident that we can devise ways to learn about the wish of the patient and again not every patient will be able to communicate."

"I don't think so actually, you know more and more abled people are using BCI's like, ALS people are one of the categories of users, I don't think so ... I really hope that actually BCI's will be more spread for healthy people than those people will also benefit."

"It is an obstacle in our way, but it is not a big obstacle because the thing is that the field is much wider than just focusing on the complete LIS, sure this is the moment a problem, that for a CLIS where in the beginning it was a hope that BCI was the one of the only dream way to communicate with them. Is not possible to do it for the time being but I still think that further down the road we should be able to make progress on that, but it's not an obstacle for field by itself that it has hindered the development because we will grow in much more paths and roads and maybe again come back and take this path further."

"Like every science in the beginning there will be difficulties and fields in which the applications will not be completely efficient. For this type of patient it is possible that for now they will not be able to use a BCI but further ahead it is possible that in this advancement path some kind of solution will be ready for them."

"I think there are too many groups working on too many other things for there to be a constraint. I think those people working with ALS patients they have done so for so many years, they know best which direction in research to take, and I really I can't see it constraining the field."

"I think it's a fact that LIS patients and helping LIS patients with BCI or with any other technology or any other tool is one of the biggest challenges in the BCI field and in general, so, but in the other hand it's one of the best opportunities to help people who cannot be helped by traditional methods, so yes it is a constraint but this constraint I think can be, I believe that it can be overcome and well, research efforts should pave – the path for this development of BCI specific for LIS patients, maybe this seems not to be a short term objective to achieve but in the médium to long term I'm sure BCI's will be – one of the most importante BCI applications will be the application for unlocking the LIS patients."

"Patients should start as early as possible with BCI training to be prepared for CLIS. The major task is to bring the BCI systems out to patients rapidly".

"In my view, this is not a constraint. The fundamental issue is that there are only very few people with CLIS. Thus, there are no financial incentives to commercial development. In other words, BCIs for communication are essentially an orphan technology irrespective of whether or not it can actually help the few people with CLIS."

The fourth and final question concerns non-invasive BCI's going beyond technical and ethical issues to become widely used to restore communication and control in completely paralyzed (CLIS):

"I answer yes and no – meaning that for Complete Locked-in I tend to believe that we really need to go, to overcome, that the non-invasive BCI like the EEG based BCI will not fully comply with this type of population, because we cannot decode the relevant information from recordings. For non-complete Locked-in I believe non-invasive are still useful and, so they can be used, they could overcome the technical and ethical issues to become broadly available for non complete Locked-in patients."

"I think that BCI will not become broadly used by locked-in patients if we think in a worldwide manner. I see BCI used by those who can afford the cost of the technology and a skill caregiver who can take care of technical aspects of BCI. I don't think that locked-in patients will use massively BCI if they can move their eyes; an eye-tracker is more comfortable, precise and useful than a BCI tool."

"I am not sure that these issues will be overcome in the case of CLIS patients, given the presently inadequate state of (neuroscientific) knowledge about the preservation of purposeful thinking in the CLIS state. In the case of LIS states, BCI systems must be able to meet the economic competition with other assistive tecnologies that LIS patients may use. However, I am confident that a variety of non-invasive BCI systems for clinical applications in other áreas of medicine will successfully address these technical and ethical issues. For example, I believe that useful BCI clinical systems will make their way in areas such a post-stroke rehabilitation therapy or hyperactive disorder treatment."

"I don't exclude the possibility that EEG at some point will allow a patient who is CLI or severely LI or severely paralized to be able to generate clicks – my big reservation is that it is a system that still depends on a caregiver for functioning so it doesn't give complete or the possibility for complete Independence or, it is not Independence but, it doesn't ensure the patient access to a means of communication whenever they want to – they're still dependente on their environment – I am a little bit skeptical about the quality of the signals improving because I think 30 years of experience and significant research does indicate that it is not easy to improve it any further but I don't exclude that there are ways to make it possible to measure

it better but it won't get beyond a switch, soa t some point in the near future it will be outdated by implantable devices in terms of what they can do. If a patient only wants a switch then obviously the EEG system would be able to do that, and that is a serious consideration."

"Totally, totally, I think once they will be spread, and there will be among, let's say abled people, everyone will understand like you know it's one of the communication devices (...) I think more people will use it, more people will understand that this is not that an ethical problem actually I don't think BCI will ever be able to make this brain Reading, forth reading, that is not this device, so no problem (and will non-invasive be able to ensure communication and control to those in Locked-in and Complete Locked-in states). Non-invasive must be working well, because invasive is too difficult like you know, too dangerous. I really believe in non-invasive."

"For purely non-invasive techniques, just EEG techniques I don't think they will overcome these technical problems, for me it's not an ethical problem, it is a technical problem – so that we will really have a good control for the CLIS, there I think for these people we have to go to more invasiveness, could be ECoG, or something like that, must be implanted, I don't know up to now, but pure EEG based BCI, I don't think we will be able to achieve that. The problem there I se eis that specially these patients have a lot of disturbances around because of their disease, conditions and they are so much dominating, and since it is very hard to know for them, you know, which areas top lace, it will be very hard, but I think it will be a multi stage process that you use something like EEG to try to localize the fields and you maybe say ok, this is the área where if I would use motor imagery it would be the motor imagery, but we can use for everything else for this CLIS, this is the target área so we will place more like say ECoG electrodes in that área because we will have a much higher signal to noise ratio, and the problem with CLIS is it is very hard, to how do you say, to speak to them, to get them to tell us what we actually wanted that they should do,so we cannot say ok."

"It is possible, the advances in BCIs is very, very big. The ethical considerations I believe would be the biggest problem, to reach a consensus about what is allowed to be done with the signals or the distribution of them between research groups. I believe that technically it is possible that this application will be able to help people and reach the level of clinical applications, I think it is possible, there is a big development for this to be done now."

"I think technical issues, there is always going to have advances in this – broadly available – I mean it is not about technical and ethical issues, it i salso about the whole idea of the medical system changing its view on how to help these patients – because they are going to need some caregiver still – who's going top ut the cap on? - certainly the ALS patient cannot do this, how do you do this – you need somebody there – so I think these issues are real issues to deal with because in terms of technical abilities there is success in the communication abilities of patients using BCI's, non-invasive, and we have seen it over and over again – from an ethical point of view, we discussed this in the first question – becoming broadly available is not a problem with technical and ethical issues, I think it's more of a medical issue, for the medical insurance companies, etc. Those are the ones that need to be targeted to ensure that they realize this is useful fo the patients, so please make it available to them and then they will become available."

"Of course and there are already plenty of solutions available that provide great functionality that cannot be achieved with any other technology."

"There are technical and ethical issues and both are challenging, again, both are challenging, technically it's difficult and all the efforts that have been put so far fall short of the expectations, it's a big challenge technically and ethically as well, for these reasons that we have talked before, it is hard if not impossible to get a proper consente from these individuals but I think, I do believe again that both issues, technical type of issues, technical and ethical will be overcome, technical it's a question of effort, research and time as I said and whenever this is attained I'm sure it will be one of the most importante advances in BCIs, so it will be something very relevant, and from the ethical perspective it's more a question of well, putting together all the efforts like yours, a study about the ethical situation, what are the diferente possibilities and at the end providing the opportunity to these people to use the technology which is, of course ethics is always important, but, the ethics is only a, well, it is a premise. This is a premise that has to be done but the final goal is to provide this technology to these people that can really improve their quality of life and I guess that there is no, there shouldn't be -, if ethics is a restriction it would be potentially not helping or restricting LIS patients to be helped in a way that can be relevant for their lives."

"The current primary issue is financial, not technical/ethical. Separately, I do not see how non-invasive BCIs for communication can be substantially further improved to increase the user base. This would require technical improvements of completely unknown nature."

3.4.1 Analysis and Interpretation

Opinions expressed in these interviews have yielded both consensus and dissensus among a pool of stakeholders. The majority of these perspectives align with those identified in the literature review. However, it is possible to find both pertinent concerns raised by both distinct stakeholder groups, as well as contrasting opinions within the same stakeholder category.

In question 1, focusing on the issue of "informed consent", responses were split. While five participants expressed that even if patients/users could not give informed consent they should be given an opportunity to access a BCI system, two said that others could give informed consent on their behalf (e.g., family members), another two mentioned that without informed consent BCI systems should not be provided.

Two answers that brought up additional issues were particularly interesting from the ethical point of view: one stated that a BCI could be used on a patient even if they could not give informed consent but that any response from them could not be used or considered as a legal statement from the user and the other asked whether it would be ethical to use a BCI system in order to learn about the state of a person (if they have conditions of giving informed consent or not) without them knowing or without them giving previous consent to doing so.

In the second question, regarding whether the growth and wider distribution of BCIs represent a threat to privacy and autonomy, the opinions of respondents were not so divided. Eight respondents believe that the growth and widespread use of BCIs do not represent a threat to privacy and/or autonomy, whereas three believe it could be. One of these three respondents complements that provided the pros and cons of the technology would be fully disclosed to the user, it would then not be considered a threat to both autonomy and privacy.

One interesting answer brought up relevant ethical issues regarding both privacy and autonomy. On what concerns privacy, the storage and accessibility of BCI data by a third party would configure a breach of it. On the topic of autonomy, the respondent mentioned a potential threat to autonomy in the use of a BCI to model the behavior of large groups (through recording (EEG data) of groups of people) with the purpose of modifying the decision-making process of individuals. Taking into consideration recent data breaches in large corporations leaking personal data, as well as cases where social media have gathered data on its users that have been used with such manipulation intent, these are especially relevant ethical issues that configure a threat to privacy and autonomy stemming from BCIs.

In the third question, regarding whether CLIS patients (Complete Locked-in Syndrome) being unable to communicate using BCIs represented a constraint to the field, the respondents mostly shared the same opinions, agreeing that the situation described was not a constraint to the field of BCIs. Two respondents did mention that it is indeed a challenge to be overcome, but from a scientific perspective of challenges actually driving research to find solutions to problems rather than a constraint that would hinder any development of the field.

In the fourth and final question of this interview, whether a scenario where non-invasive BCI's would overcome technical and ethical issues and become widely used to restore communication and control in completely paralyzed (CLIS) patients would be possible, answers were diversified.

From those who said this goal would not be able to be achieved, four respondents have listed technical issues (software, hardware, neuroscience), three have listed financial issues (although two mentioned economic inequality and other amount of investments), two listed social issues (ethical and healthcare system issues), as constraints for achieving this goal, while two mentioned that this scenario isn't a constraint, with one of them actually stating that even though technical and ethical issues are currently challenges, these can and will be overcome through combined efforts. Invasive BCIs have been mentioned by three respondents as options to overcome these challenges, although the other two respondents mentioned they are too dangerous, still. On a related topic, most of the respondents mentioned that for cases other than CLIS patients, the situation is bound to become a reality.

This level of controversies on the theme makes it clear how important it is to debate such issues and communicate the research results well among the different stakeholders, from hard sciences to social sciences, if such controversies are to be overcome.

All these answers have been of utmost importance in elaborating the survey, which is presented next. From identifying similar opinions from distinct stakeholder groups, to dissensus within stakeholder groups, these were a relevant guideline in formulating questions and future perspectives for the clinical applications of the BCI field to be applied in the survey.

3.5 Survey

3.5.1 Elaboration of Survey

A survey is a fundamental instrument of investigative methods, capable of providing valid and reliable results, which can be subject to scrutiny through their procedures and analyses. Surveys can be employed to uncover and evaluate thoughts and opinions on a topic, whether within a broader or more specific scope. The careful selection of questions and the target audience for the questionnaire is another essential element that determines the quality of the results obtained. The survey process involves the development and implementation of a structured questionnaire directed at a representative group of the sample being studied. Therefore, it is crucial that the questions are clear and precise, formulated in a manner that minimizes the possibilities of respondents interpreting them in ways not foreseen by the author. The information gathered is then organized into quantifiable datasets for subsequent analysis.

One characteristic of emerging technologies is that occasionally new developments are in the proof-of-concept stage, with trial and error often creating and dissolving potential development pathways for the future. This presents a challenge in providing a reliable picture of plausible future developmental trajectories. In order to mitigte such limitations, the interviews and survey enable the study to concentrate on specific aspects and areas within the technology's environment. Consequently, the primary objectives of this survey was devised not only to gather stakeholders' opinions regrding ethics, morals, responsibility, and R&D, but also future perspectives for the Brain-Computer Interface (BCI) field, taking into account some of the challenges, opportunities, and threats associated with the field in general, and more specifically, BCI for clinical applications.

BCI applications aimed at restoring or replacing lost natural outputs have been the primary focus of most current BCI research and development efforts. BCI stands out as a particularly intriguing and relevant emerging technology due to the social, ethical, and philosophical questions it raises, which could eventually challenge and reshape fundamental concepts and values about what it means to be human.

The survey was carried out over a period of five months between the end of 2014 and the beginning of 2015 (October to March), and was distributed to the BCI community, encompassing social groups (including BCI users), ethical, industrial, governmental, and research stakeholders (having been presented during the "6th International Brain-Computer Interface Conference"), in addition to researchers from the fields of Applied Social Sciences (particularly Technology Assessment, Science, Technology, and Society (STS), Foresight, and Future Studies). The questionnaire was also disseminated on the project website of BNCI Horizon 2020, within the scope of the European Commission.

The survey was designed in three main sections, respectively on "Ethics, Morals and Responsibilities", "Perspectives and Challenges In Research and Development (R&D) in BCI Technologies for Clinical Applications" and "Future Visions in Brain-computer Interfaces". All statements presented were taken from various articles and documents.

In the first section, as the name of the section implies, issues related to "ethics, morals and responsibilities of BCIs" were addressed, considering that the BCI community has already started to engage in the neuroethical debate. The section presented twenty three statements taken from various articles and documents and asks the respondents to give their opinions given the context that some ethical issues have not yet been adequately understood by the BCI community and that the attribution of responsibility is a socially and politically relevant act, which influences the governance of the respective field, distributing these responsibilities between all the actors in an inter and transdisciplinary process in order to assess and prioritize the possible impacts, in the present and the future (according to the concept of RRI). It provided the following options for the answers: 1) Disagree, 2) Mostly disagree, 3) I dont know, 4) Mostly agree, and 5) Agree. If respondentes believed that more information could complement their answers, they could do so using the comment section made available for each question.

The second section, "Perspectives and Challenges in Research and Development (R&D) in BCI Technologies for Clinical Applications", sought to obtain opinions on thirteen listed topics, regarding whether the provided statements were considered opportunities (enablers) or challenges (constraints) for each topic by the respondents, based on their knowledge of the field. The section intoduced statements that, given the state of BCI technology for clinical applications at the time, represented patterns emerging from the actions and interactions among researchers, institutes, companies, and policymakers. These patterns could potentially constrain or enable future activities as the technology develops. The provided options for answering were 1) Important Enabler, 2) Enabler, 3) None, 4) Constraint, and 5) Important Constraint.

The third section, "Future Visions in Brain-computer Interfaces", is split into three parts, focused on future visions for the BCI field as well as social, ethical and philosophical topics. First respondents reflect on a few vision statements about the future of BCIs, with possible answers encompassing six possibilities: the vision actually already exists, it will become a reality within the next five years, in six to ten years, eleven to fifteen years, never, or the respondent chooses the does not know option. Then, respondents answer yes or no questions regarding different philosophical related topics. The third part invites respondents to answer an open question: could you share with us, in confidentiality, any ethical or moral dilemmas that you have encountered in your work?

3.5.2 Results and Analysis

3.5.2.1 Sample Characterization

The survey had one hundred and fifty-five respondents, out of one hundred and seventy-six total respondents. In order to categorize the respondents' profiles, the initial section of the survey requested that they provided information regarding themselves (optional): Organization, Discipline Field, Specialization area, Country, and the Professional Profile they identify with (Student - Msc/PhD, Researcher/R&D Center, Industry, Government, Consulting, others - asking them to specify the other if the option is chosen).

