Ghost in the Machine

A philosophical analysis of the relationship between brain-computer interface applications and their users

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Master of Science Thesis
Philosophy of Science, Technology and Society
University of Twente

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Secondary supervisor: Prof. dr. Philip Brey
External supervisor: Prof. dr. Anton Nijholt

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Preface

This Master's thesis proudly presents the research I have been working on about the philosophical relationship between brain-computer interfaces (BCIs) and their users. I have been working on it from February 2008 till December 2008, with a pause of three months - which I spend at the Royal Institute of Technology in Stockholm, to do research about ethical dimensions of cognitive enhancements. One of the main reasons why I chose BCIs as topic of reflection is because ever since I wrote my Bachelor's thesis on *neuro-electronic interfaces,* I have been fascinated by technologies that blur the usually clear distinction between humans and technology. BCIs clearly blur this distinction and for this reason the research in this thesis gave me the opportunity to explore my fascination in more dept.

In daily life we are flooded with many different technological artifacts. We might even say that our existence is technologically textured, to speak in Don Ihde's terms. Artifacts have become an intricate part of our lives. Where would we be without our computers, televisions, cars, DVD-players, agendas and so on? We have integrated these artifacts in our existence and are to a large extend depended on them. Our relation with artifacts is largely determined by their features and how we interact with them. In many cases we interact with artifacts with our body, mostly with our hands. However, recent developments in BCI-research take it a step further. It is now possible to interact with artifacts by using thought alone. This groundbreaking development has some interesting consequences. We can sit still and by thinking alone control parts of the external world. This is done by detecting brain signals with electrodes which are either placed inside one's brain or on one's scalp. These brain signals are converted into command signals for a diverse range of applications like motorized wheelchairs, prostheses and even computers. When programmed properly, we merely have to think and the artifact will respond. This intriguing feature was previously the stuff of science-fiction and is now made possible through modern science and technology.

To finish, BCIs are a good example of the development that we are becoming ever more interwoven with our technological artifacts. This raises philosophical questions like: 'Where should we draw the boundary between humans and technology?', 'What does our relation with our tools mean for our understanding of ourselves?', 'Are we all going to evolve into cyborgs?' and 'Do we really want to?' This thesis tries to touch upon answering these questions. Doing so, is not only fascinating, but also important for a moral and philosophical anthropological understanding of who we are.

Acknowledgements

I would like to thank some people who have helped me to write this thesis. First and foremost I want to thank my primary supervisor Johnny Søraker. Johnny and I had many fruitful discussions and he convinced me that having a good research proposal is half the work. The discussions and his constructive feedback gave me philosophical insights which I would otherwise not have obtained. Furthermore, I want to thank my secondary supervisor Philip Brey. My analysis is largely based on his frameworks on human-technology relations. Without his frameworks my analysis would just not be the same. However, it is not only his frameworks that I am thankful for. His criticism always made sure that aspects I overlooked received attention as well. Next, I want to thank my external supervisor Anton Nijholt. Anton's knowledge about BCIs were of great help for understanding technical details of BCIs. Moreover, due to Anton I was able to participate in a BCI experiment which gave me first hand experience about what it is like to be a BCI user.

I would also like to thank Tom Kruijsen and Jaak Vlasveld. Tom, Jaak and myself were part of a reading group under supervision of Johnny. During the meetings we discussed and presented texts of Hubert Dreyfus, John Searle, Don Ihde and of ourselves. Their feedback was useful for adapting my research proposal. The VICI-group, to whom I presented my research proposal, gave me useful suggestions also receives my gratitude. And finally, I want to thank all the students who took part at the Master thesis seminars. Listening to other students who are working on their thesis was a valuable experience and gave me guidance, inspiration and practical tips. And last, but certainly not least - I am painfully aware that it is a cliché – but I really need to thank my parents and girlfriend who have supported me at times when I was stressed.

I can only hope that you enjoy reading this thesis as much as I did working on it!

Richard Heersmink

Wageningen, December 2008

Abstract

In this thesis I have explored the relationship between brain-computer interface (BCI) applications and their users from three philosophical perspectives. This is important for at least three reasons. First, a better understanding of this relationship can result in a more efficient design of this technology, which is beneficial for both the user and designer. Second, the outcome of this analysis could be used as a point of departure for a discussion on the moral desirability of BCI-systems, for example, in terms of personal identity or autonomy. And a third reason is, a better understanding of human-technology relations contributes to a philosophical anthropological notion of what it means to be human, which has intrinsic value. The overall research question I have attempted to answer is:

- What is the functional, epistemological and phenomenological relationship between BCIs, their applications and their users?

To answer this question, I started out with a technical description of BCI-systems in which I have conceptually analyzed the different types of applications. This resulted in the development of a taxonomy of applications which was the point of departure for the philosophical analysis. In this taxonomy I have distinguished between four types of BCI-applications. On the first level, a distinction was made between *deliberate* and *non-deliberate applications*. Deliberate applications require conscious, deliberate thought to control the application, whereas non-deliberate applications extract brain signals which are not deliberately or consciously controlled (e.g., a BCI-system that merely monitors concentration of a physician who is conducting surgery). On the second level, which is a further distinction within the deliberate applications, I have distinguished between *bodily*, *linguistic* and *virtual applications*. Bodily applications are devices which restore motor functions (e.g., a motorized wheelchair or prosthesis). Linguistic applications restore the ability to communicate by enabling its users to select letters on a computer screen. And virtual applications control a virtual environment (e.g., computer games or Google Earth).

As a second step to answer the research question, I have analyzed the functional relationship between BCI-applications and their users. In this analysis I made use of Marshal McLuhan's and Philip Brey's perspective on human-technology relationships. I have analyzed functions of BCI-applications, related them to abilities of their users and analyzed how they extend these abilities. After doing so, it turned out that BCI-applications extend the means of their users to realize their intentions. Furthermore, there is a *symbiotic relationship* between the users' brain and the application in all BCI-systems, because in each case the brain and the application *cooperate* to realize the intention(s) of the user. In essence, each BCI builds on faculties of the brain to extend the means to realize intentions of its user. Also, an important conclusion is that linguistic and virtual applications extend the means of their users to realize certain cognitive processes.

The third step in answering the research question leads to an epistemological analysis of linguistic and virtual applications. In order to analyze the cognitive, or epistemic, relation between these two types of applications and their users in more detail, I have employed Brey's perspective on human-computer relations. After doing so, it turned out that both linguistic and virtual applications are *cognitive artifacts* and form *strong coupled systems* as well as *hybrid cognitive systems* with their users. I then went on to evaluate the epistemic relation between one type of

virtual application, Google Earth, by making use of Alvin Goldman's five epistemic standards. These standards are the power, fecundity, speed, efficiency and reliability of epistemic practices. Taking the outcome of all the five standards into account, it was concluded that the epistemic quality of the virtual application of interest in this thesis, Google Earth, is good.

After having described and evaluated the cognitive relation between linguistic and virtual applications and their users, I have tried to improve it. This was done by employing James Hollan, Edwin Hutchins & David Kirsch's view on digital representations. Their notion of *history-enriched digital objects* implies that often used letters should be presented larger or brighter on the screen. Their notion of *zoomable multiscale interfaces* implies that for someone who is selecting letters on a computer screen, it might be more effective if the letter the person wants to select becomes larger when the cursor moves towards it. Their notion of *intelligent use of space* implies that for people who are not used to the *qwerty* style, it might be logical to present the most often used letters in the middle and letters that are used less often in the periphery of the screen.

As a last step in answering the research question, I have analyzed the relation between BCI-applications and their users from a phenomenological point of view. In this analysis I have employed Don Ihde's postphenomenological perspective on human-technology relationships, and Brey's and Peter-Paul Verbeek's refinement of it. Ihde has distinguished between four types of human-technology relations: the embodiment relation, hermeneutic relation, alterity relation and background relation. In the first two, the embodiment and hermeneutic relation, artifacts mediate between a human and the world. All BCI-systems display some structural features of embodiment relations and therefore mediate between its user and the world. The BCI itself is taken into the *body-schema* of its user in order to act upon the application. It is between the application and its user in a position of *mediation*, and is to some extend *transparent* and *withdraws* from attention. Moreover, BCIs have a unique feature that distinguishes them from other embodied artifacts. In Ihde's notion of embodiment relations the world is experienced through the artifact. But, in case of BCIs, it is the other way around. One can say that the application 'experiences' its user through the BCI.

Verbeek's concept *technological intentionality* was useful for describing this unique feature. BCI-systems are *directed* at the brain of its user, which implies they have technological intentionality. The artifacts that, according to Verbeek, have technological intentionality are directed at the world. But, the technological intentionality of BCI-systems is directed at its user, and - in contrast, the intentionality of the user is directed at the BCI. Consequently, the two types of intentionality are reciprocal, which may be called *reciprocal intentionality*. This relation can be called the *reciprocal relation* and may be captured as follows: (I ⇆ technology) - world. Or in the context of this thesis: (I ⇆ BCI) - world. Moreover, in the close symbiotic relation between a BCI and its user it is difficult to make a clear distinction between the human and the technological. This illustrates that we have entered a stage in which we have to reevaluate this distinction.

And finally, the background relation established with a non-deliberate application needs augmentation. We have seen that there is a reciprocal relation between BCIs and their users. But, the reciprocal relation does not apply for non-deliberate applications, because the element of human intentionality is lacking. So there is only technological intentionality involved here. This novel human-technology relation may be referred to as the *unidirectional relation* and can be captured as follows: I (← technology/world). Or in the context of this thesis: I (← BCI/world).

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1. Introduction

‘Curiosity is nonconformity in its most pure and innocent form.’

Hafid Bouazza (2001, p. 24)

A brain-computer interface (BCI) is an emerging as well as a converging technology that extracts brain activity of its user and converts it into command signals for applications ranging from motorized wheelchairs, prostheses and computers. In this thesis I will analyze the relationship between BCI-applications and their users from three philosophical perspectives. This is important because a better understanding of the relationship between a BCI-application and its user can result in a more efficient design of this technology, which is beneficial for both the user and designer. Furthermore, the outcome of this analysis could be used as a point of departure for a discussion of the moral desirability of BCI-systems, for example, in terms of personal identity or autonomy. A third reason why this is important is because a better understanding of human-technology relations contributes to a better understanding of who we are, which is important in itself.

