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Bridging Present and Future of Brain-Computer Interfaces: An Assessment of Impacts

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Bridging Present and Future of Brain-Computer Interfaces

*An Assessment of Impacts*¹

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Abstract

Technology assessment is essentially a systematic method used to investigate technology developments and assess their potential impacts on society. The assessment of emerging technologies, however, requires special attention. To address technologies at early stages of development, Constructive Technology Assessment (CTA) is considered to be one of the best options to bypass the Collingridge dilemma - which fundamentally states that controlling the direction of a technology's development is very hard. Technologies at early stages of development might appear to be unorganized, chaotic and with high level of uncertainty on future paths to take. Future Oriented Technology Analysis (FTA) represents any systematic process to produce judgments about the characteristics of emerging technologies, its development pathways, and potential future impacts. Technology Assessment is considered to be one of three subjects which form the umbrella concept of FTA. The technology assessed on this project, Brain-Computer Interface (BCI) or Brain-Machine Interface (BMI) is an emerging technology. BCIs can be defined as a technology which allows for the direct communication between the brain and an external device. It is a truly direct connection, with no use of the normal output pathways of peripheral nerves and muscles, allowing for the brain to have control over objects and softwares without intermediates. As an emerging technology, BCI is at its early stages of research and thus many challenges are still ahead. Mainstream adoption is not expected in least 10 years. There are still many problems and challenges to be overcome. The real impacts of BCI will depend directly on the development of competing technologies. If there is improvement in BCI research, then the potential applications and end users could grow dramatically. The findings of this project will be of relevant importance to researchers of the technology (especially on what concerns their interactions with other stakeholders), regulatory agencies (which establish policies for safe use of technologies) as well as for companies investing in BCI (especially on what concerns how can they shape the development of BCIs).

Keywords: Technology Assessment; Constructive Technology Assessment; Emerging Technologies; Brain-Computer Interfaces; Brain-Machine Interfaces

JEL code:

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Introduction to technology assessment of BCI

According to the European Parliamentary Technology Assessment Network, Technology Assessment is "*a scientific, interactive and communicative process, which aims to contribute to the formation of public and political opinion on societal aspects of science and technology.*"

In fact, according to Banta (2009), "Technology assessment has been defined as a form of policy research that examines short- and long-term consequences (for example, societal, economic, ethical, and legal) of the application of technology. The goal of technology assessment was said to be to provide policy makers with information on policy alternatives."

Given the recent advances of technology and the ever increasing rate of development, other approaches have also been proposed. 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 of applications;
- II. the directions and pace of technoscience is a reflection of the interests, values, motives and perspectives of decision makers;
- III. all decisions are made within a complex social setting - it includes a diverse range of socioeconomic, cultural and political components; and
- IV. 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.

There are in fact numerous approaches to technology assessment, but fundamentally it is a systematic method used to investigate technology developments and assess their potential societal effects.

The assessment of emerging technologies, however, requires special attention. Technologies at early stages of development might appear to be unorganized and chaotic. In these situations, expectations and visions guide the field. Therefore, they are very different from other technologies at later stages of development. In this sense, 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.

To address technologies at early stages of development, Constructive Technology Assessment (CTA) is considered to be one of the best options to bypass the Collingridge dilemma - which fundamentally states that controlling the direction of a technology's development is very hard. According to Collingridge, when a technology is on an initial phase of development, knowledge about the consequences or impacts of such a technology is limited, which renders very difficult the control of its development's direction. On the other hand, when a technology has reached its final stages of development, although the knowledge of its consequences or impacts is sufficient, it is still difficult to control the direction of that technology's development.

This happens because at this point the technology has already been established, so changes become costly and frequently have to face powerful interests. Then, special arrangements have to be made to deal with this dilemma. It can only be achieved by changing the relationship patterns among the stakeholders involved in the innovation process as well as broadening their perspectives, providing new insights of a sociotechnical dynamic. It will then be possible for them to have a more comprehensive view of the innovation process in itself, coupled with a new view of its consequences and a better understanding of how will these innovations develop. (Merkek & Smits, 2007)