Regarding the profile of the respondents, the vast majority were researchers (46,5%) and PhD/Master students (35,5%), representing a total of 82% of respondents. The respondents identifying as being from Government and Consulting have been disregarded due to their numbers being statistically irrelevant for the purpose of this analysis (one respondent identified as being "Government" and two respondents identified as being "Consulting"), as can be seen below:

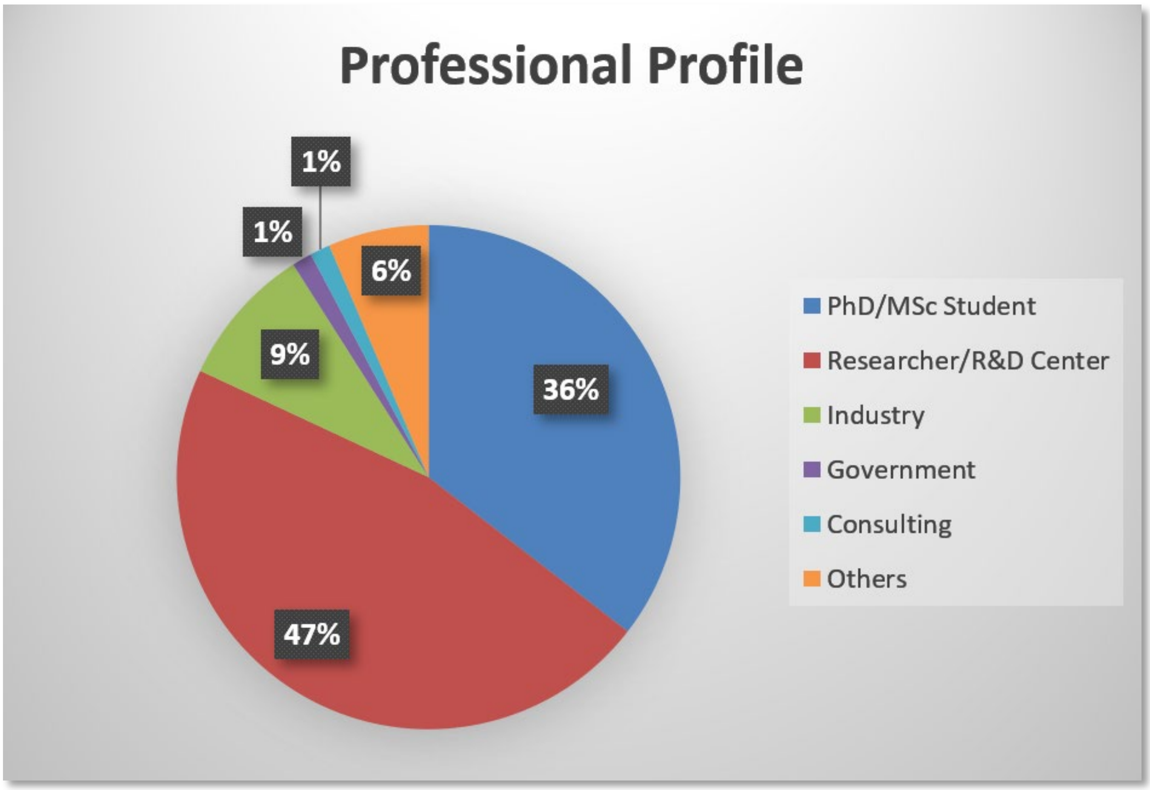

Figure 3.4 - Professional Profile of Respondents. Source: Own Elaboration.

Regarding the distribution of respondents by country, it can be observed that most of them are from the United States (28), followed by European countries, such as Germany (21) and the UK (14), while a large number of them (27) come from other countries, albeit in lower numbers, with 12 countries represented by one respondent, three countries represented by two respondents and another three countries represented by three respondents each for a total of 18 numbers within the "others" category.

The figure below illustrates it:

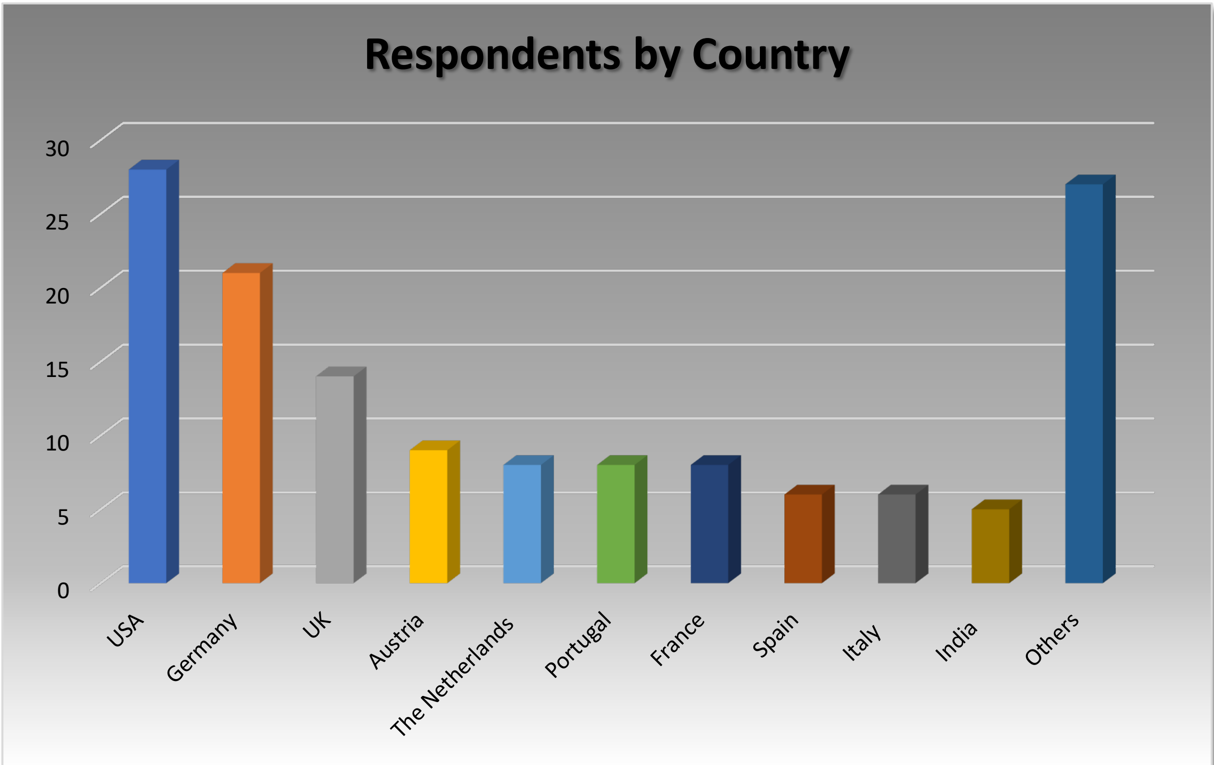

Figure 3.5 - Distribution of Respondents by Country. Source: Own Elaboration.

For a better visualization of how the regions are distributed amongst respondents, a macro level representing their distribution by continents is shown on the next page:

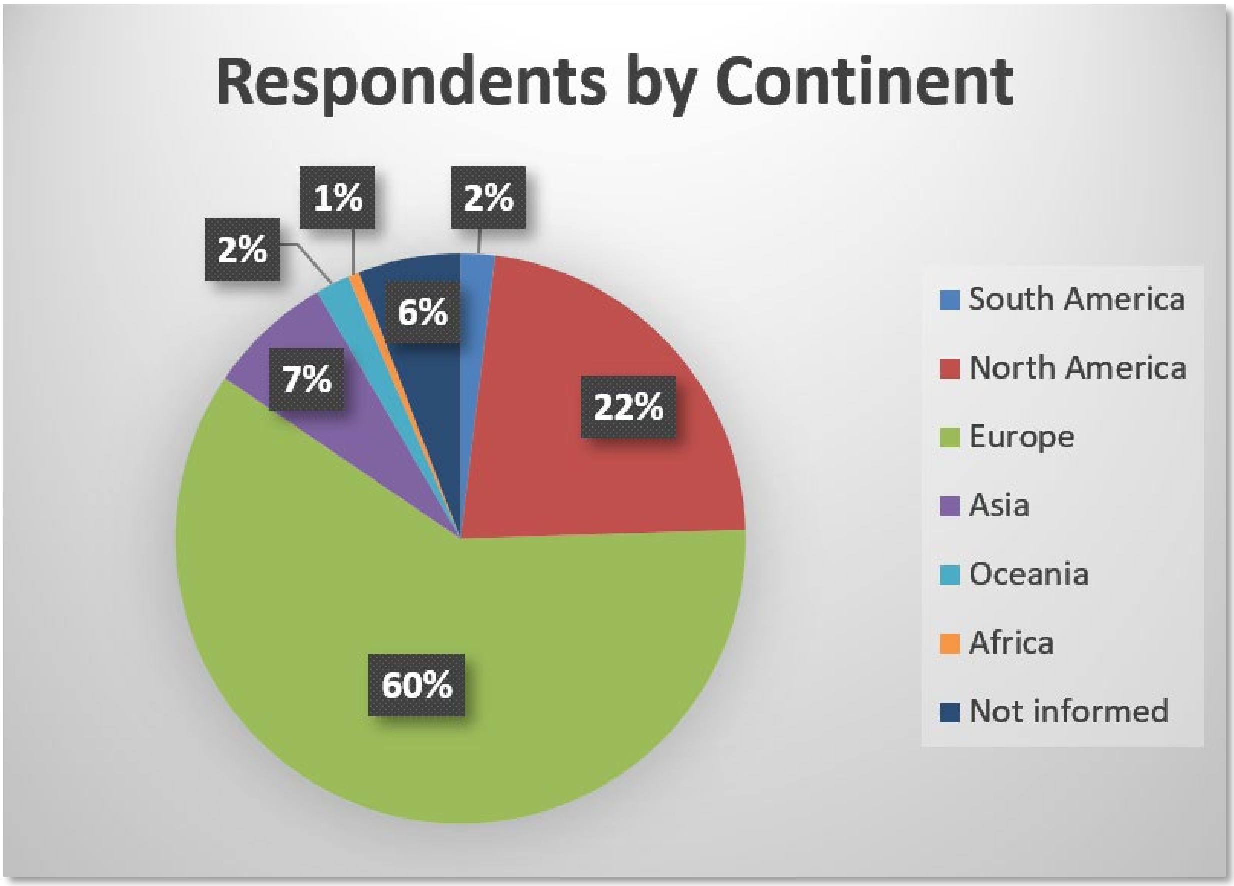

Figure 3.6 - Respondents by Continent. Source: Own Elaboration.

Respondents were also asked about their level of knowledge on the subject, providing five classifications, as seen on the next page:

Level of Knowledge
NOT FAMILIAR: you do not know anything about the topic.
CASUALLY ACQUAINTED: you have read or heard about the topic in the media or have maintained eventual relations with groups of interest regarding the subject.
FAMILIAR: you know most of the arguments for and against issues surrounding the technology; you have read about it, and you have formed opinions about it.
KNOWLEDGEABLE: you are in the process of becoming an expert, but still have to work more to achieve mastery on the topic, or you work in a neighboring field and occasionally draw up upon or contribute to the development of this topic.
EXPERT: you consider yourself a part of the community of people who currently dedicate themselves to the topic.

Table 3.3 - Level of Knowledge Classification. Source: Own Elaboration.

According to the level of knowledge, the distribution of respondents shows that ninety-four respondents declared themselves "knowledgeable" and "experts" on BCIs, followed by thirty-five respondents who declared being "familiar" with the topic. Finally, twenty-six respondents declared being "casually acquainted" and "not familiar" with the topic. On the next page, the percentages of this classification can be visualized:

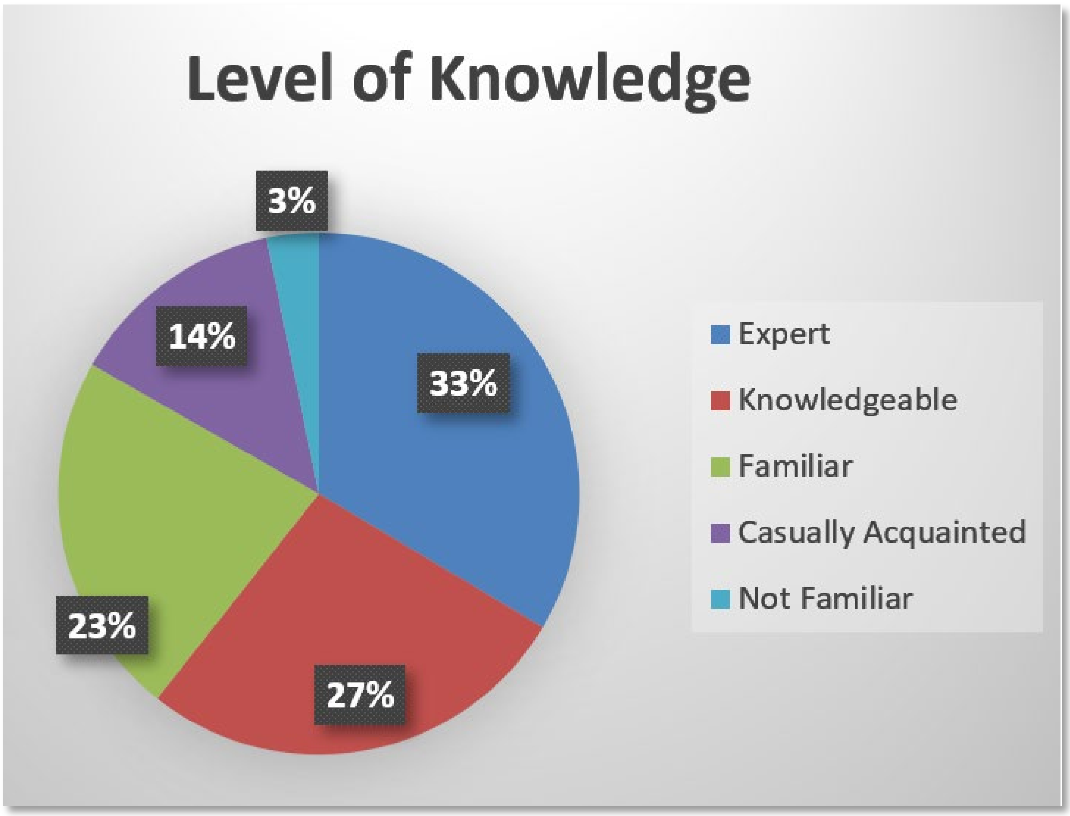

Figure 3.7 - Level of Knowledge on the Subject by Respondents. Source: Own Elaboration.

The level of knowledge is also shown by self identification of Professional Profile:

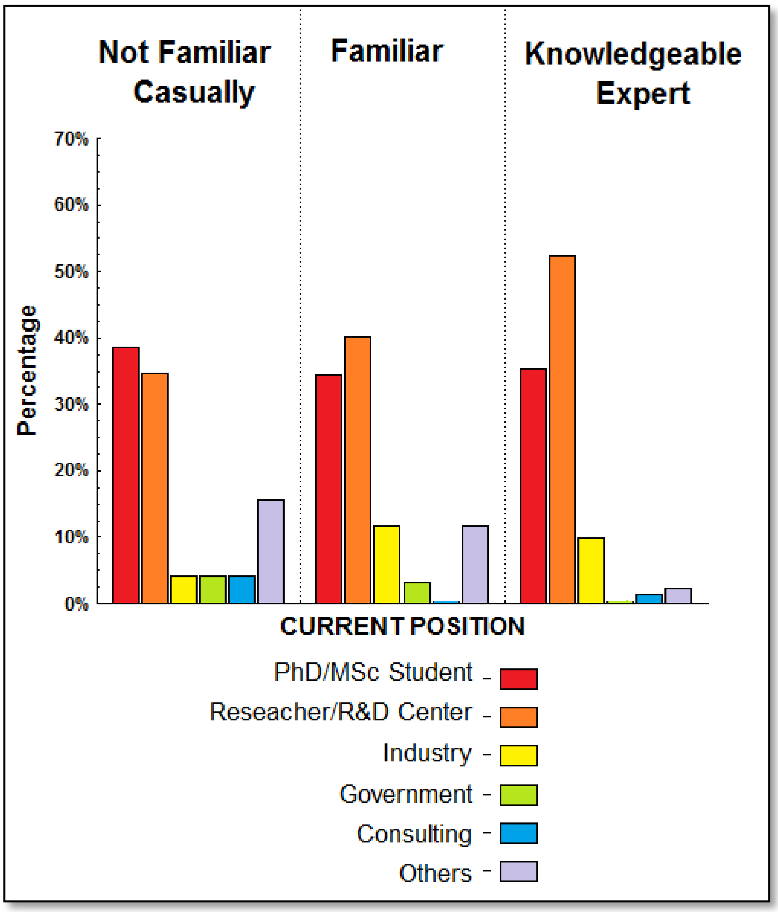

Figure 3.8 - Distribution of Respondents by Knowledge Level according to Professional Profile. Source: Own Elaboration.