The first perspective I will employ, analyses the *functional relationship* between BCI-applications and their users. This will be done by analyzing functions of BCI-applications, relate them to abilities of their users and analyze how they extend these abilities. Within this perspective I make use of the frameworks of Marshall McLuhan and Philip Brey. The second perspective I will employ, analyzes the *epistemological relationship* between BCI-applications and their users. Within this perspective, Brey’s view on human-computer relationships, Alvin Goldman’s five epistemic standards and James Hollan’s, Edwin Hutchins’ & David Kirsh’s view on digital representations will be used. And the third perspective I employ, analyses the *phenomenological relationship* between BCI-applications and their users. This will be done by analyzing how the BCI-applications mediate the experience of the world of their users. Within this perspective I make use of Don Ihde’s framework, and in addition I will make use of Brey’s and Peter-Paul Verbeek’s refinement of it. The functional, epistemological and phenomenological analysis all provide different insights which are all valuable for a better understanding of the relation between BCI-applications and their users. The analysis will point outs social, psychological and cognitive implications which are important for BCI researchers, moral philosophers and the users themselves.

In the five sections hereafter I will begin with a concise description of BCIs in which I pay special attention to the different applications. This is followed by stating the research questions. In the section thereafter I point out the goal of this thesis and argue why analyzing the relation between BCI-applications and their users is important. Then a general introduction to human-technology relations is given which allows the reader to place the research in thesis in a broader framework. This is followed by an outline of the rest of the thesis in which I briefly explain how the functional, epistemological and phenomenological view on human-technology relationships will be employed to answer the research questions.

1.1 Brain-Computer Interfaces

BCIs are an emerging as well as a converging technology that detects regulated or non-regulated brain signals and translates them into command signals for external devices, such as a computer, prosthesis or motorized wheelchair. The BCI itself: the electrodes and signal processing unit, enables a direct communication pathway between the brain and the device to be controlled. Persons for whom a BCI would be useful usually have disabilities in motor function or communication, which could be (partly) restored by using a BCI to steer a motorized wheelchair, a prosthesis or by selecting letters on a computer screen. This technology has a high societal relevance since it can significantly improve the quality of life for humans with central nervous system (CNS) disabilities, which effects millions of people worldwide. BCIs can also be used to play computer games as well as other entertaining applications such as Second Life and Google Earth. So its likely that they will play a roll in the lives of non-paralyzed persons as well. And in addition, a BCI can also be used to merely monitor certain brain activity like, for instance, cognitive workload while making an exam, concentration while conducting surgery or the electroencephalogram (EEG) of a patient.

Of particular importance are the conceptual distinctions that will be made between different types of BCI-applications. These distinctions are important because each category has distinguishing features which determine the type of relation its users has with the application. The applications will be categorized on two levels. On the first level a distinction will be made between *deliberate* and *non-deliberate* applications. Deliberate applications require deliberate, conscious thought to control the application, whereas non-deliberate applications use brain signals that are not deliberate or consciously regulated. The nature of this distinction is about *how* the extracted brain activity is *regulated*. Before giving an example that clarifies this distinction, it is important to note that deliberate applications have two distinct ways to regulate brain signals. The first is based on motor imagery (imagining movement) and the second is based on visual evoked potentials (certain brain signals that are induced by visual stimuli). How this precisely works will be explained in the next chapter.

An example may illustrate the distinction between deliberate and non-deliberate applications. First, consider a person who is using a BCI-controlled-wheelchair. This person has to consciously and deliberately regulate his or her brain activity to control the wheelchair. Now consider a BCI-system that monitors the concentration of a physician who is operating a patient. This BCI-system warns the physician when his or her concentration is below a certain level and it becomes irresponsible to continue operating. The physician does not consciously or deliberately regulate his or her concentration to control the warning system. The process goes naturally and unnoticed and the brain signals themselves are not consciously nor deliberately regulated. Thus, I will claim, a distinction can be made between deliberate and non-deliberate applications.

On the second level – which is a further distinction within the deliberate applications - I will make a distinction between *bodily*, *linguistic* and *virtual applications*. Bodily applications are devices which restore motor abilities like motorized wheelchairs and prostheses. These devices are controlled by motor imagery. Linguistic applications restore the ability to communicate by enabling its user to select letters on a computer screen with a cursor. Linguistic applications can be controlled with motor imagery as well as visual evoked potentials. And lastly, virtual applications simulate a virtual environment like computer games or Google Earth. Virtual applications can be controlled with both motor imagery and visual evoked potentials. The nature of the distinction between bodily, linguistic and virtual applications is about the *purpose* of the application. So, I will claim, a distinction can be made between *bodily*, *linguistic* and *virtual applications*. In overview, there are:

(1) Non-deliberate applications: do not require conscious and deliberate thought

(2) Deliberate applications: require conscious and deliberate thought

(a) *Bodily applications*: restore motor function
- Motor imagery

(b) *Linguistic applications:* restore ability to communicate
- Motor imagery or visually evoked potentials

(c) *Virtual applications:* control virtual environments
- Motor imagery or visually evoked potentials

Thus, I will distinguish between four categories of applications (non-deliberate, bodily, linguistic and virtual applications) which will all be analyzed in this thesis. However, both non-deliberate and virtual applications are rather diverse and there are many examples of them. Analyzing each one of them would be an immense task and would fall beyond the scope of this thesis[1]. Consequently, I will focus on one type of each. In case of non-deliberate applications, I will focus on a BCI-system that monitors the concentration of a physician who is operating a patient. In case of virtual applications, I will focus on Google Earth. Furthermore, as been noted above, deliberate applications have two distinct ways to regulate brain signals. The first is based on motor imagery and the second on visual evoked potentials. The virtual application of interest in this thesis, Google Earth, is controlled with visually evoked potentials. And the linguistic application on which I will focus in this thesis is controlled with motor imagery.

1.2 Research Questions

In this thesis I will analyze the relationship between BCIs, their applications and their users in an attempt to answer the main research question and the sub-questions which are derived from it:

- What is the functional, epistemological and phenomenological relationship between BCIs, their applications and their users?

  1) What are BCIs, what are their distinguishing features and possible applications?

  2) How do functions of BCIs and their applications relate to abilities of their users and how can they extend these abilities?

  3) How can the epistemological relationship between BCI-applications and their users be described, evaluated and improved?

  4) How do BCIs and their applications mediate the experience of the world for their users?

[1] I have chosen to limit myself to analyzing one type of virtual application because otherwise this thesis would become an analysis of virtuality, which would fall beyond the scope of this thesis.

1.3 Research Purpose

The overall goal of this thesis is to better understand the relationship between BCIs, their applications and their users. I will try to realize this goal by analyzing the human-BCI relationship from a functional, epistemological and phenomenological perspective. First of all, analyzing the human-BCI relationship from a functional viewpoint is important because BCI-systems are, just as other technological artifacts, entities designed to fulfill certain functions. By fulfilling these functions, BCI-systems ‘do’ something for their users. In order to better understand *what* BCIs precisely do for their users I will analyze the functions of BCI-systems in relation to abilities of their users, and I will analyze how they may extend these abilities. Understanding what a BCI precisely ‘does’ for its user and analyzing how they extend abilities of their users is a useful point of departure for better understanding the relation between a BCI and its user. This is so because, for one reason, the outcome of the functional analysis is the basis for a further epistemological analysis. The functional analysis will point out that there is a cognitive relation between linguistic and virtual applications and their users. Linguistic applications extend the means for communicative processes. And the virtual application of interest here, Google Earth, extends the means to obtain information. Both communicating and obtaining information are cognitive, or epistemic, processes.

Secondly, a good way to analyze this epistemic relation in more detail is by employing an epistemological perspective on human-technology relations. It is important to note that an epistemological perspective on human-technology relations only works for so called cognitive artifacts. These are artifacts that contribute to cognitive processes. Both linguistic and virtual applications contribute to cognitive processes and are therefore cognitive artifacts. An epistemological analysis will reveal how linguistic and virtual applications exactly contribute to certain cognitive processes of their users. A better understanding of this epistemic relation may result in a better design of these applications in terms of the quality of the cognitive processes.

Thirdly, both the functional and epistemological approaches to human-technology relations see technological artifacts as mere functional entities. They are indeed entities with functions, but there is more to it. By having certain functions, a BCI-application *mediates* the experience of the world for its user. For example, the function of a BCI-controlled-wheelchair is to restore motor ability. By realizing this function, it opens up a range of new possibilities, such as, visiting family or friends or going to a movie-theater. This mediates how the user experiences the world and also changes his or her lifeworld. A phenomenological analysis will reveal how a BCI-application changes the lifeworld for its user. Furthermore, the BCI itself (the electrodes and signal processing unit) is between the application and the user in a position of *mediation*. A phenomenological analysis will reveal how this mediation contributes to, or perhaps better, determines the relation between the BCI-application and its user. Additionally, Verbeek’s phenomenological concept *technological intentionality* will turn out to be very fruitful for understanding the relation between a BCI and its user. This concept is concerned with the *directedness* of technologies. BCIs are directed at their users and therefore have technological intentionality. Moreover, the concept will be used as a point of departure to form two novel human-technology relations developed for better understanding the human-BCI relation.

In this paragraph I will give three concrete examples why each of the three perspectives is useful for analyzing the human-BCI relation. Firstly, the functional analysis points out that BCI-systems extend the means of their users to realize their intentions. They extend the range of (behavioural) options for their (paralyzed) users and expand their action horizon. This influences their personal identity and autonomy and should therefore be taken into account in a discussion on the moral desirability of BCIs in terms of personal identity or autonomy. Secondly, the epistemological analysis, which partly builds on the conclusions of the third chapter - describes, evaluates and gives suggestions to improve the epistemic quality of linguistic and virtual applications. Insights resulting from the epistemological analysis are valuable for the designers because they can lead to a more efficient design of those applications, which is beneficial for the users as well. And lastly, the phenomenological analysis points out that there is an *embodiment relation* with bodily applications (BCI-controlled-wheelchairs and BCI-controlled-prostheses). The closer to invisibility, transparency and extension of one's bodily sense the wheelchair or prosthesis allows, the better it will be embodied. The degree of embodiment determines the ease with which a BCI-controlled-wheelchair or BCI-controlled-prosthesis can be used. Designers should take these criteria into account when designing a BCI.