In this sense, Brain-Computer Interface (BCI) or Brain-Machine Interface (BMI) is an emerging technology, at its initial stages of development. BCIs allow for direct communication between the brain and a computer system. It functions as a bridge connecting the two systems, thus permitting the control of software and hardware systems. It provides new and extended ways of interaction between humans and machines. As an emerging technology, many challenges still lie ahead and mainstream adoption will not come before at least 10 years. (Gartner's Hype Cycle for Emerging Technologies, 2011)

As mentioned before, BCIs allow for a direct communication between the brain and an external device. There is no use of the normal output pathways of peripheral nerves and muscles, allowing for the brain to have control over devices and softwares without intermediates. 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 any other need of the user. To achieve this, BCI systems use several techniques to differentiate among different mental tasks. (Nicolelis, 2006; Donoghue, 2002; Cabrera, 2009)

Four essential elements are used by BCIs in order to provide this direct communication pathway: signal acquisition, feature extraction, feature translation and device output (Mak, 2009). Thus, brain signals are recorded, and then processed for extraction of features (spontaneous mental activities) which are then classified for proper translation into commands for the device or application. This technology makes possible for humans to control prosthesis, wheelchairs, play videogames, write, between others tasks, only using the brain.

The first characteristic which differentiates BCIs among themselves is the method used for signal acquisition. It can be either invasive or non-invasive. 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 (Donoghue, 2002).

Although BCIs have initially been conceived as a potential new therapy to restore motor control in severely disabled patients (particularly those suffering from devastating conditions as amyotrophic lateral sclerosis (ALS), spinal cord injury, stroke and cerebral palsy (Nicolelis, 2006; Wolpaw, 2007)), current and future perspectives also include the development of BCIs in other areas and with different purposes, such as in entertainment, and also to improve human performance, as covered by the Human Enhancement Report (Coenen et al, 2009).

In order to fully understand the possible impacts of such a technology all applications coming out of BCI should be taken into account (health, entertainment, security, information / communication technologies and so on).

The findings of this project will be of relevant importance to researchers of the technology (especially on what concerns their interactions with other stakeholders), regulatory agencies (which establish policies for the safe use of technologies) as well as for companies investing in BCI (especially on what concerns how can they shape the development of BCIs). There are still many problems and challenges to be overcome. The real impacts of BCI depend directly on the development of competing technologies. If there is improvement in BCI research, then the potential applications and end users could grow dramatically. As stated before, Gartner's Technology Hype Cycle report for 2011 states that BCIs actual stage of development is the technology trigger phase, so it's expected to reach mainstream adoption in no less than 10 years.

It is one of the purposes of this thesis to understand the development of the technology and present different perspectives and pathways for the future, as well as possibilities of growth and development. Among the relevant issues to be addressed, some could be pointed out: Which are the main areas of research in BCI? Which are the main applications in each of these areas? Which are the different stages of development of each area? Which are the possibilities for evolution and improvement of each area? How can research and companies work together? How can the researchers and businesses of today help develop this technology and bring several applications to our daily lives in the future? Which are possible pathways for researchers to overcome obstacles and advance with their work? How can businesses and researchers work closer to developing the technology?

The aim of this assessment is to understand at which point BCI is today, where can it be in 10 years from now and what are the possible impacts and issues the technology will bring to society as a whole:

- a) What are its applications,
- b) Potential social, economic and technological impacts, as well as
- c) Emerging ethical and political issues (bridging present and future).

General objectives of the research

The general objective of this project is to perform an evaluation of the BCI technology in order to foster its development through an exposition of the challenges presented by it and the mapping of both its actual state and future perspectives.

It is hoped that the findings might be useful for involved stakeholders (such as governments, researchers, businesses, etc) in the development of BCIs, as well as in the decision making process and the formulation of policies and strategies concerning the technology. Thus, the specific objectives of this project are the following:

1. To map the main areas of development in BCI and point out most relevant applications for each area.
2. To identify the main applications of each area as well as its different development stages in order to visualize development possibilities for each of these areas, their evolution and time horizons.

3. To identify and analyze the main social, economic and technological associated issues with the final applications and emerging political and ethical questions.
4. To identify and analyze possible and future pathways for the technology and for researchers and other stakeholders to overcome obstacles and challenges found.
5. To offer opinions and suggestions to researchers and other stakeholders alike aimed at facilitating the development of the technology in order to promote the fulfilling of its potential, as well as indicating ways for researchers and other stakeholders to get together in developing BCIs.