Respondents who did not identify themselves as belonging to any of the areas or related areas, or who did not provide information on their specific areas within the available fields (disciplinary field, specialization, institutional affiliation) were classified as "Others", therefore being excluded from this analysis. Considering that the respondents in this classification were few, and due to the lack of additional information, this group was considered irrelevant for this specific statistical validation.

In order to identify potential discrepancies amongst actors, taking into consideration that the BCI field is highly multidisciplinary and composed by the contribution of professionals from various fields of knowledge, as well as the levels of knowledge being essentially uniform among different Professional Profiles, the respondents were further classified by Stakeholder Group.

The following groups were then defined:

The Hard Science group: includes all the respondents who declared themselves to be from areas of computer science; neuroengineering; electrical engineering; electronic engineering; brain-computer interfaces; equipment for brain-computer interfaces; medical engineering; machine learning; signals processing; physics; mathematics, among others.

The Healthcare group: It encompasses all the respondents who declared themselves to be from areas of medicine; psychology; neuropsychology; nursing; neuroscience; cognitive neuroscience; rehabilitation, among others.

The Social group: It includes all the respondents who declared themselves to be from the areas of ethics; philosophy; sociology; technology assessment; foresight; innovation analysis; education; bioethics; science, technology and society (STS), among others.

The Industry Group: It includes all the respondents who declared themselves to be from industries related to the BCIs.

For a better visualization, the following figure on the next page illustrates it:

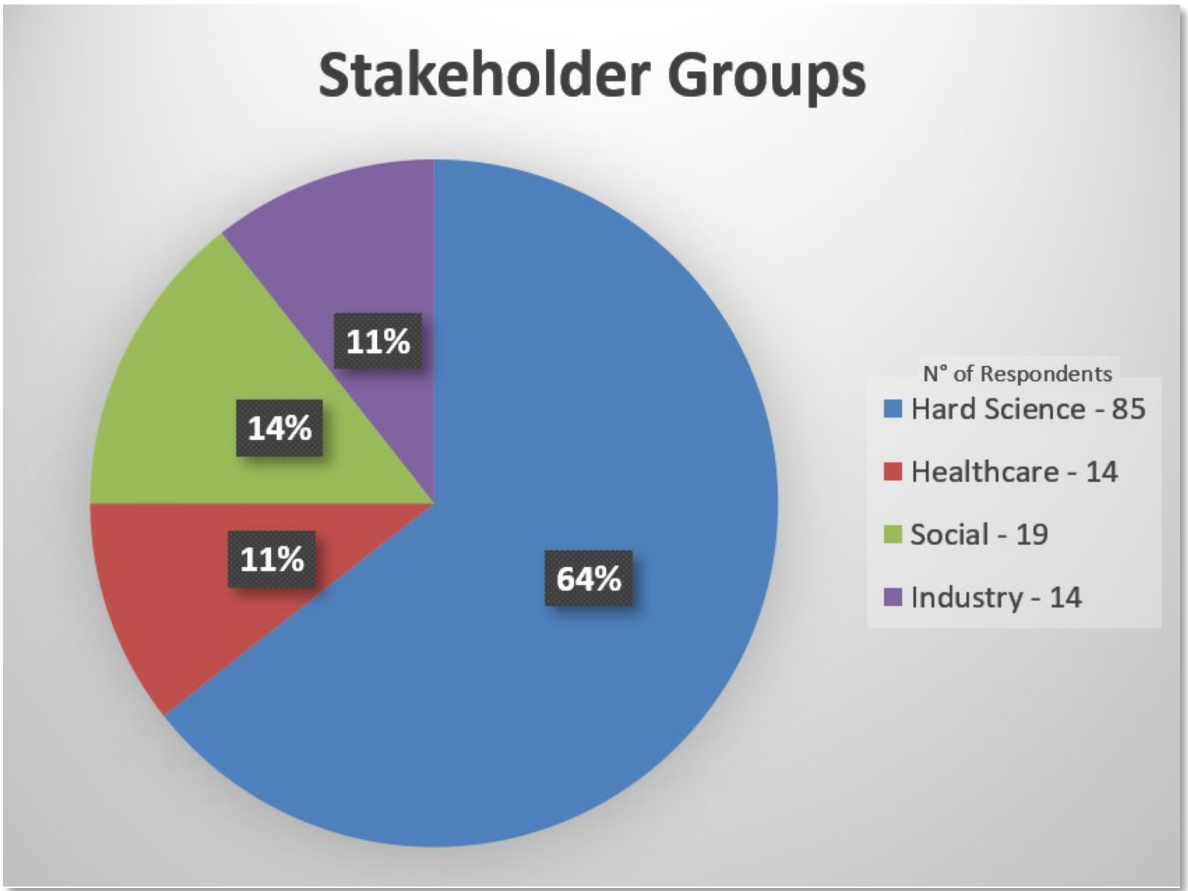

Figure 3.9 - Distribution of Respondents by Stakeholder Group Source: Own Elaboration.

3.5.2.2 Survey Sections

The analysis was then carried out focusing on the points of consensus and controversy amongst different actors. Identifying their positions on each presented topic allows for an understanding of where they stand so that potential future development pathways can then be visualized.

3.5.2.2.1 Section 1

Section 1, titled "About Ethics, Morals, and Responsibilities", comprises twenty-three questions designed to collect perspectives on social, ethical, legal, and philosophical aspects of the field.

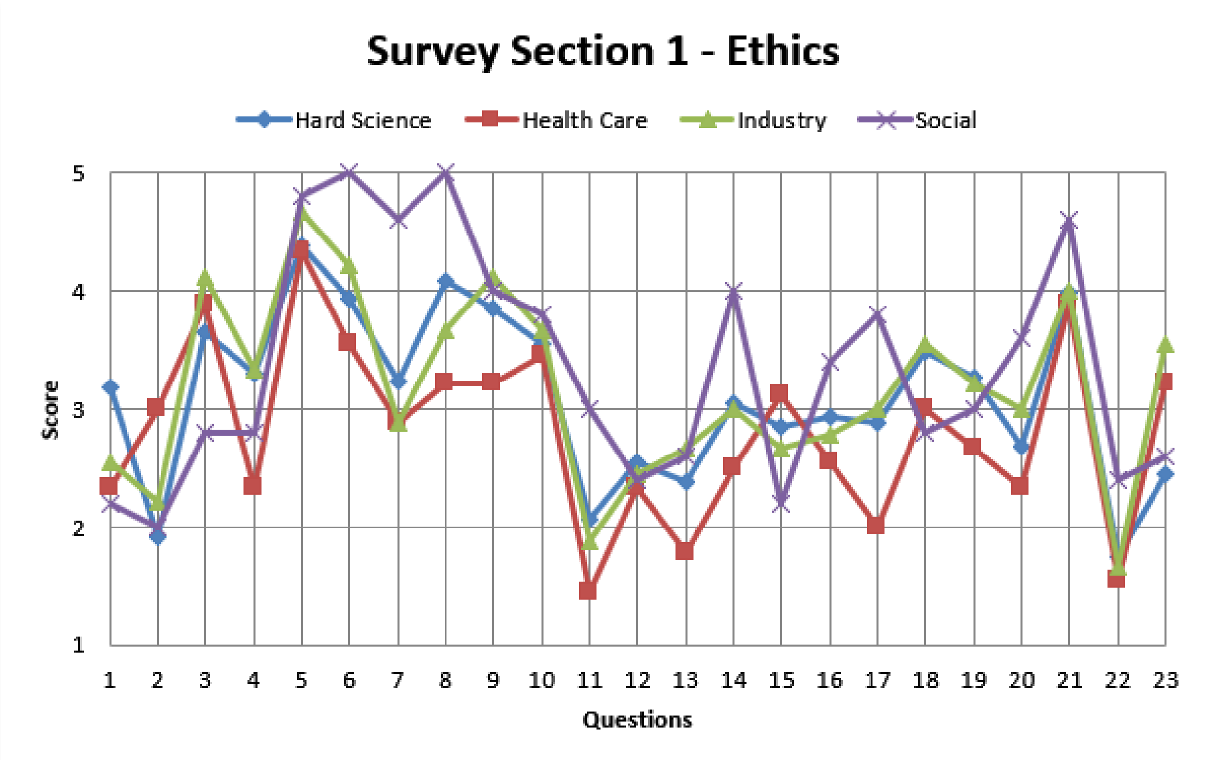

Figure 3.10 - Distribution of Answers Across Different Stakeholder Groups on Section 1. Source: Own Elaboration.

The figure above displays the mean answer from each stakeholder group for every question on this section. The graphic highlights points of consensus and controversy among stakeholder groups, as well as issues to which respondents might not yet have well-informed opinions, either due to insufficient knowledge or because the issues are not yet clearly understood, as previously mentioned in the Literature Review. Questions 05, 07, 17, 21 and 23 stand out as the most relevant ones in this sense. While items 05 and 21 show agreement amongst stakeholders, and items 17 and 23 show disagreement, item 07 exhibits a situation where stakeholders have not yet formed an opinion. On the next page, these questions are presented in detail, with some relevant anonymous comments from the respondents included:

- CONSENSUS

Q 05: To ensure that users keep the consent or want to halt the experiment at any time if desired, it is important to regularly perform a consent procedure.

This question had 152 respondents, with 87.5% of respondents agreeing with this statement (agree: 50.7% + mostly agree: 36.8%). Only 5.3% of respondents showed disagreement (disagree: 0.7% + mostly disagree: 4.6%), whereas 7.2% declared "Don't Know" regarding the question. Below the answers are displayed according to Stakeholder Group:

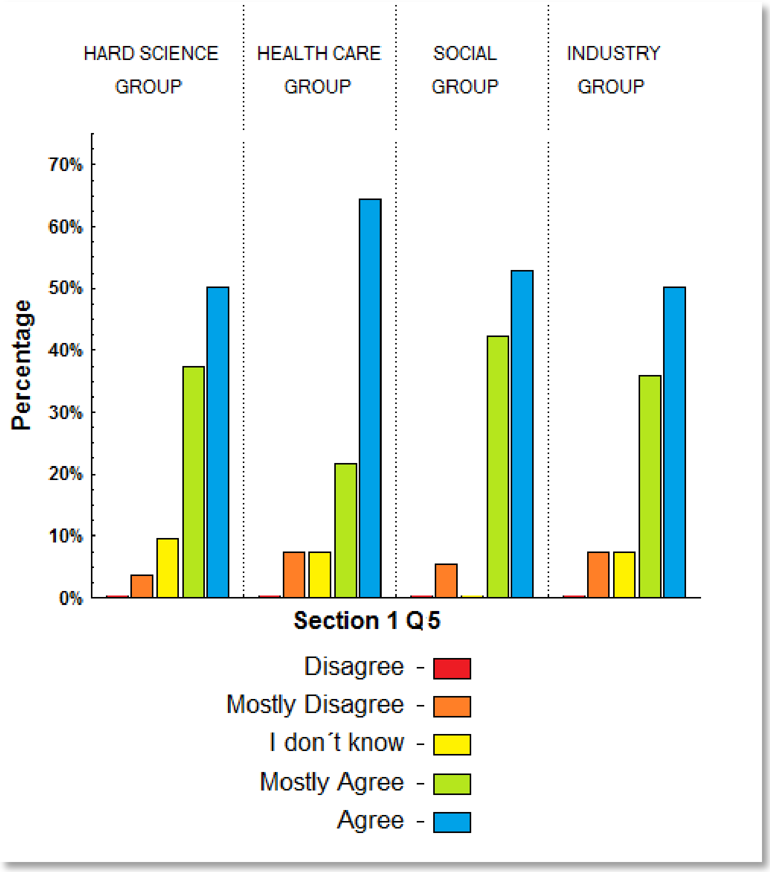

Figure 3.11 - Answers to question 05 classified by stakeholder group. Source: Own Elaboration.

It is possible to observe how the majority of respondents across the stakeholder groups agree that users have control over their consenting for any procedures they are submitted to, being able to halt the procedures at any time, if they wish to do so., thus highlighting the importance of healthcare practitioners/researchers regularly performing consent procedures with the users.

Selected comments from the open section:

- “While it needs to be clear to participants that they can halt at any time (and still receive compensation) we know that frequently making checks like this have the potential to disrupt the control of the experiment”.

- “This process must not become overly painful for the subject, but the rights and liberty of the subject must prevail”.

- “Informed consent is a dynamic process”.

Q 21: There are moral and philosophical questions when considering the blurring distinction between man and machine and the idea of the cyborg.

This question had 153 respondents, with 77.1% of respondents agreeing with this statement (agree: 37.9% + mostly agree: 39.2%). However, 11.8% of respondents showed disagreement (disagree: 0.7% + mostly disagree: 4.6%), and 11.1% declared "Don't Know" regarding the question. On the next page, the answers are displayed according to Stakeholder Group:

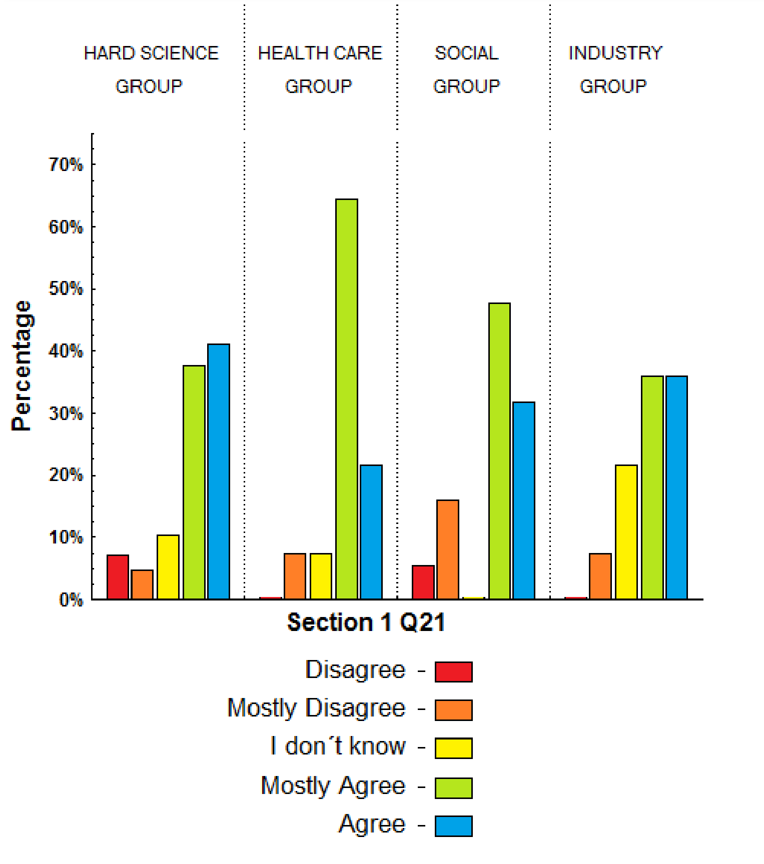

Figure 3.12 - Answers to question 21 classified by stakeholder group.
Source: Own Elaboration.