Lastly, BCIs are an emerging and converging technology resulting from a highly interdisciplinary field. It receives contributions from biomedical engineering, neuroscience, computer science, nanotechnology and neurology. The philosophical analysis in this thesis provides conceptual clarification which may contribute to the interdisciplinarity of BCI research. If all the persons involved in the research would use the same concepts to describe BCI-systems, it would make interdisciplinary communication easier. Also, the conceptual analysis of different BCI-applications in the second chapter, which resulted in the development of a novel taxonomy of different BCI-applications, allows a BCI researcher to place his or her research in a broader conceptual framework.

1.4 Human-Technology Relationships

The research in this thesis is embedded in a traditional theme in the philosophy of technology, namely human-technology relations. Many views on the relation between humans and technology are encountered in the history of thought about technology. Philosophers like Ernst Kapp, McLuhan and David Rothenberg have tried to conceptualize human-technology relations in terms of functions. The basic idea of their anthropological view is that artifacts extend and amplify human abilities by extending these abilities beyond the human body. A more specific (and contemporary) variant of this view is proposed by Andy Clark, David Chalmers and Hutchins, amongst others, and is referred to as *extended* or *distributed cognition*. Their perspective is concerned with our functional relation with so-called *cognitive artifacts*. These are artifacts that function as a contributor to human cognitive processes.

Other philosophers like Martin Heidegger and Maurice Merleau-Ponty have tried to conceptualize human-technology relations from a phenomenological standpoint. Their theories analyze the way in which artifacts transform the experience of and engagement with the world. An essential aspect in all those theories is how artifacts relate to the human body or mind, and how we interact with them. These frameworks can roughly be grouped in two classes: (1) theories that analyze the functional relation between humans and artifacts and (2) theories that analyze the phenomenological relation between human and artifacts. The first class has a specific subclass which is only concerned with the functional relation between humans and cognitive artifacts.

Contemporary philosophers of technology Brey, Ihde and Verbeek draw from these traditional theories to developed their own frameworks on human-technology relations. Brey mainly operates within the functional perspective and has developed a framework in which he conceptualizes the relation between humans and technology by arguing that technology extends the means to realize our intentions. In addition to his general perspective on humans-technology relations, Brey also developed a perspective on the functional relation between humans and computers. Ihde operates within the phenomenological perspective and has developed a framework in which he outlines how artifacts mediate between humans and the world. And Verbeek operates within the phenomenological perspective. In the following section I will explain how and which frameworks I will employ to analyze the relation between BCI-applications and their users.

The underlying idea which ties these philosophical approaches to human-technology relations together is based on a philosophical anthropological understanding of human beings and how technology relates to this. Philosophical anthropology tries to better understand what characterizes or defines human beings. An essential characteristic is that we are tool using beings. And our relation with these tools largely determines who we are. This characteristic distinguishes us from other animals[2]. Therefore, a better understanding of the relation with our tools contributes to a better understanding of what characterizes human beings. If the relation with our tools largely determine who we are, and our tools develop into ever more complex technological systems, it implies that human beings become more complex as well. Thus, the red line throughout this thesis is based on a philosophical anthropological understanding of what it means to be human and how technology relates to this. In the reflecting section of the last chapter, I will try to frame the relation between BCIs and their users from a broader historical and anthropological perspective.

1.5 Research Plan and Outline

Each BCI-system consists of electrodes, a signal processing unit and an application. In my analysis the primary focus is on the relation between the application and its user. This is so because the user primarily has a relation with the application. Features of the application largely determine the relation with its user, which is largely determined by the BCI itself: the electrodes and signal processing unit. The BCI itself establishes a direct communication pathway between the brain and the application and enables its user to interact with the application without using the body. This feature largely determines the relation with the application. In the functional and phenomenological analysis the BCI itself will be analyzed, but, again, the focus throughout the thesis will be on the application. In the next paragraphs I will present an outline of this thesis and briefly explain how I will go about.

Chapter 2

In the second chapter an overview of BCI technology will be given. I will present a technical description of the technology, explain how they are used, for whom they are useful and I will conceptually analyze different types of applications. This results in a taxonomy in which all applications with similar features are grouped. This taxonomy allows me to distinguish between different types of applications, which is the point of departure for the rest of the thesis.

Chapter 3

In the third chapter I will analyze the functional relation between BCI-applications and their users. This will be done by drawing from McLuhan's and Brey's functional perspective on human-technology relations. Their theories presuppose that artifacts are entities with certain functions.

[2] One might argue that certain animals like chimpanzees also use artifacts to realize their intentions, for example, by using a stick to get ants out of the ground. However, sticks and other artifacts animals use are not intentionally designed to realize goals (or functions), which *is* the case for the technological artifacts we use.

The function of a car, for example, is to transport and the function of a calculator is to calculate. By having these functions, artifacts extend our own functional capacities. A car significantly increases or extends our locomotive function and a calculator does this for our ability to calculate. As a point of departure I will employ McLuhan's framework in which he argues that technology literally extends human organs, senses or functions. It will be examined how BCI-applications extend organs, senses or functions. I will then make use of Brey's framework which builds on insights of McLuhan and takes the notion of technology-as-extension to a higher level of abstraction. Brey claims that technology extends the means by which we can realize our intentions. After analyzing BCI-applications in terms of McLuhan's and Brey's frameworks it will become clear that they extend the means of their users to realize their intentions. And in addition, two types of BCI-systems – linguistic and virtual applications - extend the means of their users to realize cognitive processes. This conclusion is one of the building blocks of the fourth chapter.

Chapter 4

In the fourth chapter I will analyze the relation between BCI-applications and their users from an epistemological standpoint. One of the conclusions of the third chapter (that linguistic and virtual applications extend the means of their users to realize cognitive processes) will be taken as a point of departure. I will begin with describing these cognitive processes in more detail by employing Brey's view on human-computer relations. Brey has described the cognitive relation between computers and their users which has many similarities with the cognitive, or epistemic, relation between linguistic and virtual applications and their users.

The next step will be to evaluate the *epistemic quality* of this relation by using Goldman's five epistemic standards. Goldman has developed five standards to evaluate the quality of epistemic practices. These standards are the power, fecundity, speed, efficiency and reliability of epistemic practices. After having described and evaluated the cognitive relation, I will try to improve it. This is done by making use of Hollan, Hutchins & Kirsch's view on digital representations, who have developed a number of suggestions to improve the epistemic quality of computers. These suggestions are based on a framework which is referred to as *distributed cognition*. They claim that what is important in efficiently distributing cognition across the brain and a computer is the nature of the digital representations. The authors came up with three ways of improving the representations on computer screens more effectively in terms of distributing cognition, which will be used to improve the epistemic quality of linguistic and virtual applications.

Chapter 5

In the fifth chapter I will analyze the phenomenological relation between BCI-applications and their users by employing Ihde's framework on human-technology relations. Ihde has distinguished between four types of human-technology relations: the *embodiment relation, hermeneutic relation, alterity relation* and *background relation*. In an embodiment relation artifacts mediate between a human and the world. All BCI-systems display some structural features of embodiment relations and therefore mediate between its user and the world. The phenomenological analysis will reveal *how* they mediate the experience of the world.

In the previous two chapters BCIs were approached as merely functional entities. They are indeed entities with functions. But, this is not the whole story. By having certain functions, BCIs can enhance the bodily and cognitive capacities of their users. And by doing so, they change the capacities of their users, which are therefore different from their naked capacities. Through extending the bodily and cognitive capacities of their users, BCIs also transforms them. For this reason, they are more then mere functional entities. These are valuable insights that supplement the ones gained in the previous two chapters. Additionally, I will also relate BCI-applications to Verbeek's *cyborg relation* and *composite relation*, which will result in my own development of two new human-technology relations: the *reciprocal relation* and the *unidirectional relation*. Also, the concluding sections of chapters three to five will end with a reflection in which I will try to go beyond the conclusions and try to develop some speculative ideas on the future use of BCIs and the philosophical consequences of this.

Chapter 6

To finish, in the sixth chapter an overall conclusion will be given. In this conclusion I will demonstrate to what extend the overall research question is answered and briefly sum up the most important insights of this thesis. And additionally, I will reflect on my analysis, place it in a broader framework and provide some moral considerations on the desirability of BCI-systems. In the reflection I will claim that BCIs could induce a new stage in the evolution of our cognitive system. I will do so by relating possible developments in BCI-research with Donald Merlin's book *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition.* In this book he claims that the human cognitive system has evolved over three stages each of which was characterized by a change in the memory system. Certain BCIs could induce a radical change in our memory system and can result in the evolution of a new type of human being.

2. Brain-Computer Interfaces

'For what is special about human brains, and what best explains the distinctive feature of human intelligence, is precisely their ability to enter into deep and complex relations with non-biological constructs, props and aids.'

Andy Clark (2003, p5)

Manipulating devices by using thought alone has a science fiction touch to it. However, recent developments in BCI-research have made this possible. A BCI, sometimes called brain-machine interface (BMI), is an emerging technology which translates brain activity into command signals for external devices. The interface establishes a direct communication pathway between the brain and the device to be controlled. When using the interface one does not take the normal route through the body's neuromuscular system – from brain and nerves to the muscles - but one controls artifacts merely by means of increasing or decreasing specific neural activity.