Methodological Aspects

Technology Assessment is considered to be one of three subjects which form the umbrella concept of FTA (Future Oriented Technology Analysis). FTA represents any systematic process to produce judgments about the characteristics of emerging technologies, its development pathways, and potential future impacts. (Porter et al, 2004)

As previously stated BCI is a technology at an early stage of development and is expected to reach mainstream adoption in no less than 10 years. However, not only *when* will it get there but also *how* will it get there is also very important. In this sense, FTA represents a macro-environment which integrates technology foresight and technology assessment, encompassing a broad selection of stakeholders. It allows for the analysis of possible impacts of technologies to be done together with its future perspectives, in such a way that modeling and creating futures based on the current characteristics of the technology becomes possible. Therefore, a future oriented assessment which is also participatory fits well with the proposed idea. A more extended time horizon allows for broader discussion, including the marketability and adoption of the technology in the future, as well as provides for a better understanding of the full potential of the technology.

In addition, technology is not isolated, but rather an evolving discipline which interacts closely with societal systems. Constructive technology assessment (CTA) would come to help bring together “how do we get there” with “where is there”. CTA is viewed as “an active, positive form of shaping technological development in reaction to the original “early warning”

approach” (Eijnhoven, 1997). This approach would be more in line with the objectives of the thesis, providing then a space for discussion, interaction, feedback and mutual contribution.

Among the methods and techniques suitable for this task are expertise-based methods. In those methods, experts from all areas could come together and share their views on the actual and future state of BCIs. In this case, it is very important to select a very broad and diverse group of stakeholders involved from different areas of expertise. At the same time the selected stakeholders must be well informed about how are the technological routes being designed for the future, as well as how is the innovation process for the technology at hand here being established. To offer a structured environment is crucial for constructive dialogue to take place effectively. This is one of the requirements of constructive methods for the study of emerging technologies.

Other methods suitable for this task are roadmapping, interviews - interaction-based methods, where different stakeholders (including non-expert) could come together and discuss impacts and directions - as well as stakeholder analysis, surveys and finally evidence-based methods; all fundamental tools for technology and impact assessment, scanning activities and particularly important for understanding where the technology is at the present moment and to encourage interaction and get feedback from participants. (Georghiou et al, 2008).

On this thesis it is proposed the use of constructive technology assessment (CTA) as a main methodological approach while bringing technology foresight into consideration. Thus, a window to visualize future perspectives can be opened.

The focus is to assure that uncertainties are reduced and to create a suitable environment for promoting a transparent and structured relationship among stakeholders without taking eyes off the time horizon.

Therefore, to abide by the aspects of this approach, this project will follow the steps presented below:

1. Literature review, in order to obtain a deeper knowledge of state of the art technologies, on what concerns scientific advancements as well as open and current issues;
2. STEEP-V (limits and constraints of social, technological, economic, environmental, political and cultural values) in order to better understand both the environment in which these technologies are being used in as well as its current challenges and obstacles;
3. Scenario development with a time horizon of 10 years;

4. Interviews, surveys and stakeholder analysis (preparation of questionnaires or interviews, selection of a broad group of stakeholders (scientists, researchers, business representatives, government representatives, and opinions of the civil society); application of questionnaire; in person interviews);
5. Roadmapping - in order to show possible and necessary evolution pathways as well as time horizons for the development of the technologies involved in BCI under scrutiny in the next 10 years. (Selection of technologies analyzed, definition of analysis plan, perform study);
6. Analysis of results and conclusion of project.

Expected findings

Much more than aiding people with severe disabilities, BCIs can become the greatest technological advancement in recent history. It can change the way human beings are perceived and accepted, as well as change how the world is seen. Its implications in social, ethical, technological and even anthropological and religious aspects can be severe.

It is hoped that the results of this project can contribute with the development of BCIs through a comprehensive analysis of the present challenges and obstacles to the advancement of the technology. It is also expected that the results can offer researchers, industry and governments alike a broader view of the relevance of this technology in several fields of human society, as well as of the difficulties and impacts associated with its development. Views which can prevent and/or minimize negative impacts perceived, therefore improving the performance of BCIs.

In addition, this project aims to offer a future perspective of the development and the evolution of BCIs in such a way which everyone involved can find guidance. The results of this project should be able to provide insights to pave the way for the future.

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