It is possible to observe how the majority of respondents across the stakeholder groups agree that there are moral and philosophical questions when considering the blurring distinction between man and machine and the idea of the cyborg, thus highlighting the importance of discussions and further debate on this topic, however potentially disrupting it may be.

Selected comments from the open section:

- “People should have choice and never be coerced or blocked. But I worry about a tipping point where there is indirect social coercion. Like once you could choose not to carry a mobile with no stigma, but now you would be a real oddity. I hope that people don’t do irreversible things because of peer pressure.”

- “There are ethical and moral questions. Moral relates to group beliefs, but ethical beliefs are personal.”

- “In my opinion among the most important questions resides on the definition of voluntary actions when these actions are jointly performed by man and machine (in particular, when the later has increasing autonomy). Another is the fact the potential enhancement of human capabilities (through melding with machines) may further increase social inequality depending on who has access to such technologies.”

  - DISSENSUS

Q 17. BCI can induce changes in cognitive capacities, psychological continuity or personal identities, which challenge the capacity of autonomous decision making.

This question had 152 respondents, with 35.5% of respondents (agree: 9.2% + mostly agree: 26.3%) agreeing with the statement. However, 38.2% of respondents (disagree: 9.9% + mostly disagree: 28.3%) stated that they disagree. It is worth noting that 26.3% of respondents declared they were unable to provide an opinion on the matter at hand. Thus, in the overall sample, it can be inferred that there is no consensus on this issue within the surveyed community. On the next page, the answers are displayed according to Stakeholder Group:

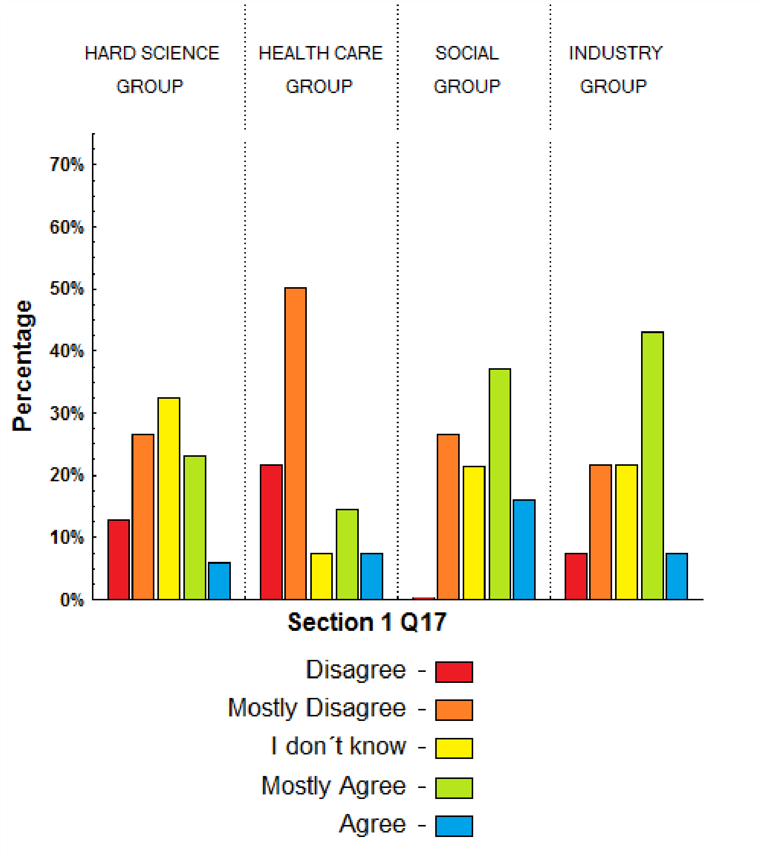

Figure 3.13 - Answers to question 17 classified by stakeholder group.
Source: Own Elaboration.

It is possible to observe that this is still a controversial issue, as the responses vary across all stakeholder groups, with no single answer being predominant, denoting dissensus on what concerns BCIs being able to induce changes in cognitive capacities, psychological continuity or personal identities, challenging the capacity of autonomous decision making. In the hard science group opinions vary with a predominance of "I don't know", followed by "mostly disagree" and "mostly agree". In the healthcare group, the majority lean towards "mostly disagree", followed by "disagree", while in the social group, the majority favor "mostly agree", closely followed by "mostly disagree" and "I don't know". In the industry group, the predominant view is "mostly agree", followed by a tie between "mostly disagree" and "I don't know".

Selected comments from the open section:

- "Right now, we have no idea how BCI might change any of these things by direct action on the brain, but I think it'll be a drop in the ocean compared to the effects of coping with disability, having surgery, etc, on the same things."

- "So can drugs but that doesn't mean people taking them aren't capable of making autonomous decisions. They might make stupid ones, but it is their prerogative."

- "The future will tell but what's the difference between using a remote control to do channel hopping or doing it with your thoughts? At the end watching 4 hrs. TV every day is more damaging…".

- "Your brain will adapt to what you do. We, BCI researchers, need to take care of the paradigms we use to make sure that long time use won't be negative for the brain."

- "I would say they challenge our current conception of autonomous decision making."

- "Unless BCI cause involuntary action and thus force people to behave in ways they would not choose, it is unlikely that they will change the personality and the contents of thoughts cannot be influenced by others mechanically or electronically, no more than your computer can determine the topic of your email. Neurology provides the wiring, nothing more."

- "Neurofeedback has been shown to alter cognition. I don't know about altering the capacity to make decisions."

Q 23. There are sufficient standards and regulations to control the quality of hard/soft/firmware in the commercial sector.

This question had 152 respondents, with 19.7% of them agreeing with the statement (agree: 7.9% + mostly agree: 11.8%). However, 52% of the respondents expressed disagreement (disagree: 23.7% + mostly disagree: 28.3%). It is important to note that 28.3% of the respondents stated they did not know how to respond to the question. On the next page, the answers are displayed according to Stakeholder Group:

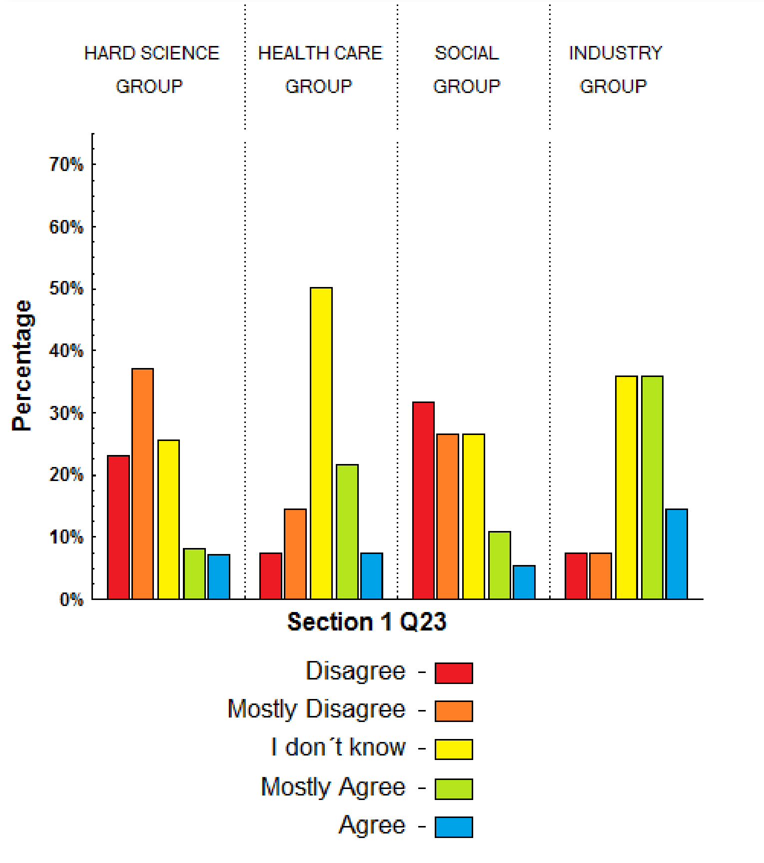

Figure 3.14 - Answers to question 23 classified by stakeholder group.
Source: Own Elaboration.

It is apparent that there is some variation in the responses, with the hard science and social groups predominantly disagreeing with the statement, while in the healthcare group, the prevalent answer is "I don't know", although there is a relative percentage that declares agreement with the topic. The industry group presents a tie between the responses "I don't know" and "mostly agree". This denotes further dissensus among stakeholder groups concerning the existence of sufficient standards and regulations to control the quality of hardware, software, and firmware in the commercial sector.

Selected comments from the open section:

- "Basically, there are no standards and regulations, and commercial companies can claim anything regarding their BCI-related technologies, even if it is not really BCI."

- “For now, there are some standards, but there exist new commercial trades that put in danger these standards, like TTIP/CETA/TiSA. The corporations are looking for a complete liberalization of commercial uses.”

- “Consumer product safety standards cover some of this. There is no specific international standard governing this area (or any other wearable equipment such as fitness trackers).”

- “Not at all. Any and all existing regulatory institutions are compromised.”

- “Hard to know. The standards and regulations probably exist in one form or another, but it is a question of how they are applied/enforced.”

- “Price is frequently a determinant, have no illusions about that and the morals that cut corners or supply low grade product to poorer communities.”

Q7. A global governance structure is needed to enforce team responsibility and ensure the establishment of each Ethical Advisory Board.

This question had 152 respondents, with 47.4% of them agreeing with the statement (agree: 19.1% + mostly agree: 28.3%). However, 26.3% of the respondents expressed disagreement (disagree: 7.2% + mostly disagree: 19.1%). Thus, although the overall sample indicates agreement with the statement, it is important to note that a total of forty respondents (26.3%) stated they did not know how to respond to the question. On the next page, the answers are displayed according to Stakeholder Group:

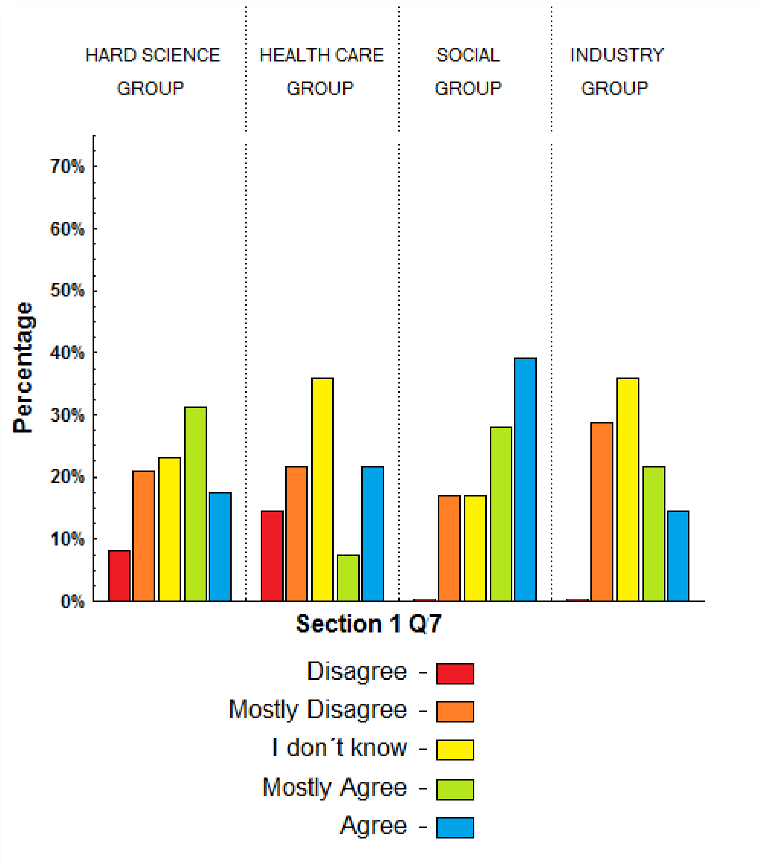

Figure 3.15 - Answers to question 7 classified by stakeholder group.
Source: Own Elaboration.

It is apparent that the responses "agree," "mostly agree," and "I don't know" prevail across all groups. However, "mostly disagree" and "disagree" received significant contributions in all groups, with the "disagree" opinions being particularly relevant in the hard science and healthcare groups. This indicates that the topic of a global governance structure being needed to enforce team responsibility and ensure the establishment of each Ethical Advisory Boards is a dissensus across the board.

Selected comments from the open section:

- "Ethical approval is so varied that it does not mean the same thing from region to region. It is important to have standards and governance within the BCI community so that it is keeping the people needs central rather than the technology. In the UK and Ireland gain ethical approval is rigorous and very difficult compared to mainline Europe. So we need guidance to support these applications for emerging technology and ensure mainland Europe are operating within appropriate governance structures".

- "Governance yes, but global no. Global sounds like it would be too bureaucratic and take too long to decide. Also, for the principles to gain global agrément, they would probably be too weak".

- "A global advisory structure, signed on by discipline-specific and jornal-specific organizations, would be helpful. Governance sounds like a bureaucratic mess, though".

- "Existing Ethical Committees are doing their job. I agree with awareness to ethical issues and, eventually, having global ethical advisory boards. But I find a 'global governance structure' to be a burden".

- "It is more important to incorporate ethics training into scientific training programmes".

- "Where this comment applies to volunteer subjects participating in experiments, clear Ethical Reviw Board oversight is required, although it is not clear why a global governance structure is required specifically for this purpose. The advent of consumer EEG systems with BCI capabilities opens the possibility for Family members and carers to try BCI, there should not need to be any oversight of this activity any more than for trying a diferent keyboard, compute ror eye tracking system".

3.5.2.2.2 Section 2

Section 2, titled "Perspectives and Challenges In Research And Development (R&D) In BCI Technologies For Clinical Applications", comprises thirteen questions designed to collect perspectives from the Stakeholder groups on how certain hypothetical situations would influence the development of BCIs for clinical applications, classifying them as either enablers or constraints.

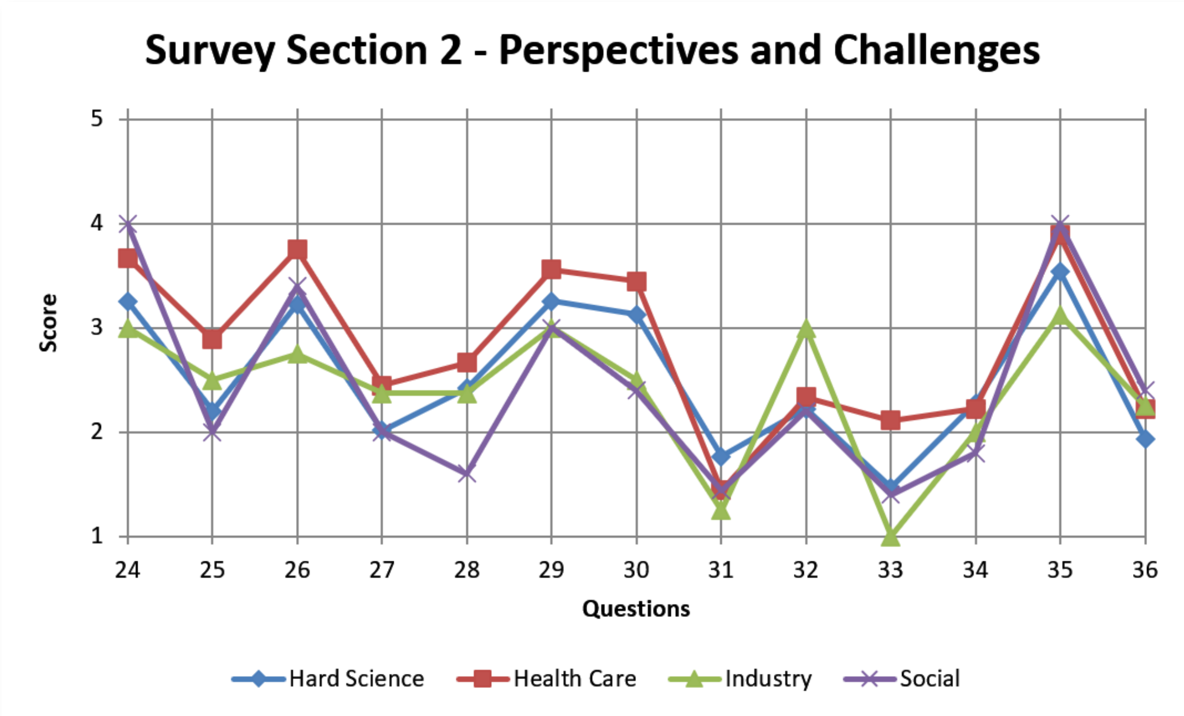

Figure 3.16 - Distribution of Answers Across Different Stakeholder Groups on Section 2.