This technology is mainly being developed for medical reasons, because there is a societal demand for technologies which help to restore functions of humans with central nervous system disabilities. The brain and spinal cord, when damaged, are often unable to repair themselves. Moreover, the world population is increasing as well as the average age of humans. This means that diseases like Parkinson, Alzheimer, epilepsy, accident-induced spinal cord injuries and neural damage resulting from diabetes are likely to increase. Patients for whom a BCI would be useful usually have disabilities in motor function or communication. This could be (partly) restored by using a BCI to steer a motorized wheelchair, a prosthesis or by selecting letters on a computer screen with a cursor. This technology can significantly improve the quality of life for humans with central nervous system disabilities and has for this reason a high societal relevance. Furthermore, BCI-research is an increasingly expanding area and due to the interdisciplinary character of BCIs it also induces growth at the interface of biomedical engineering, neuroscience, computer science, nanotechnology and neurology (Berger, 2007). Due to the interdisciplinarity of BCIs they may be referred to as a converging technology. In the remaining part of this chapter I will give an overview on BCI-technology and thereby try to answers the first research question:

- What are BCIs, what are their distinguishing features and possible applications?

In the following sections I start out with contrasting BCIs with neuroprosthetics. Next, I will outline different approaches to how a BCI can be controlled. After that, I will present a short overview on different sensor systems. Thereafter, I will point out different categories of BCI-applications and construct a conceptual framework of these applications. And this chapter ends with a conclusion in which I will present the most essential features of BCIs.

2.1 Brain-Computer Interfaces vs. Neuroprostheses

When someone is using a BCI the causal flow goes from the brain to an artifact. The technology is designed in such a way that the brain is the first element in a causal chain (Figure 1). This causal chain goes as follows. A subject has an intention to reach a particular goal, for example, moving a cursor to select a letter. In order to do so the subject has to increase or decrease certain neural activity in order to move the cursor on the screen. This can be done by imagining certain movements, which is referred to as *motor imagery*. This change in neural activity is detected by electrodes and translated by the signal processing unit into command signal for the spelling device. The subject receives visual feedback of the movement of the cursor and sees whether it succeeds in the task. If the particular letter is selected the subject has reached its goal and can begin with selecting another letter. Due to the feedback mechanism this process is a causal loop.

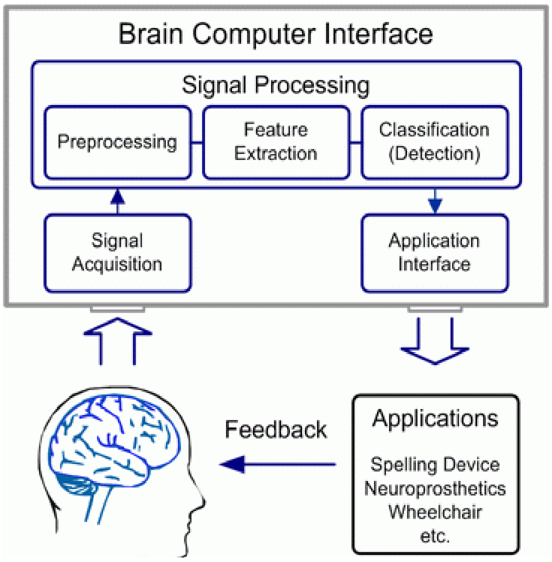

Figure 1. Schema of a BCI-system.

A second way to use a BCI is by making use of evoked potentials. An evoked potential, sometimes called evoked response or event related potential (ERP), is an electrical potential recorded from the brain after a subject is presented with a sensory stimulus. In case of BCI-systems that make use of evoked potentials the system itself produces the sensory stimulus that induces the evoked potential. In the next section this will be explained in more detail.

In the previous paragraphs I have described BCI-systems that require conscious and deliberate thought to control the application. But, in addition, there are also BCIs that do not require conscious and deliberate thought to control the application. For example, a BCI that monitors cognitive workload of a student who is taking an exam. Or to give another example, a BCI that monitors concentration of a physician who is conducting surgery. Latter on in this chapter I will give a more detailed description of different types of BCIs.

Neuroprostheses

In contrast, a neuroprosthesis is designed to transmit electrical signals *to* the brain like, for example, sensory information or electrical signals to reduce chronic pain, tremor or clinical depression. In case of sensory information, the retina implant or cochlear implant are examples of sensory neuroprostheses. In both cases, the neuroprosthesis translates sensory information - vision and hearing – into electrical signals which are transmitted to the visual nerve or the auditory nerve. In case of reducing chronic pain, tremor or clinical depression, an invasive electrode stimulates particular parts of the brain. A neuroprosthesis can also be called a computer-brain interface, because the causal flow is from an artifact to the brain. In this case the brain is the last element in the causal chain. In both BCIs and neuroprostheses the causal flow is one-way, either from brain to artifact or vice versa. Two-way BCIs would enable a brain and an external device to exchange information in both directions, but are not successfully implanted in animals or humans yet (Soussou & Berger, 2007).

2.2 Approaches to Brain-Computer Interface Control

There are three different approaches to controlling a BCI. The first approach is learning to regulate brain activity by means of *neurofeedback* and operant learning principles. The second approach is a machine learning procedure which reduces – by means of algorithms and statistics - neural noise of brain states within a calibration session. In practice many BCIs use a combination of these two methods. And a third approach is based on evoked potentials.

Neurofeedback

During the neurofeedback method a participant receives real-time visual or auditory feedback of his of her brain activity. The participant is explicitly asked to increase or decrease certain brain activity, for example, imagining specific movements. By means of a feedback signal, the participant receives information about the brain activity of interest. When the participant succeeds in controlling a particular brain activity he or she is rewarded with, for example, a signal on a screen, sound or vibration. After a number of training sessions the participant acquires, to a certain extend, conscious control over certain brain activity, which is causally linked to the application.

Machine learning

In case of the machine learning approach the training is done by adaptive algorithms. These algorithms require examples from which they can infer the underlying statistics of the particular brain state. During a calibration session a participant has to produce a particular brain state a number of times. The algorithm can extract spatiotemporal blueprints of this particular brain state, which can subsequently be used in neurofeedback sessions. It is important to note that 20% of the users is unable to successfully classify brain activation patterns. Both neurofeedback and machine learning do not work for these subjects. This group is referred to as the BCI illiterates. Further research is needed why this phenomena occurs (Dornhege et all., 2007).

Evoked potentials

BCIs that make use of evoked potentials are somewhat easier to use because they require less training. This is so because the participant is not required to induce certain brain signals him- or herself, but the BCI-system itself induces it. There are different ways to evoke brain signals, or brain potentials. In case of BCIs, visually evoked potentials (VEPs) are often used. A VEP is a response of the brain to a visual stimulus. One way to make use of VEPs to control a BCI goes as follows. A participant is presented with a screen on which the letters of the alphabet are presented. Each letter flickers with a different frequency. If the participant looks at the letter A, for example, the brain responds to the specific frequency of this letter, which results in a specific evoked potential. To be more precise, evoked potentials that are induced by high frequency flickering visual stimuli are referred to as steady state visual evoked potentials (SSVEPs). These SSVEPs are detected by the electrodes and used as command signals for the spelling device. So instead of focussing to control a cursor to select letters on a screen, the participant merely has to look at the letter he or she wants to select (Friman, Luth, Volosyak and Graser, 2007).

A second way to make use of VEPs to control a BCI is by using the P300 potential (P3), which is a specific type of evoked potential. It is referred to as the P300 potential because it is visible on the electroencephalogram (EEG, see next section) after roughly 300 ms. Using the P300 potential for BCI based spelling device goes as follows. A participant is presented with a 6 x 6 grid of characters (Figure 2). This grid has 6 rows and 6 columns. First each row is highlighted and then each column is highlighted. When a highlighted row or column contains the character the participant has in mind the P300 potential is evoked. The combination of the row and column which evoked the P300 potential locates the desired character. A number of trials must be averaged to clear neural noise from the recordings (Sellers and Donchin, 2006).

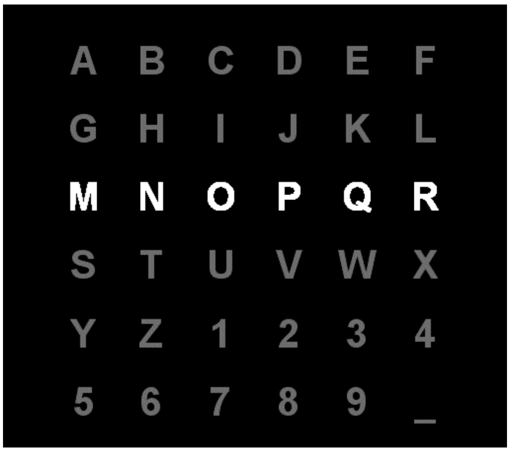

Figure 2. The screen of a P300 based spelling device.

2.3 Sensor Systems

In the previous paragraphs I have described how brain activity can be controlled. These brain signals are extracted from the brain with electrodes, which are either *invasive* or *non-invasive*. Invasive electrodes, sometimes called *direct brain-computer interfaces*, interact with the brain directly and are placed inside one's brain or on the surface of one's brain. Non-invasive electrodes interact with the brain indirectly by transmission through the skull.

Invasive Electrodes

Invasive electrodes usually consist of multielectrode arrays. These multielectrode arrays provide a means to detect both electrophysiological activity and chemical activity of neurons in the brain or spinal cord. Neurosurgery is needed to place the electrodes. The majority of invasive electrode research is still in an experimental stage and are being tested on animals. Multielectrode arrays can be implanted directly in the motor cortex and therefore extract direct motor commands. Research with monkeys has shown that it is possible to use an implanted multielectrode array in the motor cortex and use the extracted brain signals to control a robot arm. After a while, the motor cortical neurons had learned a direct representation of the robot arm, independent of its real arms. The monkey could move its arms and robot arm at the same time without apparent problems (Chapin, 2007).

There is currently a growing use of electrocorticography (ECoG) as a method for invasive electrodes. In this method the electrode is placed on the surface of the brain. There are three reasons to use ECoG. First, it is safe and has been tested in more then thousand humans. Second, its resolution comes close to that of direct penetrating electrodes and it is higher than the resolution of non-invasive electrodes. Third, the recorded signals have a high amplitude and broader band width (Gerhardt & Tresco, 2007). Invasive electrodes have different characteristics than non-invasive electrodes. First, subjects do not need extensive training to control the output signals. And second, the number of tasks (i.e., degrees of freedom) are potentially higher, because a number of multielectrode arrays can be implanted in different brain areas.

Non-invasive Electrodes

Non-invasive electrodes are placed on the scalp. The most common technique for non-invasive sensor systems is electroencephalography (EEG), which records electrical activity of the brain. Evoked potentials are usually detected with EEG. Other non-invasive techniques are positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). However, the latter two are demanding, expensive and tied to the laboratory and are therefore not often used. In contrast, EEG electrodes (Figures 3, 5 and 6) and invasive electrodes are portable and can therefore be used in daily life. The bottleneck of BCIs are the sensors. Invasive sensors only last for a limited amount of time before they loose signal. Non-invasive sensors need conductive gel and have therefore a long preparation time.

2.4 Applications of Brain-Computer Interfaces

The BCI itself consist of the electrodes and signal processing unit, which are used to steer a particular application like, for example, a motorized wheelchair, prosthesis, spelling device or computer game. Although the applications are diverse and used for both healthy and disabled subjects, BCIs are mainly developed for persons who have disabilities in motor function and communication. Disabilities in motor function can be partly restored by using a BCI to steer a motorized wheelchair or a prosthesis (Figures 3 and 4).

Figure 3. A BCI-controlled-wheelchair.

Figure 4. A BCI-controlled-hand-prosthesis.

At this point in time, using a BCI-controlled-wheelchair is possible. However, using a BCI-controlled-prosthesis is still in an experimental stage (Hochberg et al., 2006). It is important to note that controlling a motorized wheelchair or prosthesis by means of a BCI is done by imagining certain movements, for example, by imagining to move the right arm to the left or to the right.

A BCI may also help to restore one's ability to communicate. The application then uses brain signals to control a cursor on a computer screen. After some practice, the cursor control becomes accurate enough to spell words and sentences by using the interface to pick out letters of the alphabet (figure 5). There are drawbacks, however, the subjects need extensive training and intense concentration to successfully use the spelling device, which is by the way the case for many BCIs. We have also seen that letters on a computer screen can be selected by making use of visually evoked potentials. Thus, selecting letters on a computer screen can be done by controlling a cursor and by using visually evoked potentials.

Although applications for healthy subjects are not pursued as much as applications which restore disabilities, they do have a high industrial and commercial significance. At this point in time it is easier to use a computer or other device with a mouse, keyboard, or speech or gesture recognition device. Nonetheless, there is an increasingly growing field of research within the BCI-research-community that concerns the use of BCIs for playing computer games (Nijholt & Desney, 2007). Perhaps it is interesting to note that at this point in time the first BCI for playing computer games is commercially available. Computer games may be controlled by using motor imagery. An avatar in a game, for instance, can be controlled by using imagining movements.

Figure 5. A person using a BCI based on motor imagery to select letters on a computer screen.

Figure 6. A person using a BCI based on visually evoked potentials to control Google Earth.

Another example of an application for healthy subjects is using Google Earth with a BCI (Figure 6). Google Earth can be controlled by visually evoked potentials. In the above figure you see a person who is using a BCI based on visually evoked potentials to control Google Earth. On the computer screen in the left of the picture the command signals like 'go to right', 'go to left' or 'zoom in' are presented. Each command signal lights up and when the participant looks at it, it induces the P300 potential, which is causally linked to the application.

An often overlooked feature of BCIs is that they can provide an independent channel for man-machine interaction. One could, for instance, monitor alertness, concentration, emotions or cognitive workload, because the brain holds the key to access of these variables which are otherwise difficult to obtain (Dornhege et. al., 2007). The r*eal-time* monitoring of concentration or alertness could be useful for safety critical procedures, such as driving a truck or a medical operation (Nijholt, 2008). A driver or physician can be warned by a BCI-system when his or her concentration is below a certain level and it becomes irresponsible to proceed with driving or operating. Other examples are monitoring cognitive workload of students while performing a particular cognitive task or monitoring the brain activity of a comatose patient.

A Taxonomy of Applications

In the previous paragraphs I have described a number of BCI applications. In order to provide some clarity and structure I will categorize all applications with similar features and develop a conceptual taxonomy of different types of BCI-applications. Making these distinctions is important because each category of applications has distinguishing features and will after analysis result in a different relation between the BCI and its user. I will categorize the applications on two levels. On the first level I make a distinction between *deliberate* and *non-deliberate applications*. The nature of this distinction is about *how* the detected brain signals are regulated. In case of deliberate applications the detected brain signals are consciously and deliberately regulated to control the application. Whereas, non-deliberate applications do not use consciously or deliberately regulated brain signals to control the application. Note that deliberate applications have two distinct ways to regulate brain signals. The first is based on motor imagery and the second on evoked potentials.

An example may clarify the distinction between deliberate and non-deliberate applications. Consider a person who is using a spelling device. This person has to consciously and deliberately regulate his or her brain signals to control the cursor or to look at a specific letter. Now, in contrast, consider a BCI-system that monitors the concentration of a physician who is operating a patient. This BCI-system warns the physician when his or her concentration are below a certain level and it becomes irresponsible to continue operating. The physician does not consciously or deliberately regulate his or her concentration to control the warning system. The process goes naturally and unnoticed and the brain signal of interest, concentration, is not consciously nor deliberately regulated. Thus, I conclude, there are applications that use consciously and deliberately regulated brain signals and there are applications that use brain signals that are not consciously or deliberately regulated. The first I refer to as deliberate applications and the second as non-deliberate applications.

Further distinctions can be made within the deliberate applications in which I have identified three categories. First, BCIs can be used for controlling devices that restore motor function like motorized wheelchairs and prostheses. These devices are controlled by motor imagery (imagining movement). I refer to this category as *bodily applications*. Second, BCIs can be used for restoring the ability to communicate by selecting letters on a computer screen. I refer to this category as *linguistic applications*. Linguistic applications can be controlled by both motor imagery and by using visually evoked potentials. And finally, BCIs can be used for controlling a virtual environment like computer games, Google Earth and so forth. I refer to this category as *virtual applications*. Virtual applications can be controlled by motor imagery as well as visually evoked potentials. Thus, I conclude, within the deliberate applications a distinction can be made between bodily, linguistic and virtual applications. In sum, there are:

(1) Non-deliberate applications: do not require conscious and deliberate thought

(2) Deliberate applications: do require conscious and deliberate thought

(a) *Bodily applications:* restore motor function
- Motor imagery

(b) *Linguistic applications:* restore ability to communicate
- Motor imagery or visually evoked potentials

(c) *Virtual applications:* control virtual environments
- Motor imagery or visually evoked potentials

2.5 Conclusion

In this chapter I have presented an overview on BCI-systems in an attempt to answer the first research question:

- What are BCIs, what are their distinguishing features and possible applications?

BCIs are an emerging as well as a converging technology that extracts brain activity and translates it into command signals for external devices. The most distinguishing feature of a BCI is that it establishes a direct communication pathway between the brain and an artifact. They have a significant societal relevance, because they can help with restoring disabilities in motor and communicative abilities, which effects millions of people worldwide. Neurofeedback, machine learning algorithms and visually evoked potentials are three distinct methods for controlling a BCI. Furthermore, brain signals are extracted with invasive or non-invasive electrodes. Invasive electrodes are implanted in one's brain, whereas non-invasive electrode are placed on one's scalp. The extracted brain signals are processed by a processing unit and used as command signals for the external device. Applications of BCIs are diverse and can be categorized on two levels. On the first level I made a distinction between non-deliberate and deliberate applications. Deliberate applications can, depending on the type of application, be controlled by motor imagery or evoked potentials and have three subcategories: bodily, linguistic and virtual applications.

3. The Functional Relationship Between Brain-Computer Interface Applications and their Users

'Today, after more than a century of electronic technology,
we have extended our central nervous system itself
in a global embrace, abolishing both space and time
as far as our planet is concerned.'

Marshal McLuhan (1994, p.3)

In the previous chapter I have presented a technical description of BCIs. In this description it became clear that BCIs detect brain signals that are used to control a diverse range of applications like motorized wheelchairs, prostheses or spelling devices. Of particular importance are the conceptual distinctions I have made between different categories of applications. I have argued that a distinction can be made between *deliberate* and *non-deliberate* applications. The nature of this distinction is about *how* the extracted brain signals are regulated. Deliberate applications require deliberate, conscious thought to control the application, whereas non-deliberate applications use brain signals that are not deliberate or consciously regulated. Furthermore, I have made three conceptual categories within the deliberate applications. Firstly, BCIs can be used for controlling devices which restore motor function, which I refer to as *bodily applications*. Secondly, BCIs can be used for devices that restore communication, which I refer to as *linguistic applications.* And finally, BCIs can be used for controlling a virtual environment, which I refer to as *virtual applications*.

In this chapter I will analyze the functional relationship between BCIs, their applications and their users. In better understanding this relation I will draw from two thinkers: Marshal McLuhan and Philip Brey. The underlying idea in their conceptualization of human-technology relations is that artifacts are entities with certain functions[3]. For instance, the function of a car is to transport and the function of a calculator is to calculate. By having these functions, artifacts extend our own functional capacities. A car significantly increases or extends our locomotive function and a calculator does this for our ability to calculate. There is, however, a difference in how McLuhan and Brey argue that technology extends our functional capacities. McLuhan claims that technology literally extends human organs, senses or functions. Whereas Brey takes the technology-as-extension concept to a higher level of abstraction and claims that technology extends the means by which we can realize our intentions. By analyzing the functional relation between BCI-applications and their users I will try to answer the second research question:

- How do functions of BCIs and their applications relate to abilities of their users and how can they extend these abilities?

[3] The notion of 'function' has several conceptualizations. McLuhan and Brey adhere to the notion of function as it is used in engineering, where a function is defined as denoting the property of a technological object which is used for realizing a particular goal or purpose.

In the following three sections I will start out with presenting McLuhan's theory on technology as extension of man. In the section thereafter I will outline Brey's view on the functional relation between humans and technology. And in the final section I will give a conclusion in which I will argue to what extend the research question at hand is answered, which framework was best equipped to do so and speculate about the future abilities of BCI-systems.