Source: Own Elaboration.

The figure above displays the mean answer from each stakeholder group for every question on this section. The graphic highlights points of consensus and controversy among stakeholder groups, as well as issues to which respondents might not yet have well-informed opinions, either due to insufficient knowledge or because the issues are not yet clearly understood, as previously mentioned in the Literature Review. Overall consensus amongst stakeholder groups is observed here. However, questions 30, 33, and 36 emerge as having significant differences, as although no major disagreements are evident, some stakeholder perspectives vary to a certain extent. For item 33, the healthcare group's choice slightly deviates from the rest. Furthermore, item 36 exhibits strong consensus among stakeholder groups, whereas item 30 reveals a divided stance, with half of the groups perceiving the situation as an enabler and the other half considering it a constraint, albeit with low confidence in their responses (all remarkably close to the option "I don't know"). Below these questions are presented in detail, with some relevant anonymous comments from the respondents included:

- CONSENSUS

Q36. More funding from governments and the attraction of significant commercial interests.

This question had 137 respondents, of which 75.2% considered the statement either an important enabler (36.5%) or an enabler (38.7%) to the development of BCIs for Clinical Applications. On the other hand, 16.8% of respondents considered the statement either a constraint (9.5%) or an important constraint (7.3%) to the development of BCIs for Clinical Applications. It should be noted that 8% of respondents claim that this fact does not represent either an enabler or a constraint to the development of BCIs for Clinical Applications. Below, the answers are displayed according to Stakeholder Group:

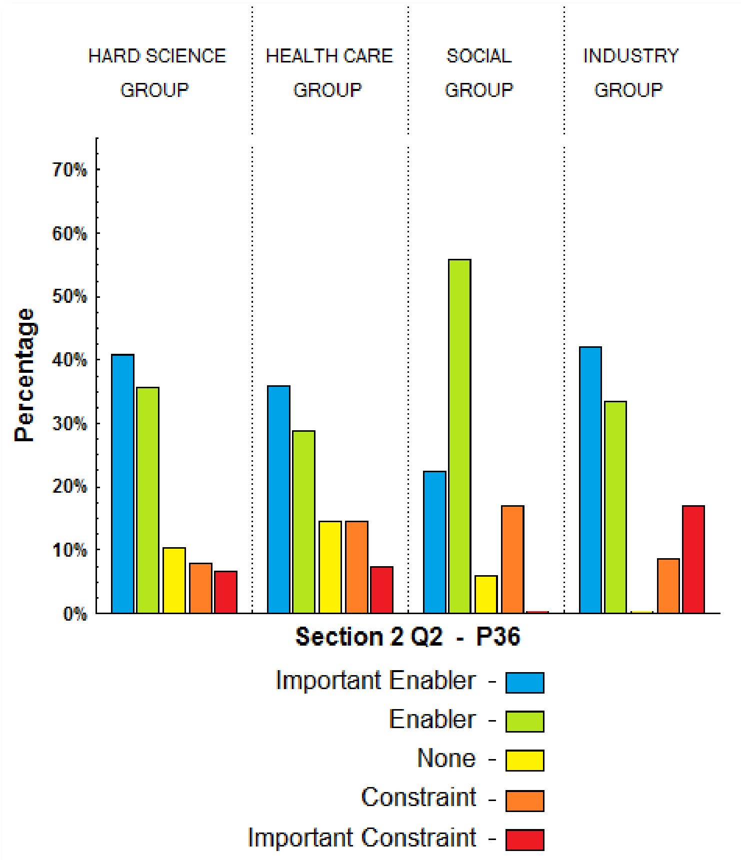

Figure 3.17 - Answers to question 36 classified by stakeholder group.
Source: Own Elaboration.

It is possible to observe how the majority of respondents across the stakeholder groups agree that more funding from governments and the attraction of significant commercial interests is considered as an 'enabler' and 'important enabler' to the development of BCIs for Clinical Applications.

Selected comments from the open section:

"The governments have poured loads of money into BCI but the results are pretty disappointing. However, the claims are getting bigger and bigger".

"Brain Initiative, Human Brain Project, BNCI are very good initiatives that will help us fast forward brain technologies".

"Often significant commercial interests market products which are detrimental to societies' understanding of the overall picture. Deliberate increases in government funding for academic research aren't necessarily useful: very few dedicated BCI groups exist to take advantage of increased funding, instead these increases promote people moving into the field on a short term basis (while the funds last)".

- DISSENSUS

Q30. The size of the target population which could benefit from BCI as an assistive technology.

This question had 138 respondents, with 45.6% of them considering this topic to be an enabler (important enabler: 18.1% + enabler: 27.5%). However, 40.6% of the respondents state that this fact hinders the development of BCIs for clinical applications (constraint: 29.7% + important constraint: 10.9%). It is important to note that 13.8% of the respondents declare that this fact neither facilitates nor poses a difficulty for the development of the field. Below, the answers are displayed according to Stakeholder Group:

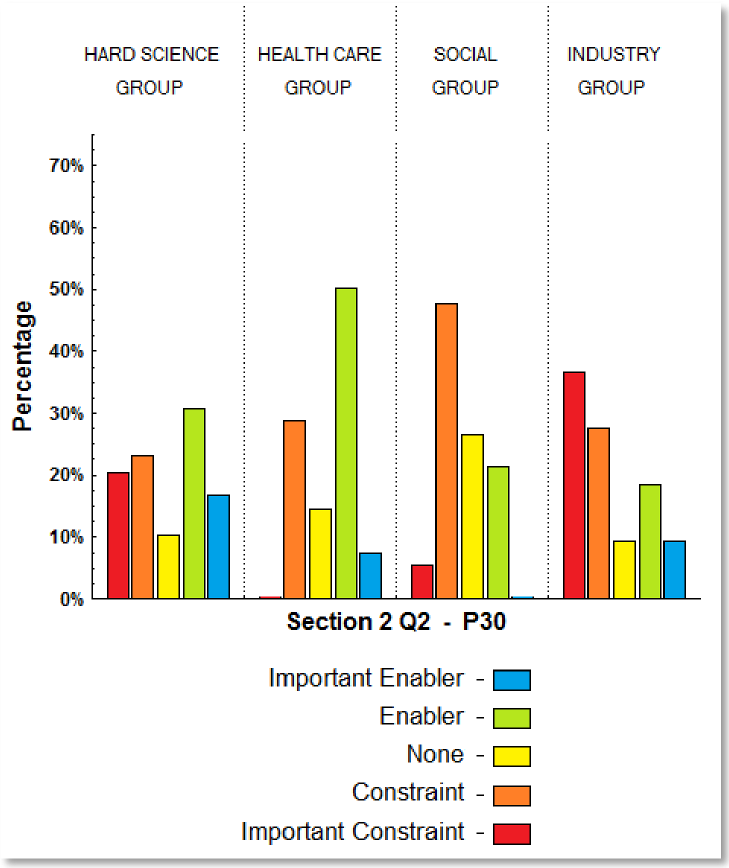

Figure 3.18 - Answers to question 30 classified by stakeholder group. Source: Own Elaboration.

Clearly a dissensus can be observed, splitting opinions on whether the size of the target population which could benefit from BCIs as an assistive technology is an enabler or a constraint to the development of the BCIs. While the hard science and healthcare groups consider this to be a constraint, the social and industry groups consider it to be an enabler. On the other hand, it can be said that almost half of the respondents from across all stakeholder groups agreeing that it is an enabler could be an encouraging fact to further stimulate research and development in the field.

Selected comments from the open section:

"The amount of people who could benefit is very small. Only a small percentage that has no means of natural communication. In any other case, normal interhuman relationships are reliable and more personal."

"Actually, it depends whether the size is assuming small or large in the question. To me the current target population is too small which constraints fundings and research efforts in the field. A larger target population would attract more fundings and research efforts, thus benefiting the field."

"There might not be enough (wealthy) people that could benefit from the first generations of BCI and thus BCI could be unfeasible from an economic point of view."

"Lots of people could use that technology at home. Even if the technology is not perfect to go outside the house, it could improve the mobility of a lot of people."

"It is getting larger as BCI science and technology matures."

"As the BCIs are getting better and the applications multiples, this will reach a larger public."

Q33. The incorporation of professionals from the fields of neuroscience, engineering, computer science, mathematics, psychology, neurology, philosophers, ethics, etc.

This question had 138 respondents, with 92.8% of them considering this topic important for the development of BCIs for clinical applications (important enabler: 58% + enabler: 34.8%). Only 3.6% of the respondents declared that this fact may hinder its development (constraint: 2.9% + important constraint: 0.7%). Below, the answers are displayed according to Stakeholder Group:

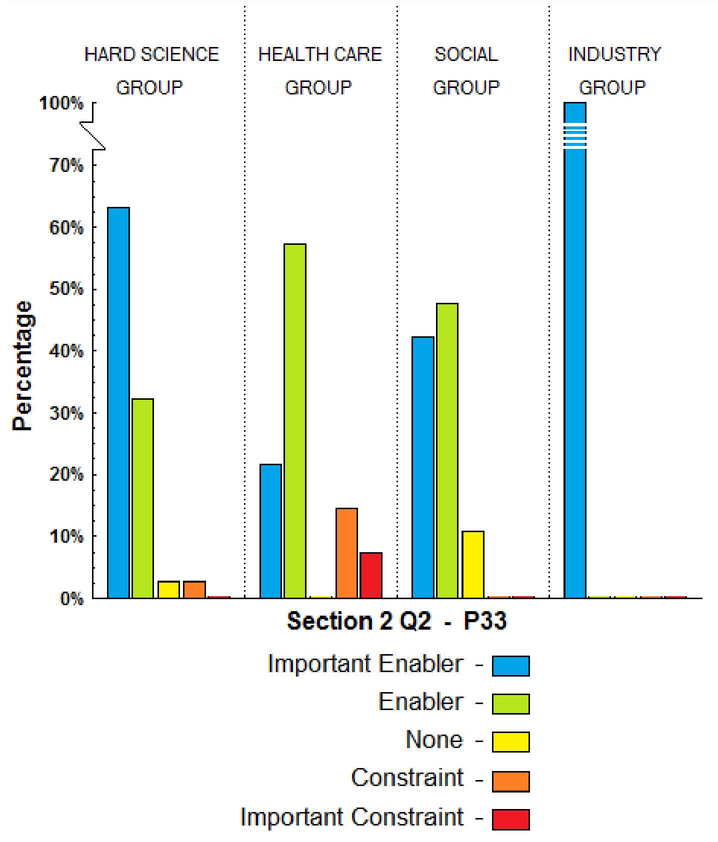

Figure 3.19 - Answers to question 33 classified by stakeholder group. Source: Own Elaboration.

It is evident looking at the data that the incorporation of professionals from various fields, such as neuroscience, engineering, computer science, mathematics, psychology, neurology, philosophy, ethics, and others, is considered both an "enabler" and an "important enabler" for all of the groups.

Selected comments from the open section:

“The BCI community is a very closed shop and not much new has come out of it except of endless claims, but I said before I still haven’t seen a EEG controlled wheelchair on the road – after 20 years of promises. Fresh input from other disciplines is badly needed.”

If you include actual psychology representatives and not just neuroscientists (who don't do psychology) and if the ethical representatives were there in equal numbers to the hard-science representatives, some humanity may be preserved.

Professional from the education and philosophy fields, Nursing (mental and physical), New Zealand, The Healthcare Group (Familiar).

"One of the most important factors in the field right now. BCI is heavily multidisciplinary. Contribution from all fields is very important!"

PhD Student, Electrical Engineering, École de Technologie Supérieure (ETS), Montreal, Canada, The Hard Science Group (Expert).

3.5.2.2.3 Section 3

Titled "Future Visions In Brain-Computer Interfaces", this section aims to identify the opinions of respondents on some ethical topics, which future visions would be possible and feasible to happen as well as on which timeframe they could take place. The whole section is comprised of twelve multiple choice questions divided into three parts, the third one being a single open-ended question. The first part deals with timeframes for a number of different vision statements, while the second part presents some transhumanism related statements and asks respondents to state whether they agree or not with them, providing a brief explanation of why. BCIs have great potential to benefit society, especially in its clinical applications, however they also bring up important potential implications for social, ethical, and philosophical questions, implications that are not limited to the present time, but could also impact future generations.

3.5.2.2.3.1 Section 3.1

For part 3.1, two items displayed particular significance: items 37 and 41, respectively one of consensus and one of dissensus. On item 37, opinions were essentially the same across stakeholder groups, while on item 41 the industry group displayed a rather different opinion from the other stakeholder groups. On the next page, these questions are presented in detail, with some relevant anonymous comments from the respondents included:

Q 37. Non-invasive EEG BCIs for clinical applications will overcome technical issues and will be fine-resolution, friendly, wireless, cheaper, faster, reliable, high performance and will become broadly available to ensure communication and motor control to those with Locked in and Complete Locked-in Syndrome.

This question had 141 respondents, with the most prevalent time horizon being "11 to 15 years," chosen by 28.4% of the respondents. In second place, respondents selected "6 to 10 years," accounting for 24.8%, followed by "next 5 years" with 19.9%. On the other hand, 16.3% of respondents declared they were unable to answer the question, and 5% stated that this event would never occur. Below, the answers are displayed according to Stakeholder Group:

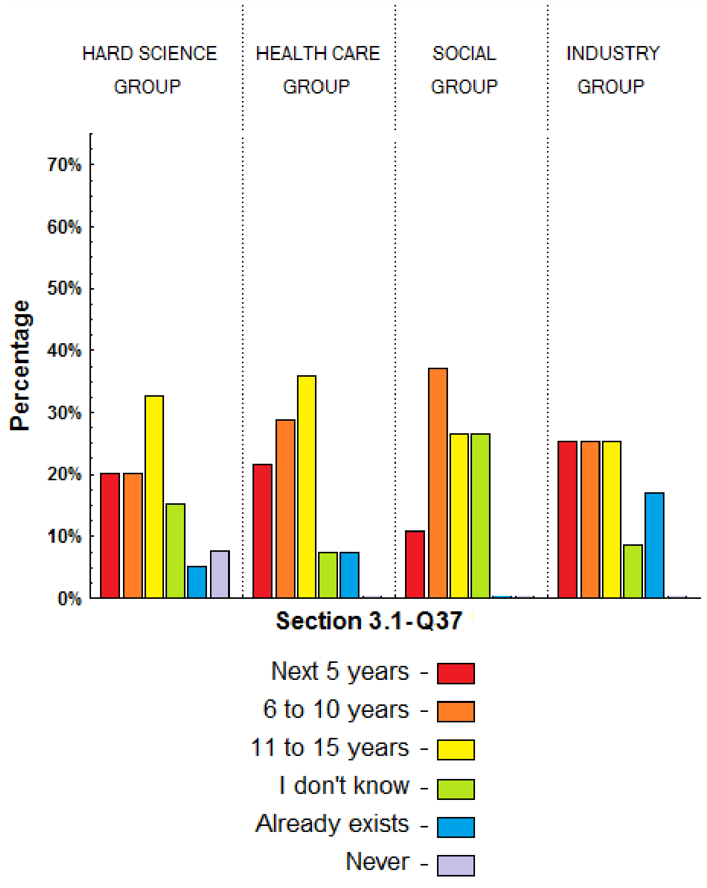

Figure 3.20 - Answers to question 37 classified by stakeholder group. Source: Own Elaboration.