3.1 McLuhan on Human-Technology Relationships

Marshall McLuhan (1911 - 1980) - a Canadian professor in English literature - published his Magnus opus *Understanding Media: The Extensions of Man* in 1964. In this influential and multidisciplinary study of technology and media, McLuhan draws from historical, sociological, aesthetical and philosophical theories to outline his view on technology in general and (electronic) media in particular.

3.1.1 Technology as Extension of Man

McLuhan's main claim was that technologies are an extension of our physical and nervous system to increase our power and speed. In the introduction of *Understanding Media* he wrote:

> 'During the mechanical ages we had extended our bodies in space. Today, after more than a century of electric technology, we have extended our central nervous system itself in a global embrace, abolishing both space and time as far as our planet is concerned' (McLuhan, 1994, p. 3).

In the above quote he more or less summarizes his view on technology. In general, he argued that mechanical technologies extend the body and electric technologies extend our senses and central nervous system. For example, a bicycle extends the feet, a radio extends the ears and a computer extends memory. McLuhan defined the concept 'extension' as an 'amplification of an organ, a sense or a function, (…)' (McLuhan, 1994, p. 172). This means there are three basic types of technological extensions: (1) extensions of organs, (2) extensions of senses and (3) extensions of functions. In the following paragraphs I will briefly describe a number of examples of each type of extension.

Extensions of Organs

The first category of extensions are extensions of organs[4]. McLuhan defined teeth, nails and hands as organs. So the concept 'organ' has to be interpreted rather broadly. He argued that clothing is an extension of our skin. In his words 'clothing, as an extension of the skin, can be seen both as a heat-control mechanism and as a means of defining the self socially' (McLuhan, 1994, p. 119). A house is seen as an extension of our bodily heat-control mechanisms as well. Furthermore, weapons like bow and arrow, spears and knifes are seen as extensions of hand, arm, nails and teeth. And finally, a phonograph – the predecessor of the record player – is analyzed as an extension and amplification of the human voice.

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[4] Ernst Kapp – by many referred to as the first philosopher of technology - was the first who developed the idea that technology extends human organs. In *Grundlinien einer Philosophie der Technik* (1877), he argued that *all* technical artifacts are projections of human organs. According to Kapp, humans unconsciously transfer the shape and functions of their body to artifacts. Any artifact is morphologically similar to the organ. This may be true for some artifacts, but there are many counterexamples to Kapp's theory, for example, books, airplanes and houses (Brey, 2000a).

Extensions of Senses

The second category of extensions are extensions of the senses. According to McLuhan, three of the senses can be extended by technology, namely: seeing, hearing and sense of touch. For example, the telephone extends one's auditory perception and is a kind of extra sensory apparatus. A radio is analyzed as an artifact that extends one's auditory perception as well. And finally, television – in cooperation with the video camera - extends one's seeing, hearing and sense of touch, which McLuhan called an *unified sensorium*[5].

Extensions of Functions

The third and last category of extensions are extensions of functions. McLuhan distinguished between bodily functions and functions of the central nervous system, which I refer to as *cognitive functions*. The wheel is analyzed as an extension of the locomotive function of the feet. A book is a medium which stores and expedites information and therefore extends human memory and our ability to communicate, which are both cognitive functions. In addition, McLuhan claimed that electronic media in general and the computer in particular contribute to information management, storage and retrieval, which are all cognitive functions. And finally, clocks are seen as an extension of our sense of time, which is a cognitive function as well.

Accelerated Interplay of Functions

The last concept of McLuhan's theory I want to introduce is *accelerated interplay of functions*. According to McLuhan, technologies can cooperate to extend or accelerate certain human functions. The example he uses - borrowed from Lewis Mumford's *The City in History* - are roads and wheeled traffic. They cooperate to extend the locomotive function of the legs. He called this accelerated interplay of functions. Consider another example. A pen and paper cooperate to extend the function of writing.

Summary

McLuhan argued that technology and media extend human faculties. Roughly, he argued that mechanical technologies extend the body and electric technologies extend our senses and central nervous system. Furthermore, technologies can cooperate to accelerate certain human functions, which McLuhan called accelerated interplay of functions.

McLuhan argued that technology can extend organs, senses or functions. The organs that technology can extend, he mentioned, are the central nervous system, skin, nails, teeth, voice, legs, feet, arms and hands. The senses technology can extend are one's seeing, hearing and sense of touch. And finally, the functions technology can extend are bodily or cognitive. In overview, technology can extend:

(1) Organs:	CNS, skin, nails, voice, hand/arm or leg/foot
(2) Senses:	Seeing, hearing or sense of touch
(3) Functions:	Bodily or cognitive

[5] One can also think of other artifacts that extend our perceptual apparatus. For example, microscopes, telescopes, glasses, hearing aids and a blind man's cane. In the fifth chapter, the relation we have with artifacts that extend our sensory apparatus will receive more attention.

3.1.2 Evaluating McLuhan's Theory

How plausible is McLuhan's theory about technology and media? The basic idea, that technology extends organs, senses or functions, seems plausible. Indeed, bow and arrow extend the arms and hands, a radio extends one's hearing and a computer can extends one's memory. However, McLuhan claimed that 'Any invention or technology is an extension or self-amputation of our physical bodies (…)' (McLuhan, 1994, p. 45). And 'that any technology could do anything but *add* itself on to what we already are' (McLuhan, 1994, p. 11 original italics). These claims seem rather doubtful, because there are technologies that do not extend an organ, a sense or a function (Brey, 2000a). For example, electric lighting is a technology that has as function to give light. There is no human organ, sense or function that can give light. There are other examples of artifacts that have functions not possessed by humans, such as burning, freezing, magnetizing or ionizing. This means there *are* technologies that add something new on to what we already are. Therefore, Brey (2000a; unpublished) has argued that a distinction can be made between artifacts that enhance or extend abilities of the unaided body or mind, and artifacts that add genuinely novel abilities. In the analysis of BCI applications in the next section of this chapter this distinction will turn out to be very useful.

Lastly, McLuhan claimed that television extends our seeing, hearing and sense of touch (a unified sensorium in his terms). I agree with McLuhan that television in cooperation with the camera extends one ability to see and hear, but I do not see how it can extend one's sense of touch. However, this does not mean that artifacts are unable to extend one's sense of touch. A blind man's cane, for instance, does extend one's sense of touch[6]. By using the cane, the blind man can feel his environment through the cane and thereby the cane extends his ability to sense his environment. In contrast, a television only provides visual and auditory information and not tactile information.

3.1.3 Brain-Computer Interfaces in Terms of McLuhan's Perspective

In this subsection I will try to answer the research question at hand by employing McLuhan's framework. Recall that I distinguished between four categories of BCI applications and that each application will be analyzed separately. In my analysis I will focus on the function of the application, because the user has a functional relation with the application - rather than with the BCI itself: the electrodes and processing unit, which largely determine the relation with the application. Before turning to the analysis, it must be noted that in terms of McLuhan's framework, all BCI-systems literally extend the central nervous system, an organ in McLuhan's taxonomy. They do so by detecting either regulated or non-regulated brain signals and convert them into command signals for the application.

Non-Deliberate Applications

Non-deliberate applications use brain signals that are not deliberately or consciously regulated. The application of interest here is a BCI-system that monitors the concentration of a physician who is operating a patient. This BCI-system warns the physician when his or her concentration is below a certain level and it becomes irresponsible to continue operating. The physician does not consciously or deliberately regulate his or her concentration to control the warning system. We have seen that McLuhan argued that technology can extend organs, senses or functions. The function of this non-deliberate application is to warn a physician when his or her concentration

[6] This example was used by Merleau-Ponty in his book *Phenomenology of Perception* to demonstrate that artifacts can be taken into the body-schema and extend one's body-schema.

are below a certain level. Humans are to some degree able – by means of introspection - to detect their level of concentration. This is a cognitive process and can - in terms of McLuhan's framework – be seen as a cognitive function. Thus, this non-deliberate application extends the cognitive function of detecting the concentration of its user.

Bodily Applications

Bodily applications restore motor function by steering a motorized wheelchairs or prosthesis. First, in the light of McLuhan's framework, a BCI-controlled-wheelchair extends the locomotive function of the legs of its user. They do this in the same way as McLuhan argued that the wheel extends the locomotive function of the legs. And second, a BCI-controlled-prosthesis extends an organ. Depending on the body part the prosthesis is used for, it extends, or better, replaces one's legs and feet or one's arms and hands of its user.

Both BCI-controlled-wheelchairs and BCI-controlled-prostheses are used to restore motor functions. But, there is a conceptual difference in the way a BCI-controlled-wheelchair and a BCI-controlled-prosthesis establish the extension. The wheelchair is merely controlled by the brain, whereas the prosthesis is controlled by both the brain and the stomp on which it is placed. In other words, the wheelchair is controlled by extending the central nervous system, whereas the prosthesis is controlled by extending both the central nervous system and the stomp on which it is placed.

Linguistic Applications

Linguistic applications restore the ability to communicate and are used for persons who are severely paralyzed and are therefore unable to communicate, verbally or otherwise. These applications enable the user to select letters on a computer screen and thereby to form words and sentences. By so doing, these applications extend the ability to communicate with language use in roughly the same way books did in McLuhan's theory. Communicating by means of language use is a cognitive process. This means that linguistic applications extend a cognitive function of its user.

In case of linguistic applications there is a not only a relation between the application and its user, but also between the application and the person(s) for whom the spelled words are meant. But this relation is difficult to analyze in terms of McLuhan's framework, because for a mere reader a linguistic application does not extend an organ, sense or function. One can argue that when someone reads the spelled words there is a cognitive relation between the linguistic application and the reader. But in terms of McLuhan's framework, it is difficult to see how it extends a cognitive function of a reader. In the following chapter I will present a theory which can account for this.

Virtual Applications

In this thesis I focus on one type of virtual application, Google Earth, which has as main function to provide geographical information. How does this function relate to organs, senses or functions. McLuhan argued that a book is a medium which stores and expedites information and therefore extends human memory, which is a cognitive function. Google Earth does the same, it provides information and thereby extends the memory function of its user, a cognitive function in McLuhan's taxonomy. In the next section I will refine the functional analysis between BCI applications and their users in terms of Brey's view on human-technology relations.

In this section I have analyzed BCIs in terms of McLuhan's framework. I related the function of the particular application to organs or functions of its user. In my analysis I focussed on the function of the application, because the user has a functional relation with the application, rather than with the BCI itself: the electrodes and signal processing unit. But, as we have seen, all BCIs literally extend the central nervous system, which is realized by the BCI itself. So the electrodes and signal processing unit facilitate, or better partly determine the relation with the application. McLuhan's concept *accelerated interplay of functions* can be used to include the BCI in the functional equation. Electrodes, signal processing unit and application all cooperate to accelerate a certain function. The BCI has as function to extend the central nervous system by extracting and translating brain signals into input signals for the application and the application builds on these signals to perform a function. The whole system can be seen as an architecture of functions all cooperating to accelerate one human function, wherein each component builds on functions of the previous one.

3.2 Brey on Human-Technology Relationships

In the previous section we have seen what McLuhan's framework could tell us about the relation between BCIs and their users. In this section I will explore what Brey's framework on human-technology relations can tell us about the relation between BCIs and their users. Brey - a Dutch philosopher of technology – was inspired by Kapp, McLuhan and Rothenberg to formulate a notion of technology-as-extension, not as extending organs, senses or functions - but as extending the means humans have to realize their intentions.

3.2.1 Brey on Technology-as-Extension

Brey's (2000a) notion of technology-as-extension is mainly inspired by Rothenberg's claim that technology extends human intentions. Rothenberg argued that our intentions become embodied in artifacts and are therefore extended by artifacts. Brey had some difficulty accepting the idea that intentions as such can be extended by technology. Therefore, he reformulated Rothenberg's claim - that technology extends intentions - into saying that technology extends the *means* by which human intentions can be realized. The intentions themselves are not extended. Humans have bodily and mental faculties to realize their intentions. Bodily and mental faculties are the naturally given means to realize intentions. Artifacts can extend or add to these means. Brey refers to this idea as the extension thesis:

> 'All artifacts extend the set of naturally given means (i.e., human bodily and mental faculties) by which human intentions are realized' (Brey, 2000a, p. 7).

The extension thesis emphasizes that artifacts build on the human body by adding functional features to functional features of the human body. Note that Brey does not claim that the added functional features must resemble the functional features of the human body. In this way, the framework can also account for artifacts that have functions not possessed by human faculties, which was a drawback in McLuhan's framework. So, bodily and mental faculties form one's original 'tool set' that humans use to get around in the world, which can be extended by other external means. These external means serve to extend the range of actions that someone is capable of doing by either enhancing existing capacities or adding genuinely new capacities. By using these means one's action horizon is extended. In the following paragraphs I will present Brey's taxonomy of different types of extensions.

Extensions in Relation to the Body

Of particular importance are Brey's extensions in relation to the body. He makes a distinction between *complementary extensions* and *amplificatory extensions*. Complementary extensions do not functionally extend a human faculty, but introduces new functional features next to existing ones, such as ionizing or freezing. Amplificatory extensions have functions also possessed by a human organ and add to, amplify or take over some of the functioning of that organ. Note that in McLuhan's framework all artifacts are amplificatory extensions.

Amplificatory extensions can have three types of relations with the extended organ, they can: *replace*, *supplement* or *enhance* the extended organ (or body part). Note that the brain is an organ as well. An artifact can replace the functioning of the organ by performing the function of that organ in such a way that makes the organ redundant for that purpose. For example, when taking a bus the legs are not used for transportation and the bus takes over the locomotive function of the legs[7]. An artifact can supplement the extended organ by performing a function the organ is also performing. For example, clothing add to the protective and heat-preserving properties of the skin which are also performed by the skin itself. When an artifact enhances the functional powers of an organ, it does so - not by independently performing a function that resembles the organ's function - but by cooperating with the organ in such a way that it enhances its functioning. In an enhancement relation, the artifact has a *symbiotic relation* with the organ. For example, a telescope extends visual perception, not by independently engaging in perceptual tasks, but by cooperation with the eye. The telescope and the eye form a new symbiotic unit which is more powerful than the eye alone. The same is true for a megaphone and the human voice. The megaphone and voice team up to form a new functional symbiotic unit that is more powerful then the voice alone. Note that a megaphone is different from a speech synthesizer, which produces speech independently from the human voice.

However, not every symbiotic relation is a functional enhancement of the organ. For instance, a saw is used in combination with the hand and arm, but is not an amplification of the hand and arm, because the hand and arm are not capable of sawing. So the saw is not an amplificatory extension, but a complementary extension, and has a symbiotic relation with the hand and arm. The same holds for a piano. One's hands and piano form a functional unit that produce music, but the piano does not enhance already existing capacities of the hands to make music.

Non-Technological Extensions

Non-technological artifacts, such as rocks, sticks and even organisms, are also included in Brey's framework. In principle any object or organism can become a means to an end and thereby extend the human organism. A stick or stone can amplify one's ability to defend oneself or to modify raw material. Technological artifacts distinguish themselves from non-technological artifacts in that they have been intentionally designed to function as extensions. Animals can also be used as an extension of our inventory of means to realize our intentions. Consider a horse that extends the means to get a human from a to b. Human beings as such, can also serve as an extension of our means to realize intentions. Humans can perform intelligent tasks, which means that they can serve as extension of someone's mental faculties.

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[7] Brey originally used the car as an example of an artifact that replaces the functioning of the legs. But when using a car the legs and feet cooperate with the gas and break pedals and are not redundant. A bus is, I think, a better example of an artifact that completely replaces the functioning of the legs and feet.

Summary

Brey argues that technology extends the *means* by which human intentions are realized, rather than human faculties themselves. The inventory humans have to realize their means can be extended by technological artifacts, animals or other humans and non-technological artifacts. Technological extensions can be either complementary or amplificatory. If the extensions are amplificatory they can replace, supplement or enhance human organs. If an artifact enhances human functions one has a symbiotic relation with the artifact. A complementary extension can also have a symbiotic relation with the organ. In overview, humans have the following means to realize their intentions:

(1) Technological artifacts

(I) Complementary extensions, with possible symbiosis

(II) Amplificatory extensions

(a) Replace

(b) Supplement

(c) Enhance → symbiosis

(2) Animals/other humans

(3) Non-technological artifacts

3.2.2 Evaluating Brey's Theory

How plausible is Brey's framework? His extension thesis - that technology extends the means by which human intentions are realized - seems plausible. By arguing that technology extends human means to realize intentions, rather than human faculties themselves, he takes the technology-as-extension thesis to a higher level of abstraction and thereby making it less vulnerable to criticism. Brey's theory can explain the same as McLuhan's theory and can withstand counterexamples and is, therefore, a better way to describe the notion of technology-as-extension. Also, including complementary extensions, next to amplificatory extensions, makes it possible to account for artifacts that have functions with no analogues to functions possessed by humans. In this way, Brey's taxonomy can account for all artifacts, including organisms and non-technological artifacts.

The telescope is used by Brey as an example of an extension in relation to the body. According to Brey, a telescope enhances vision and as a result has a symbiotic relation with the eye. This is indeed clearly the case, but there is more to it, I think. The eye is an organ that enables visual perception, which is a cognitive function and not a bodily function. Hence, by enhancing perception a telescope enhances a cognitive function. So, either a telescope is not a good example of an extension in relation to the body. Or a telescope simultaneously enhances an organ and a cognitive function. The latter option seems to me more plausible to me. This example shows that the distinction between an organ and a function is not always clear.

3.2.3 Brain-Computer Interfaces in Terms of Brey's Perspective

In the following paragraphs I will try to answer the research question at hand by employing Brey's framework. We have seen that Brey's extension thesis claims that artifacts extend the means to realize intentions. To put this forward in my analysis, I will begin with outlining which intention(s) are realized by the application. Thereafter I will point out the function of the application and relate it to abilities of its user. But first I will point out two things all BCIs have in common.

The BCI Itself

In terms of Brey's framework, there are two things all BCIs have in common. First, BCIs realize intentions of their users by detecting and translating brain signals into command signals for the application. And second, there is always a *symbiotic relation* between the brain and the application, which is partly determined by the BCI itself: the electrodes and signal processing unit. Brey wrote that symbiosis occurs when the artifact cooperates with the organ to perform a certain function. According to Brey, symbiosis occurs with amplificatory extensions that enhance the functioning of an organ and can occur with complimentary extensions as well. However, as will become clear in the next paragraphs, symbiosis also occurs with amplificatory extensions that replace or supplement the functioning of an organ.

Non-Deliberate Applications

Non-deliberate applications use brain signals that are not deliberately or consciously regulated. The application of interest is a BCI-system that monitors the concentration of a physician who is operating a patient. This BCI-system warns the physician when his or her concentration are below a certain level and it becomes irresponsible to continue operating. The physician does not consciously or deliberately regulate his or her concentration to control the warning system. This BCI-system extend the means to realize the intention to be warned when one's concentration is below a certain level.

The function of this BCI-system is warning a physician when his or her concentration is below a certain level. By means of introspection humans have the ability to *estimate* when their concentration is too low to continue with activities like operating or driving a truck. However, it is not uncommon that humans overestimate the level of their concentration, which can result in accidents or other undesirable events. Nonetheless, this BCI-system has a function that humans posses as well, namely detecting the level of concentration. Brey made a distinction between amplificatory and complementary extensions. Complementary extensions introduce new functional features, whereas amplificatory extensions have functions also possessed by a human organ. In Brey's terminology, this BCI-system is an amplificatory extension, because it has a function humans posses as well. It is merely more accurate in determining levels of concentration. Furthermore, Brey argued that amplificatory extensions can replace, supplement or enhance the functioning of the extended organ. This BCI-system *supplements* the introspective ability to detect the level of concentration of its user, because it performs a function the brain is also performing. Furthermore, brain and application cooperate to supplement a function. Cooperation implies symbiosis. So symbiosis also occurs with amplificatory extensions that supplement the functioning of an organ.