It can be observed that opinions on the shared vision are varied, although it is clear that there are high expectations on what concerns the development and application of non-invasive EEG based BCIs. No stakeholder group considered the vision presented as impossible to happen. The healthcare and hard science groups held lower expectations, setting a longer time horizon for the vision presented, choosing the "11 to 15 years" timeframe. The social group is divided, but agrees that it will take place eventually, while the industry group displayed the greatest dissensus, with all options but "never" on an almost equal footing.

Selected comments from the open section:

"Technically: no problem, this already exists. The problem is what organizations get to assert proprietary control over the technologies. This is an economic and political, not a technical question."

"We will get better and better with BCIs and it will be a 'never ending' project. Neurotechnology will reshape the world forever."

"We are still a long way off systems to be used at home for daily use by people with complete LIS."

"Predicting the future is not something that humans are good at (most human predictions are not better than chance), and several of these statements are mostly revolutions in BCI technology. I honestly have no idea whether they could come true and if so when. But does it really matter? Is that really important to know what people think may happen in the future?"

Q 41. The BCI technologies will evolve allowing for direct communication between two individual's brains with great possibilities for enhancement purposes, even creating home-made brain interfacing devices, but this will be accompanied by massive violations of privacy and coercive control from the man over another man.

This question had 138 respondents, with the primary response being "I don't know," accounting for 38.4%, followed by the "Never" response at 29.7%. Regarding the time horizon "11 to 15 years," it was chosen by 15.2% of the respondents. Below, the answers are displayed according to Stakeholder Group:

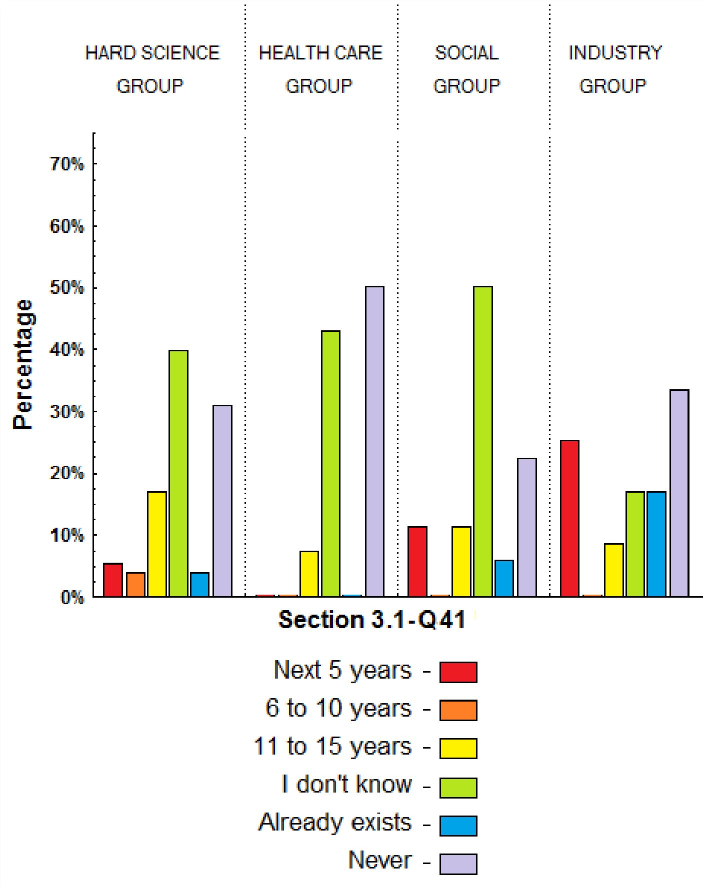

Figure 3.21 - Answers to question 41 classified by stakeholder group. Source: Own Elaboration.

It can be observed that opinions on the shared vision are varied, although it is clear that there are high expectations on what concerns the development and application of non-invasive EEG based BCIs. No stakeholder group considered the vision presented as impossible to happen. The healthcare and hard science groups held lower expectations, setting a longer time horizon for the vision presented, choosing the "11 to 15 years" timeframe. The social group is divided, but agrees that it will take place eventually, while the industry group displayed the greatest dissensus, with all options but "never" on an almost equal footing.

Selected comments from the open section:

“A lot more than 50 years”.

“I actually think it will take 50 years”.

“At least not on a large scale. If something like this would happen to early adopters (and it would, compared to e.g., computer viruses) the development would end immediately.”

“If this enables a paralysed and/or handicapped blind, autistic, immobile person to enjoy a relatively normal level of movement and communication, this could be justified.”

3.5.2.2.3.2 Section 3.2

On part 3.2, two items displayed particular significance: items 44 and 46, respectively one of dissensus and one of consensus. On item 44 the social group displayed a rather different opinion from the other stakeholder groups, while on item 46, opinions were essentially the same across stakeholder groups.

Q 44. Do people have the right to enhance their memory, augment their intelligence, maximize their pleasure, or even change their physical forms on demand?

Q 46. Is there a danger of one not being able to define oneself anymore as a person when brains are wired between individuals?

For question 44, more than 80% of respondents declare that Yes, they believe people do have such right. This answer was different only for the social group, in which only a little over 60% agreed with the statement.

As for question 46, all respondents across stakeholder groups had essentially the same answer, with their average answer being neither an agreement nor a disagreement, indicating a strong dissensus amongst them, reinforcing the divide in opinions when philosophical questions come into play in the field of BCIs.

Selected comments from the open section:

QUESTION 44:

- "To the extent that human freedom does not conflict with other values (such as justice, equality, personal identity, persistence, etc.)"
- "They are permitted to do this. But they do not have a right to do it."
- "Incredibly difficult question. There are low-tech ways of enhancing ones intelligence, memory, pleasure and physical forms that are very much legal and accepted at the moment, so it is hard to deny this right in principle. However, the movie Gattaca comes to mind as an undesirable scenario that should be avoided."

- “Question too simple - many rights are conditional, and here there are issues like equity.”

- “That need an ethical discussion that not all which is technical possible can use as human enhancement. But it is difficult discussion similar to use dops in competitive sports.”

- “We are the first species able to hack itself, to transcend itself. We must explore.”

QUESTION 46:

- “At least not in the near future (50-100 years)”.

- “You don't know how much of the "machine" is actually yourself.”

- “This will never happen.”

- “One may imagine conflicting memories, desires, beliefs, etc., coexisting in the same mental theatre without those having these conflicting experiences being capable of identifying their sources in different brains that are BCI connected to each other.”

- “It will become difficult to think of autonomous decisions. But this is also the case within cultural environments.”

- “Even wired in a coupled system, person will always remain a person, because the person finds its roots in ontology not in the brain.”

- “It's essentially unpredictable what may happen to us.”

- “Nevertheless, the notions of individuality (and privacy) are currently changing due to factors besides BCI.”

3.5.2.2.3.3 Section 3.3

On part 3.3, respondents had an open space to share anonymously with the survey any ethical or moral dilemmas they have encountered in their work. Below are some of the most interesting and ethically relevant commentaries amongst them:

Q - Could you share with us, in confidentiality, any ethical or moral dilemmas that you have encountered in your work?

- "A very simple and basic point to consider: legal rights to the recorded data without a transfer form, the copyright stays with the subject!"
- "The inability to provide ALS participants with an in-home system. Many of our disabled participants would like to have access to an in-home system but financial and resource constraints prevent us from doing so."
- "Neuromarketing. If BCI are used to modify our decision making indirectly processes. We will not be any more owners of our decisions. We think that we took a decision but it wasn't us. Because there was an ad particularly designed (with BCI technology) to modify our decision-making process."
- "I work with EEG. The data is essentially garbage. Perhaps (without foresight) I wrongly consider this harmless, but I never think of ethical questions, or work with patients, or in clinical situations."
- "Dealing with people with discapacities with can potentially benefit from mature technology that exist as prototypes * I'm increasingly concern by the fact that only millionaires will benefit from the results of research paid mostly by the average citizen."
- "We promise more than we are able to deliver (at least at the moment)."
- "Risk of raised expectations that technology provides the "answer" when it doesn't."
- "When researchers and/or companies claim that their system measures EEG but they know it's actually EMG and/or noise."

- “Policymakers do not want to address ethical questions in times of economic constraint...something that is unethical itself.”

- “I created ... to talk about Brain-Computer Interfaces (in a project of mine) and extend it a little to transhumanism (as seen by Zoltan Istvan) and the Singularity (as seen by Ray Kurzweil). People don't understand the field of BCIs. I think that people working in BCIs need to explain the field as it is and not let companies like Neurosky and Emotiv market their devices as being able to read our minds. Recently, I received an e-mail from someone suffering from ALS and controlling his wheelchair with his mouth, asking me if I could help him to control his wheelchair with a BCI. It breaks my heart to say no, when I know that I could do something 'very basic' that could help him at home. The problem is that this person might be tempted to use it outside thinking that the device works fairly well. It's hard to understand the limitations for someone outside the field. “If the brain were so simple we could understand it, we would be so simple we couldn't.” — Lyall Watson.”

- “I don't work with BCIs, but I have worked with paralyzed patients and with medical ethics and psychological ethics. The problem is that moral and ethical are not objective and that no congruence can ever be reached between people on these topics, which is itself a result of their different personalities. If people were all born with the same psychological possibilities, humanity would never have developed to the level it is now. It is impossible for all people to be clones.”

- “None, except the difficulty of telling parents of subjects with disabilities that the BCI system being tested may not provide any benefit for their child.”

- “How many times to keep returning trying a system that is not showing promise for a young man? This person is CLIS due to Cerebral Palsy. Unsure how much the mother is affecting/influencing reported evidence of cognition and classifiers have not proven successful with a non-invasive EEG system. How much of limited lab resources should be allotted to this family? With a smaller, unfunded research lab, this is an ongoing dilemma.”

- “1) A group I work for had to report an individual who misunderstood BCI and believed we controlled brains using computers. 2) I used a BCI long term for three consecutive days and found my sleep to be badly disrupted. 3) I do not have faith that academic research is the way to progress the BCI field, the publication system favors many 'new' things and not slow incremental progress.”

- “Neuromarketing - currently there is no evidence that it surpasses traditional marketing techniques. But what if it does? Do we really want science and technology to push marketing, advertising, and consumerism even further?

- “When working with passive BCI (mental state monitoring), you have to induce mental/affective states to the users to collect EEG data in these states (ground truth). This means you have to make your users happy, surprised, excited but also sometimes sad, afraid or stressed. Is that right to do that? Even after approval by the ethical committee, it may still not very nice to the users...”

- “Giving more interest in the scientific output than on the expectations of the patient who benefit from a BCI system. The use of a good willing patient for promoting self in front of cameras and press without ensuring that the patient would have a BCI system that Works.”

4

Main Findings and Discussion

4.1 Synthesis and Critical Analysis

There is no question that the relevant technological advances in BCIs will have a greater impact on many different areas in the human life, especially regarding to solve or minimize health problems associated with many different diseases if the field managed to overcome the technological and ethical challenges and obstacles. The ethical questions have appeared in response to rapidly increasing scientific and engineering developments of the BCI field and its possible impacts and consequences. There are many different categories of issues that arise from the increasing understanding of brain mechanisms, as neuroscientists and engineers make more progress in their understanding of how the brain functions, no doubt the ethical implications of that understanding will continue to develop, as will the array of issues and applications for which ethical implications are identified.

Thus, on what ethical questions raised by BCIs are concerned, below are some examples that are relevant, although it is clear that it does not deal with all ethical issues, but, in general, the most important and discussed ones:

- The adequacy of how to address risks and benefits (social benefits and harms). The impact of the technologies on the practice of clinical medicine.
- Obtaining informed consent from people who have difficulty communicating.
- Privacy and the protection of human subjects in research.
- Autonomy, Human Dignity and Free Will and Moral Responsibility.

- Side effects on brain structure and functioning. Side effects in cognitive capacities, personal identity, mood, behavior.
- The regulation (guidelines, procedures, behavior, and technical rules).
- Changes in the concept of "Self". Self perception and body ownership. Bodily integrity. Identity.
- Mind reading and mind control.
- Social divide.
- Selective enhancement.
- The end of the idea of man – blurring boundaries, cyborguism, singularity.

4.1.1 Implications on social, ethical, legal and philosophical aspects

4.1.1.1 On Informed Consent

In any kind of BCI study or training it is crucial to obtain the person's informed consent, which means a well-informed decision. It is necessary to inform individuals about risks and benefits and be sure they consent freely. In case of patients with partial or Complete Locked-in Syndrome, it is difficult to obtain this consent, in view of the difficulties these patients have to communicate. Here, advances directives may be necessary mainly because research is far from resolving these problems (Hildt, 2010).

The opinion of the vast majority of the respondents of the survey, regarding the issue of informed consent, in which it is expected that a blink of an eye is enough to establish that the patient has the emotional and cognitive capacity to make complex decisions is still, until now, a reason for contradictions. It is not yet possible to easily detect what the message is behind the thoughts, but it is possible to assume that some activity is going on. No strong conclusions can be drawn, neural activity is indicative but not confirmation. Scientists cannot confirm what really happens, only identify which areas of the brain are active and indicate the possibility of understanding. Not enough is known about the brain to draw such conclusions. A positive BCI response can confirm cognitive ability, but its absence does not confirm a lack of these skills.

Consent was established to protect the person (the subject), sometimes evolving into a mechanism to protect who applies the procedure, occasionally at the expense of intent. Consent is important, but as in all other interactions between humans, when regulation is too much, it becomes discriminatory for certain personality types, remembering that paralyzed people do not lose their personality. Although free choice is a human prerogative, unless a new technology is developed capable of establishing that the user has a healthy brain and therefore is able to make complex decisions, the issue still remains unresolved. Such BCIs do not exist at present and are unlikely to exist in the near future.

However, recent discoveries can alleviate such contradictions, as well as shed light and some hope on this issue, as Chaudary and collaborators demonstrated that a patient without any stable and reliable means of eye-movement or identified communication was capable to select letters to form words and sentences using a type of BCI, as will be better explained in the next chapter (Chaudhary et al., 2022).

4.1.1.2 On Privacy

With regard to privacy, there is a difference between the general knowledge of the brain and the extraction of personal information from the brain. However, similar to any technology that can extract information from an individual or from a brain, BCI raises concern of privacy. Everyone knows that advertising, for example, is invasive, but the notion of privacy in BCIs actually changes. If a BCI device used some metrics about fatigue, attention and the like, these cannot be considered private. If, however, in the future, science succeeds in cracking the brain's code and mind-reading becomes possible, then it will be different. Currently, it is not possible to extract information from neural activity beyond of the centers that are being activated in the treatment or study. At least for the time being, the actual content of the brain is not accessible by neurology, so all this information is an interpretation of the researcher.

But, certainly, in the future, if two-way communication is possible, in which control signals would be decoded from brain activity and sensory feedback could be sent back in a natural and intuitive way, it will be a serious concern. And this is starting to become reality with the so-called Brain-to-Brain Interfacing (BTBI). In 2013, the technology took a leap forward as researchers replaced the external computer connection with a second embodied brain, dubbing the approach BTBI (Trimper, Wolpe & Rommelfanger, 2014). Some studies mark the first advances in this sense: the transference of relevant motor information from the brain of one rat into that of another (Pais-Vieira, Lebedev, Kunicky, Wang & Nicolelis; 2013); the demonstration that cognitive information related to the encoding of a memory could also be transferred from one rat's brain to another's (Deadwyler et al.; 2013), and, also, in Harvard Medical School, using a non-invasive form of BTBI, information had been transferred from human to rat brains, characterizing what they called cross species neural interfacing (Yoo et al.; 2013). Thus, the direct transfer of information between two brains raises new and important ethical issues, for example, potential violation of privacy, human enhancement and agency and identity.

BTBI adds another dimension to the neural privacy concern; not only is information extracted and decoded from the transmitting brain, but it is also introduced to a receiving brain, presumably without the ability of that brain to refuse or inhibit the impulse. The specter of introducing various kinds of information coercively is also a plausible ethical concern.

4.1.1.3 On Autonomy, Human Dignity, Free Will and Moral Responsibility

Autonomy is a humanistic value, one that may be on the verge of a profound change if a post-human society comes into place, challenging our perspectives and understanding of ourselves as a species. Researchers agree that the proliferation of BCIs does not pose a threat to privacy and autonomy, although biohacking is one example of a practice which could open doors to such possibilities.

Questions ranging by those posed by potential neuromarketing practices to the privacy concerns raised by social media that are used to feed algorithms that can effectively influence whole populations, especially in the fake news era, arise and bring with them threats to autonomy. It is known that social media big techs are experimenting with ideas of virtual reality and even future devices that may be somehow linked to brain-computer interfaces. BCIs, background noise and other information could be included in the fine print of terms and conditions of the use of social media, allowing companies to use sensitive information, in the same way that already happens today, although information collected from the brain, including, for instance, emotions. If the correct connections are made, emotions could be linked to specific actions in people's smartphones and/or computers, allowing companies to better understand what moves people and use it in their interest. The need for governance and ethics, and regulation of neurotechnologies is paramount when taking such concerns into account.

Notions of free will and moral responsibility change when the brain is seen as a mere component of the body. But the brain is not consciousness. There is no free will or moral responsibility without the body and brain. Neurotechnologies already have the capability to influence mood and behavior. Potential brain side effects involved with BCIs could directly affect mood, cognition and behavior, such as medications that impact even our decisions.

Regarding issues of human dignity, it is observed that human dignity is at risk when interacting with a technology that is not sufficiently understood. Managing expectations and educating populations is essential. The concept of digital citizenship deals with such issues, as in being responsible for educating users of information technologies on their use and impacts, among other subjects.

4.1.1.4 On self-perception, body ownership, and enhancement

A substantial questioning about self-perception and body ownership is coming. With transhumanism, cyborgism and singularity, it will be necessary to discuss and even to redefine what it means to be human. Possibly, it may also bring to light deeper three-dimensional questions about the concept of life. Is possible that, in the future, humans will use different BCIs for different reasons and these systems will be linked to computers. BCI is a rapidly advancing and emerging research field. Although it has potential to benefits individuals and society, especially through its clinical applications, it is also posing questions regarding the development of the new dynamics between people and their relations to a technology which transforms their interactions with the world. It is important to pay attention to challenges which arise from this relation/relationship dynamics between bodies and technologies.

In the future it is possible that there will be the emergence of a new division between 'enhanced' and 'non-enhanced'. This is definitely an important question that will come up when it is common to improve. This will lead to social inequalities such as external pressure for improvement. However, the new division will be superimposed exactly on the old one - whether or not the individual can pay for it, that is, whether he has money or not. And yes, the pressure will be there, but it will hardly be overt: it will be indirect and driven by market forces as usual.

The foundation of knowledge about brain functionality is the starting point for a new era of human enhancement. BCIs will find many other applications. In their current form, BCIs will not directly extend life and health, but they will if we have a better understanding of how the brain works. So yes, there will be a new era of human enhancement. That said, it seems that the development of BCIs is part of a series of innovations (medical, technological, social) that are changing the way humanity perceives and interacts with each other. However, we must be humble and recognize that BCIs are just one part of this and not the main driving force.

4.1.1.1 On regulations

On the topic of regulations, ethical approval is so varied that it does not mean the same thing from region to region. Even if regulations exist, each committee member will respond with their own personality and interpret the regulations in their own way. A global advisory structure, signed off by discipline-specific and journal organizations, would be helpful, although it could mean more bureaucracy. Moreover, consensus is often so hard to reach that the regulations themselves could become futile if they are so diluted as to ensure consensus that they do not actually work in reality. In any case more important than a global ethical structure would be to incorporate training in ethics into scientific training programs all around the globe.

4.1.2 Reflection on potential future pathways and challenges for BCIs

The Horizon 2020 Future Brain-Neuro Computer Interaction (BNCI H2020, 2015) highlights a Vision for 2025:

"In 2025, a wide array of applications will use brain signals as an important source of information. We will see routine applications in professional context, personal health monitoring, and medical treatment. We envision a future where humans and information technology are seamlessly and intuitively connected by integrating various bio signals, particularly brain activity. People will be supported in choosing the best time for making difficult and important decisions. People working in safety-relevant fields will be capable of anticipating fatigue, and authorities may find good (evidence-based) reasons to incorporate such applications in regulations. Game, health, education, and lifestyle companies will link brain and other bio signals with useful applications for a broad community. People will want to monitor their brain states to provide them with reliable estimates of their mental capacity and performance level. Rehabilitation will benefit from BCI-based treatments in the coming years. Stroke rehabilitation will benefit from plug and play home use of non-invasive BCI systems. Restoration of lost motor functions will likely require fully implantable neural recording and stimulation devices. In the longer run, new treatments of brain disorders may include electroceuticals, where BCIs are used to provide corrective neurostimulation for epilepsy, depression, Parkinson's disease, and schizophrenia. Restoration of mobility in people with paraplegia will be achieved with BCI-based locomotion systems, where decoded brain signals either control an exoskeleton or activate limb muscle stimulation programs for walking."

On the other hand, a vision written back in 2006 aiming at 2026 presented by Lebedev & Nicolelis (2006) states that neuroprosthetic developments will include: "a fully implantable recording system that wirelessly transmits multiple streams of electrical signals, derived from thousands of neurons, to a BMI capable of decoding spatial and temporal characteristics of movements and intermittent periods of immobility, in addition to cognitive characteristics of the intended actions.".

This raises several questions: will BCI's be able to reach one of its main goals of restoring communication for locked-in individuals? Or even so, will BCI's (implantable or not) be able to reach the development mentioned in the scenario above? Once the complex functioning of the human brain is still not yet fully understood, will advancements in BCI research remain dependent on further developments in neuroscience? The answer is "no", at least not in the coming years. It is possible that in the more distant future, humanity will arrive at these scenarios. However, there is no guarantee that everyone will have access to these technological innovations.

According to the data collected in the survey, although different stakeholder groups often do not agree with each other, they concur that the incorporation of professionals from various stakeholder groups is considered an important enabler for the development of the BCI field. One comment present in section 2 of the survey would eventually inspire the very title of this thesis, making clear how important it is for this incorporation to take place, and how regardless of field or level of knowledge, this is a general concern:

"If you include actual psychology representatives and not just neuroscientists (who don't do psychology) and if the ethical representatives were there in equal numbers to the hard-science representatives, some humanity may be preserved."

(Healthcare Group: nursing - mental and physical, New Zealand)

5

FINAL CONSIDERATIONS

Bearing in mind that this project suffered several discontinuities and part of the information presented here was collected a few years ago, this topic presents some innovations, advances and new perspectives that occurred in recent years. Despite everything, an analysis of the most current literature in the field of BCIs shows many advances in knowledge, experiments and technological developments, most of which still do not represent significant advances that could change the situation in which technology was found about 10 years ago.

Even with regard to ethical, social, legal and philosophical aspects, it can be said that little progress has been made. Although ethical issues have been extensively enumerated and articles have been published, the fact is that few desired recommendations have yet to be implemented.

5.1 Integration of findings with updated Literature Review

The BCI field is evolving in many directions. New types of BCIs are emerging (like the "semi-invasive" approach of Stent BCIs (Mitchell P, et al., 2023)) and advancements in machine learning and artificial intelligence are used in interpreting, decoding and translating brainwaves into commands like it was not possible before. Wolpaw, Milán & Ramsey (2020) state that, in recent decades, research in BCIs has shown that the creation of natural outputs is distributed throughout the CNS, from the cerebrum to the spinal cord, meaning that no individual area is completely responsible for natural output. Walking, speaking, singing, playing the piano, among other activities involve complex interactions among different regions of the brain. BCI use is a unique challenge for the CNS that has evolved and continually adapts to acquire and maintain actions produced by the natural CNS outputs. In other words, it is crucial to realize that successful BCI use requires effective interaction between the CNS and the BCI. The achievement and guarantee of such effective interaction between CNS adaptations and concurrent BCI adaptations is among the most difficult tasks of BCI research.

Personalized BCIs have been designed and developed on the basis of general BCIs, and customized BCI systems to meet the needs of specific users according to their characteristics. Then, it is necessary to design, develop and evaluate the general BCI system and fully consider the individual differences among individual users in physiological and mental states, sensations, perceptions, imageries, cognitive thinking activities, and brain structures and functions. The idea is to improve user satisfaction with the system, enhance the user experience, and make the system practical (Yixin Ma, Anmin Gong, Wenya Nan, Peng Ding, Fan Wang and Yunfa Fu; 2023).

Recently, European researchers (Chaudhary et al., 2022) presented a breakthrough: they demonstrated that an individual unable to move for prolonged periods of time, considered to be in the Complete Locked-In Syndrome situation was capable of meaningful communication. A paralyzed patient with Complete Locked-in Syndrome was able to select letters to form words and sentences and express his desires and experiences using a neurally based auditory neurofeedback system independent of his vision. The patient used an intracortical BCI based on voluntarily modulated neural spikes from the motor cortex to spell semantically correct and personally useful sentences.

However, Pires (2022) states that although the BCI research community has already made such great efforts and that BCIs are a promising tool for communication with Completely Locked-in Syndrome (CLIS) patients, the cases of success are still very few, very exploratory, limited in time, and based on simple 'yes/no' paradigms. Still, on the other hand, this is also good news in a certain way, since it becomes a good motivation to continue researching new approaches or replicating experiments to infer the effective feasibility of the proposed approaches (Pires, 2022).

5.1.1 Developments in the Technology Assessment Field

The concept of Future-oriented Technology Assessment (FOTA) was introduced by Nazarko (2017), in which the author argues that the main reasons for reviewing and updating the assumptions and practices established for TA reside in the emergence of an important concept oriented towards innovation policy called Responsible Research and Innovation (RRI). The author points out that RRI requires that research and innovation be planned and conducted in an open and transparent manner so that society in general has the chance to anticipate their consequences. Then, RRI can be defined as a transparent and interactive process by which social actors and innovators become mutually responsive to the (ethical) acceptability, sustainability and social desirability of the innovation process and its marketable products (in order to allow adequate incorporation of scientific and technological advances into our society).

This author explains the concept of Future-Oriented Technology Assessment (FOTA) as a particular form of Technology Assessment (TA) which is focused less on risk assessment and more on the innovation governance with regards to the emerging technologies. For him, the analysis and/or assessment of emerging technologies from the perspective of the potential results of their implementation are critical in contemporary economies, societies and businesses. The main argument for revisiting the main assumptions and established practice of Technology Assessment lies in the emergence of a major innovation policy-oriented concept called Responsible Research and Innovation, mentioned in Chapter 2. For Nazarko, the main characteristics of Future-Oriented Technology Assessment are:

- re-orientation from risk assessment toward innovation governance.
- integration with Responsible Research and Innovation Agenda (RRI), and
- more extensive methodological reliance on qualitative and heuristic tools common to foresight studies.

And for him, the role of Technology Assessment in the FTA approach could be an understanding of the impact that an introduced or developed technology may have on society, environment and economy, through:

- study of an existing or emerging technology, its potential and possible applications.
- envisioning its direct and indirect (intended or unintended) technical, economic, health, environmental, human, social and other consequences.
- reflection about the consequences from the perspective of the assumed values.
- recommendation of possibilities for action and design, supporting decision makers in taking informed action.

5.1.2 Developments in the Brain-computer Interface Field

According to Wolpaw, Milán & Ramsey (2020) about 20 years ago, BCI research was an endeavor pursued by only a few isolated laboratories. Today it is a growing field of research involving many hundreds of scientists, engineers, and clinicians throughout the world in an increasingly interconnected community that is addressing key issues and pursuing the high potential of BCI technology. Within the scope of clinical applications, the main measure of the development of BCIs continues to be the benefits that can be achieved by people with neuromuscular disorders. Thus, the clinical evaluation, validation and dissemination of the BCI is essential. It is also a complex and difficult process that requires multidisciplinary collaboration and effective management of the demanding requirements of clinical trials.

According to the "Brain-Computer Interface Market 2023- 2028 Report"[5], BCIs market growth is being driven by the possibilities of using these devices to meet the growing demand for treatments for neurodegenerative diseases (and/or) neurological disorders, such as, for example, Alzheimer's and Parkinson's disease, strokes, multiple sclerosis, epilepsy migraine, brain injuries, and neuro infections. Already in 2007, the United Nations reported, about one billion

[5] The Brain-Computer Interface Market 2023- 2028 Report, a free sample, was produced by Mordor Intelligence. The Report was obtained from one of its analysts. In : https://samples.mordorintelligence.com/67438/Sample+-+Brain-computer+Interface+Market%C2%A0+(2023-2028)+-+Mordor+Intelligence1677625554434.pdf. Accessed in 16/04/2023.

people, nearly one in six of the world's population at the time, suffered from these diseases and disorders, with some 6.8 million dying of the disease each year.

This report highlights that this market is segmented by type (Invasive Brain-Computer Interface; Non-Invasive Brain-Computer Interface, and other types), by application (Restoration of disabilities; repair of Brain Function, and other applications) and by geography (North America; Europe; Asia-Pacific; Middle East and Africa, and South America). And, in the competitive landscape, that includes Business overview, Financials, Products and Strategies and the recent developments, it is possible to see main actors (Natus Medical Inc.; g.tec medical engineering GmBH; Medtronic PLC; Compumedics Ltd; Nihon Kohden Corporation; Integra Life Sciences Corporation; Advanced Brain Monitoring Inc.; Emotive Incorporation; NeuroSky; ANT Neuro; NextMind; Cadwell Industries Inc.; MindMaze; Brain Products GmBH; NIRx Medical Technologies) although this list not exhaustive.

On what concerns non-invasive brain-computer interfaces, the high applicability of the technology and increasing of neurological disorders are driving the demand for non-invasive brain-computer interfaces for the management of neurodegenerative disease, which will impact the market segment's growth positively. Furthermore, according to the "World Alzheimer Report 2021", published in September 2021[6], over fifty-five million people live with dementia worldwide, this is forecasted to reach seventy-eight million by 2030. The increasing burden of Alzheimer's disease globally surges the demand for non-invasive brain-computer interfaces, thereby leading to the growth of the studied segment market. Nearly a million Americans are living with Parkinson's disease in 2022, according to the Parkinson's Foundation. This number is expected to rise to 1.2 million by 2030. Parkinson's is the second-most common neurodegenerative disease after Alzheimer's disease. Nearly 90.000 people in the United States are diagnosed with Parkinson's every year, and more than ten million people worldwide live with this disease.

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[6] The World Alzheimer Report 2021 (https://www.alzint.org/resource/world-alzheimer-report-2021/). This report focuses on the crucial and timely subject of diagnosis. Diagnosis is still a major challenge globally, with those who seek a diagnosis often experiencing long wait times, if they are able to receive a diagnosis at all. Societal stigma, self-stigma and clinician related stigma also exacerbate what is already a difficult journey. Accessed on 11/04/2023.

Finally, it is essential to mention that, in accordance with this thesis, the most recent literature corroborates the fact that more research into ethics is needed for the field of BCIs. Alharbi (2023) says: " Ethics remain one of the major areas where there is a significant need for greater and more transparent oversight, and therefore, more research into ethics is a major priority for future research".

5.2 Recommendations for future research

Coenen & Stieglitz (2021) consider the need for specific Neurotech-ethics to allow such issues to be inserted in social, cultural and governance approaches, so that the interactions between the various actors and their analyzes are differentiated and modeled to meet the various needs and interests of social groups. When neurotechnologies relate to the nervous system, especially in the context of brain-computer interfaces, various aspects of the individual, such as privacy and consensus; individual, mental and physical identity; autonomy, the ability to make decisions and choose one's own actions must be protected as basic rights.

It should be emphasized that further relevant ethical points other than those discussed in detail here have also been identified in the literature and to some extent even surveyed in the comments and answers in the questionnaire, such as side effects, while topics such as agency, artificial intelligence and machine learning for BCI algorithms in decoding brain waves and transforming them into actions, bodily integrity, mental integrity, social divide (stigmatization to both sides (enhanced and non-enhanced, selective enhancement and access to technologies restricted to purchase power, etc). It could be said that both the communities of TA and BCI could benefit from a deeper analysis into the data which may yield further publications and insights. These insights could also be compared to current state-of-the-art, perhaps offering a different understanding of how these issues may evolve over time in the opinions and perspectives of stakeholders in BCIs, and why not neurotechnologies in the context of assistive technologies. Thus, further research on a follow up of advancements and perception of the technologies and stakeholders is recommended to keep on being able to better anticipate potential enablers and constraints for the future of the technology and its unintended impacts, providing knowledge to policy makers, industry and other key stakeholders to make decisions today in order to shape the future accordingly, in a humane and dignified way for all.

6

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A

APPENDIX

Here the survey is presented as it was used, starting on the next page in order to maintain its original formatting.

A.1 Structured Survey

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

ITAS Institute for Technology Assessment and Systems Analysis

KIT Karlsruher Institut für Technologie

KIT – Universität des Landes Baden-Württemberg und nationales Forschungszentrum in der Helmholtz-Gemeinschaft

SURVEY
PERCEPTIONS ON BRAIN-COMPUTER INTERFACES

This survey is an initiative of the **Faculdade de Ciências e Tecnologia – Universidade Nova de Lisboa** and the **Institute of Technology Assessment and Systems Analysis – ITAS, Karlsruher Institut für Technologie (KIT)**.

BCI applications for restoration or replacement of lost natural outputs have been the goals of most current BCI research and development. BCI comes in as a particularly interesting and relevant emerging technology given the social, ethical and philosophical questions it raises which could eventually confront and modify core concepts and values about what it means to be human.

Thus, this survey aims to get the stakeholders' perceptions about ethics, morals, responsibility and R&D as well as future perspectives considering some challenges, opportunities and threats of the Brain Computer Interface field.

We really appreciate your contribution. Thank you for taking your time to complete this survey.

Gabriel T. Velloso, PhD Student, Institute of Technology Assessment and Systems Analysis – ITAS, Karlsruher Institut für Technologie (KIT)/ Faculdade de Ciências e Tecnologia – Universidade Nova de Lisboa.

Antonio Moniz, Faculdade de Ciências e Tecnologia – Universidade Nova de Lisboa.
Armin Grunwald, Institute of Technology Assessment and Systems Analysis – ITAS, Karlsruher Institut für Technologie (KIT)
Femke Nijboer, Health, Medical and Neuropsychology unit, Leiden University

Gabriel T. Velloso is the contact person at the Conference. Feel free to contact him if you have questions about this survey. You can also email him at gabriel.velloso@partner.kit.edu

Please, indicate your organization/company, your discipline field, field of specialization and your country.

Organization: ______________________________

Discipline Field: ____________________________
(field of training)

Specialization area: _________________________

Country: ___________________________________

Please, check item(s) that better describe your experience background:

___ PhD/MSc Student

___ Reseacher/R&D Center

___ Industry

___ Government

___ Consulting

___ Others (specify) ________________

If you are interested in receiving the results from this survey, please provide your contact details. Identification for the survey itself is optional and absolute confidentiality is guaranteed.

e-mail: _____________________________

Name: ______________________________

After you have completed the SURVEY, please leave it at the event secretariat or deliver directly to Gabriel Velloso.
Moreover if you can't answer the SURVEY now, please leave your email so we can send it to you electronically.

Please indicate your <u>level of knowledge</u> of the BCI TECHNOLOGIES

<u>NOT FAMILIAR</u> - Don't know anything about the topic.

<u>CASUALLY ACQUAINTED</u> - You have read or heard about the topic in the media or have maintained eventual relations with groups of interest regarding the subject.

<u>FAMILIAR</u> - You know most of the arguments for and against issues surrounding the technology; you have read about it and you have formed opinions about it.

<u>KNOWLEDGEABLE</u> – You are in the process of becoming an expert, but still have to work more to achieve mastery on the topic, or you work in a neighbouring field and occasionally draw up upon or contribute to the development of this topic.

<u>EXPERT</u> - You consider yourself a part of the community of people who currently dedicate themselves to the topic.

Not familiar	Casually Acquainted	Familiar	Knowledgeable	Expert

(<u>You may choose not to answer any particular question</u>)

SECTION 1. "ABOUT ETHICS, MORALS AND RESPONSIBILITIES"

Q 1. The **BRAIN-COMPUTER INTERFACE (BCI)** field has an established and significant community of researchers who have already initiated a neuroethical debate. According to the concept of Responsible Research and Innovation (RRI), the attribution of responsibility is a socially and politically relevant act, which influences the governance of the respective field. RRI includes moral, epistemic and governance dimensions of responsibility, as well as the need of distribution of these responsibilities between all the actors in an inter and trans disciplinary process in order to assess and prioritize the possible impacts, in the present and the future. BCIs raise hopes for patients with severe motor impairments and could benefit individuals and society as a whole. Although the BCI community has already started the ethical debate, some issues have not yet been adequately understood whereas some deserve further consideration. The following table presents some **<u>statements</u>** from various articles and documents. So, please, give your opinion regarding these statements

Statement	Disagree	Mostly disagree	I don't know	Mostly agree	Agree
P 1. To people in locked-in states, a simple "yes" or "no" given by the blink of an eye is sufficient to establish that the patient had the cognitive and emotional capacity to make complex decisions.					
Comments:					
P 2. BCI technology is the same as an eye tracker. Only now people use their brain activity to control something.					
Comments:					

Statement	Disagree	Mostly disagree	I don't know	Mostly agree	Agree
P 3. All paralyzed individuals should have equal opportunity to access a BCI, even if they cannot give informed consent in a clear way.					
Comments:					
P 4. Advanced BCIs that detect neural activity correlating with					

complex semantic process can demonstrate if patients have the cognitive and emotional capacity to make an informed and autonomous decision.					
Comments:					
P 5. To ensure that users keep the consent or want to halt the experiment at any time if desired, it is important to regularly perform a consent procedure.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 6. To regulate the **Consent Process,** a more detailed and standardized set of guidelines is needed.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 7. A global governance structure is needed to enforce team responsibility and ensure the establishment of each Ethical Advisory Board.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 8. Guidelines and standards need to be updated to reflect the importance of privacy and data protection.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 9. The notion of privacy will change when the brain's extracted information is used for commercial purposes such as smarter advertising or to maximize productivity through employees' surveillance.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 10. Commercial BCI devices might transform modern notions of privacy.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 11. The long-term use of non-invasive BCI leads to negative consequences on brain structure and functioning.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 12. The psychological issues (for example joy or frustration), which are raised especially in BCI trainings, are the same for people with disabilities and able-bodied people.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					

P 13. Human dignity may be at risk when patients discover that they are incapable to get the ability to control a BCI.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 14. The long-term use of an invasive BCI could lead users to reconsider their bodies, raising problems related to self-perception and body ownership.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					
P 15. Invasive BCIs will provide to the users a self-perception as similar as the one provided by other wearable devices such as Google Glass.	**Disagree**	**Mostly disagree**	**I don't know**	**Mostly agree**	**Agree**
Comments:					

	Disagree	Mostly disagree	I don't know	Mostly agree	Agree
P 16. The potential side effects in the brain involved with invasive BCIs (such as effects on mood, cognition and behavior) threaten the autonomy of the patients.					
Comments:					
P 17. BCI can induce changes in cognitive capacities, psychological continuity or personal identities, which challenge the capacity of autonomous decision making.					
Comments:					
P 18. Invasive BCIs can lead to improved self-control which may be beneficial for improving control over desires and preferences enhancing autonomy (such as avoiding drugs or junk food).					
Comments:					
P 19. The proliferation of BCI technologies does not represent a threat to privacy and autonomy.					
Comments:					
P 20. The notions of free will and moral responsibility change when the brain is seen as a mere component of the body.					
Comments:					
P 21. There are moral and philosophical questions when considering the blurring distinction between man and machine and the idea of the cyborg.					
Comments:					
P 22. The use of BCIs outside the context of therapeutics violates individual authenticity, disrespects the limits of nature and puts at risk losing what make us humans.					
Comments:					
P 23. There are sufficient standards and regulations to control the quality of hard/soft/firmware in the commercial sector.					
Comments:					

SECTION 2. "PERSPECTIVES AND CHALLENGES IN RESEARCH AND DEVELOPMENT (R&D) IN BCI TECHNOLOGIES FOR CLINICAL APPLICATIONS"

Q 2. As an emerging technology, BCI is in its early stages of technological development. Insofar as the technology develops, patterns that result from the actions and interactions among researchers, institutes, companies and policymakers may eventually constrain and enable futures activities. Regarding the **CURRENT STATE OF THE TECHNOLOGY FOR CLINICAL APPLICATIONS**, the table below lists some **TOPICS** which have been identified in various documents and might represent opportunities and challenges in the field. Based on your knowledge, please evaluate these statements considering if they represent an **enabler** or a **constraint** to the development of the field. For example, the inclusion of more end users in every design stage, including research and development will be an important enabler (facilitator) to the development of the field, while the incapacity to overcome the technical problems to run a BCI in optimal way could be an important constraint.

TOPICS	Important enabler	Enabler	None	Constraint	Important constraint
P 24. The fact that complete locked-in syndrome (CLIS) patients are unable to communicate using BCIs, at the present time.					
P 25. The understanding of the central nervous system (CNS) functioning.					
P 26. The efforts related to training time and sessions required for non-invasive EEG based BCI patients to learn and to properly use the system.					
P 27. A powerful computer (hardware and software) that can support complex high speed analysis of brain activity in a real-time BCI operation.					
P 28. Defined technical standards to support the transition of BCI hardware and software from isolated demonstrations to systematic investigations and commercial products.					
P 29. The issues related to the technical points related to speed, accuracy, consistency, convenience, usability, reliability and usefulness to establish BCIs as ATs in the user's home.					
P 30. The size of the target population which could benefit from BCI as assistive technology.					
P 31. The development of BCIs for other purposes beyond clinical applications such as gaming, therapies to treat hyperactivity disorders or military purposes.					
P 32. The development of other non-invasive approaches such as MEG, fMRI, NIRS that could replace actual non-invasive EEG-BCIs.					
P 33. The incorporation of professionals from the fields of neuroscience, engineering, computer science, mathematics, psychology, neurology, philosophers, ethics, etc.					
TOPICS	**Important enabler**	**Enabler**	**None**	**Constraint**	**Important constraint**
P 34. Stakeholders' and societies' understanding of the overall picture of the BCI field.					
P 35. The lack of systematization of ethical issues that are placed in the present and will emerge in the future.					

P 36. More funding from governments and the attraction of significant commercial interests.					
Comments:					

SECTION 3. "FUTURE VISIONS IN BRAIN-COMPUTER INTERFACES"

Q 3.1. The Brain-Computer Interface field has great potential to benefit individuals and society as a whole, especially in clinical applications. It also has strong potential implications for ethical, moral and philosophical questions. However, these issues aren't limited to the present time or to immediate consequences. Society also needs to consider the potential risks and consequences for future generations. The following table presents **<u>BCIs vision statements</u>** from various documents. In your opinion, which of the following statements below are possible and feasible to happen and which would be the time horizon for each to take place?

TOPICS	Mark with an "X" the period if time when each topic will occur					
	Next 5 years	6 to 10 years	11 to 15 years	I don't know	Already exists	Never
P 37. Non-invasive EEG BCIs for clinical applications will overcome technical issues and will be fine-resolution, friendly, wireless, cheaper, faster, reliable, high performance and will become broadly available to ensure communication and motor control to those in locked in and complete locked-in states.						
P 38. Established assistive devices will complement clinical non-invasive BCI systems with fine-resolution, high spatial and temporal resolution signal recording, potentially reducing or eliminating the need for invasive electrode implants.						

TOPICS	Mark with an "X" the period if time when each topic will occur					
	Next 5 years	6 to 10 years	11 to 15 years	I don't know	Already exists	Never
P 39. Implantable devices will include "a fully implantable recording system that wirelessly transmits multiple streams of electrical signals, derived from thousands of neurons, to a BMI capable of decoding spatial and temporal characteristics of movements and intermittent periods of immobility, in addition to cognitive characteristics of the intended actions."						

P 40. The interfaces between computer and brain will evolve to a degree where the information flows in both directions, the brain sends out information and receives information from the computer, which learns and develops. And if the computer is also connected to the internet, it will allow the human brain to be connected into the internet itself becoming then a node on that system.						
P 41. The BCI technologies will evolve allowing for direct communication between two individual's brains with great possibilities for enhancement purposes, even creating home-made brain interfacing devices, but this will be accompanied by massive violations of privacy and coercive control from the man over another man.						
Comments:						

Q 3.2. Considering your knowledge and experience, evaluate the following topics and please give your opinion.

Mark with an "X" (yes or no)	Yes	No	Please, provide a brief explanation
P 42. Are BCI innovations, which will extend life and health as well as increase performance, part of a new era of human enhancement?			
P 43. Are BCIs as assistive technologies controversial?			
P 44. Do people have the right to enhance their memory, augment their intelligence, maximize their pleasure, or even change their physical forms on demand?			
Mark with an "X" (yes or no)	**Yes**	**No**	**Please, provide a brief explanation**
P 45. Is there a danger of 'new divides' (enhanced and non-enhanced persons) arising, as well as in the question of pressure to use enhancements against one's will?			
P 46. Is there a danger of one not being able to define oneself anymore as a person when brains are wired between individuals?			
P 47. Is there a danger of struggles about who rightfully owns the ideas that are generated during the brain-to-brain interfacing?			
Comments:			

Q 3.3. Could you share with us, in confidentiality, any ethical or moral dilemmas that you have encountered in your work?

B

INFORMED CONSENT FORM FOR THE INTERVIEWS

Here is the informed consent form used for the interviews, on the next page.

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

ITAS Institute for Technology Assessment and Systems Analysis

KIT Karlsruher Institut für Technologie

KIT – Universität des Landes Baden-Württemberg und nationales Forschungszentrum in der Helmholtz-Gemeinschaft

Informed Consent for recording and use of interviews (video and/or audio)

I agree to voluntarily participate in Mr. Gabriel Velloso's research study for ITAS – Institute for Technology Assessment and Systems Analysis and UNL - New University of Lisbon as part of the interviewers' Doctor's Program.

I confirm that I have read and fully understand the research study here presented. I have had the opportunity to ask questions or seek clarification about the purpose and nature of this study.

☐ I give permission for my interview to be recorded (video and/or audio) and subsequently used for research purposes in Mr. Gabriel Velloso's research as presented.

☐ I want anonymity to be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my interview may be quoted in any subsequent publications and in the thesis if I give permission below (Please tick one box):

☐ I agree to quotation/publication of extracts from my interview

☐ I do not agree to quotation/publication of extracts from my interview

☐ I would like a summary of the study's findings following its submission and approval.

☐ I would like to receive a copy of my transcript once it has been completed.

☐ I give permission for the researcher to contact me by telephone or email following my interview to ask further questions or clarify any issues raised. (Optional)

Name of Interviewee - ………………………………………………………………………

Signed…………………………………… Place and Date……………………………….

Interviewer - Gabriel Velloso

Signed…………………………………… Place and Date……………………………….

UNIVERSIDADE NOVA DE LISBOA

A TECHNOLOGY ASSESSMENT
OF BRAIN-COMPUTER INTERFACES

GABRIEL T. VELLOSO

2023