Bodily Applications

Bodily applications restore motor function by steering a motorized wheelchairs or a prosthesis. These applications extend the means to realize a range of intentions, because with motor skills one can realize many intentions like, for example, getting from a to b, grabbing a cup of tea, opening a door, using a computer mouse and so on. More generally, one can say that they extend the means for motor abilities of their users.

The function of a BCI-controlled-wheelchair is to *restore* locomotive abilities. Bear in mind that amplificatory extensions have functions also possessed by a human organ. Consider someone in need of a BCI-controlled-wheelchair. This person has lost his or her locomotive abilities, which are restored by the wheelchair. The wheelchair introduces a new function, a function he or she had previously lost. For this person, the BCI-controlled-wheelchair is a complementary extension, because it introduces a new function. However, if the same BCI-controlled-wheelchair is used by someone who is still able to walk, it is an amplificatory extension, because it then completely *replaces* the locomotive function of the legs, a function that person still has.

In the previous paragraph I have demonstrated that for a person in need of a BCI-controlled-wheelchair, it is a complementary extension. Recall that one can have a symbiotic relation with a complementary extension. This is the case when the organ cooperates with the artifact to perform a function the organ itself is unable to perform. However, the legs and feet of a person using a BCI-controlled-wheelchair do not cooperate with the wheelchair. Hence, there is no symbiosis between wheelchair and legs. This person directly cooperates with the wheelchair with his or her brain to replace the locomotive function of the legs and feet. So the brain cooperates with an artifact to perform a function which it is itself incapable of doing. This implies that there is a symbiotic relation between the brain and the BCI-controlled-wheelchair, because they cooperate to perform a function the brain itself is incapable of doing. So the user is engaged in a complementary symbiotic relation.

A BCI-controlled-prosthesis is placed on a stomp and literally extends – depending on the type of prosthesis - one's leg and foot, or arm and hand. The stomp cooperates with the prosthesis to perform a particular motor function. The function performed by the prosthesis was previously impossible for the user. That is why the user needs a prosthesis in the first place. A prosthesis *restores* particular motor functions, which means it enables an ability the user had previously lost. So for a user in need of a BCI-controlled-prosthesis, it is a complementary extension, because for such a user it introduces a new function. However, if a user still has one arm and needs a prosthesis for the other, that user is still able to perform most functions the arm can carry out. This means that for that user a prosthesis *supplements* functions of the other arm. As a result, different users can have different types of relations with the application.

In the above paragraph I focused on the cooperation between stomp and prosthesis. But in addition, there is also a cooperation between brain and prosthesis. So there are two organs, brain and stomp, both cooperating with the prosthesis to perform motor functions. This means there is a functional relation between prosthesis and stomp and between prosthesis and brain. In fact, there is a functional relation between stomp, brain and prosthesis. All three are needed to restore motor functions. Without one of these three elements the motor function of interest cannot be restored.

Linguistic Applications

Linguistic applications restore the ability to communicate for persons who are severely paralyzed and are therefore unable to communicate, verbally or otherwise. These applications enable the user to select letters on a computer screen and thereby to form words and sentences. A linguistic application extends the means to realize the intention to communicate of its user. In short, it extends the means to communicate. By so doing, the application makes the ability to communicate possible again. For such a user, it introduces an ability the user had previously lost. This implies that for a user that is unable to communicate, verbally or otherwise, linguistic applications introduce a new ability. It is therefore, a complementary extension. Furthermore, in case of complementary extensions, symbiosis occurs when artifact and organ cooperate to perform a function the organ is itself incapable of doing. Brain and linguistic application cooperate to perform a function the brain is itself incapable of doing, namely communication. So there is symbiosis between brain and linguistic application.

In the previous paragraph I have focused on the relation between a linguistic application and a person in need of such a device. However, if a linguistic application is used by a person that is able to communicate (e.g., to test it), it becomes an amplificatory extension. Specifically, the application *replaces* the communicative functioning of the user by taking over that function. Again, this means that different users can have different types of relations with the application.

There is another type of human-technology relation which is worth mentioning here. A linguistic application is being used to communicate with others. These ‘readers’ have a relation with a linguistic application as well. But in terms of Brey’s framework it is difficult to analyze this relation, because for someone who merely reads the words which are spelled by the BCI user, the application does not extend the readers means to realize intentions.

Virtual Applications

The virtual application of interest, Google Earth, extends the means to realize the intention to search for geographical information. More general, one can say that it extends the means for obtaining information. The function of Google Earth is to provide geographical information. In the previous section we have already seen that Google Earth extends one’s memory function. This means that it is an amplificatory extension. More specific, it *supplements* the memory of its user. Furthermore, the brain and the application cooperate to extend one’s memory function. This means there is symbiosis between the brain and application, which is facilitated by the BCI itself. In the following chapter the cognitive relation between linguistic and virtual applications and their users will be analyzed in more detail.

3.3 Conclusion and Reflection

In this chapter I have analyzed the functional relationship between BCIs and their users in an attempt to answer the second research question:

- How do functions of BCIs and their applications relate to abilities of their users and how can they extend these abilities?

McLuhan

Using McLuhan's framework to answer this question leads to the following. To start with, it must be noted that all BCIs literally extend the central nervous system, which is an organ in McLuhan's taxonomy. This being said, I will now sum up the relation between the application and their users. First, the function of a non-deliberate application is to warn a physician when his or her concentration are below a certain level. Detecting levels of concentration is an ability humans have as well. This introspective process can be seen, according to McLuhan's taxonomy, as a cognitive function. A non-deliberate application extends this cognitive function. Second, the function of bodily applications is to restore motor abilities, either by steering a wheelchair or a prosthesis. A BCI-controlled-wheelchair extends the locomotive function of the legs. A BCI-controlled-prosthesis extends - depending on the body part the prosthesis is used for - one's legs and feet or arms and hands, which are organs in McLuhan's framework. Third, the function of a linguistic application is to restore the ability to communicate. By doing so, it extends the ability to communicate, a cognitive function in McLuhan's taxonomy. And fourth, the function of the virtual application I analyzed, Google Earth, is providing geographical information. By doing so, it extends one's memory function.

Finally, in my analysis I focussed on the function of the application, because the user has a functional relation with the application – rather than with the BCI itself: the electrodes and signal processing unit. However, the functional relation between the BCI-applications and their users is largely determined by the BCI itself. We have seen that all BCI-systems literally extend the central nervous system, which is realized by the BCI itself. McLuhan's concept *accelerated interplay of functions* was useful for including the BCI in the functional equation. Electrodes, signal processing unit and application all cooperate to accelerate a certain function or organ.

Brey

Using Brey's general framework to answer the research question results in the following. To begin with, there is a *symbiotic relation* between the users' brain and the application in all BCIs, because there is a *cooperation* between the brain and the application. This cooperation is largely determined by the BCI itself. This being said, I will now sum up the relation between BCIs and their users. First, a non-deliberate application extends the means of its user to realize the intention to be warned when his or her concentration are below a certain level. Because a non-deliberate application has a function its user has as well, it is an amplificatory extension that supplements the introspective ability to detect the concentration of its user.

Second, bodily applications extend the means to realize a range of intentions, because with motor skills the user can realize many intentions, such as getting from a to b, opening a door or grabbing a cup of thee. Depending on who uses it, it can be both a complementary or amplificatory extension. For a person in need of a BCI-controlled-wheelchair it is a complementary extension, because it introduces a new function. However, if the same BCI-controlled-wheelchair is used by a healthy person, it is an amplificatory extension that replaces the locomotive function of the legs. In case of a BCI-controlled-prosthesis, it is a complementary extension if it is used by a person who is completely unable to walk or to use his arms. For such a person the prosthesis introduces new motor functions. However, if a person who still has one leg or one arm and needs a BCI-controlled-prosthesis for the other, it supplements functions of the other limb. So the abilities a user has or has not determine the relation with the application.

Third, a linguistic application extends the means to realize the intention to communicate. Depending on who uses it, it can be both a complementary and amplificatory extension. For a person in need of a linguistic application, it is a complementary extension, because it introduces a function the user had previously lost. For a person who is still able to communicate, it is an amplificatory extension that replaces the communicative functioning of that person. And fourth, the virtual application of interest in this thesis, Google Earth, extends the means to realize the intention to obtain geographical information. It is an amplificatory extension that supplements the memory of its user.

McLuhan or Brey?

We have just seen that both McLuhan's and Brey's perspective on human-technology relations were capable of answering the research question at hand. Both frameworks could account for all four categories of applications and could be used to analyze the functional relation between BCI-applications and their users. But which framework was best equipped to do so? And which framework gave deeper insights? McLuhan's taxonomy - extensions of organs, senses and functions - was able to account for all categories. But, although useful as a point of departure, the claim that technology extends organs, senses or functions could be falsified with counterexamples. There are no human organs, senses or functions that can give light, burn, freeze, magnetize or ionize. However, this does not mean that McLuhan's framework was useless for analyzing the relation between BCIs and their users. It did provide valuable insights, such as that all components in the equation: electrodes, signal processing unit and application form a functional architecture cooperating to accelerate or extend a human organ or function.

Brey's claim that technology extends the means to realize our intentions, rather than claiming that technology literally extends organs, senses or functions - is a better way to describe the technology-as-extension concept. By claiming that the functional features of artifacts do not have to resemble functional features of the body, Brey's theory can account for all artifacts. Also, his taxonomy of extensions gave deeper insights than McLuhan's one. First, the symbiotic dimension of the relation between all BCIs and their users could not be accounted by McLuhan's framework. And second, the distinction between replacing, supplementing and enhancing functions can describe in more detail the functional relation between BCIs and their users. For example, McLuhan's framework could only say whether the application extends an organ or a function. Whereas Brey's framework could describe how the application extends the means to realize an intention by replacing, supplementing or enhancing an organ or function.

Reflection

In this last subsection I will try to developed some speculative ideas on the future possibilities of BCIs. A feature all BCI-systems have in common is that they externalize brain activity for controlling technological artifacts. One could argue that the function of the BCI itself is to establish a direct one-way communication pathway between the human brain and a technological artifact. There are no other artifacts which are able to do this, and distinguish BCIs from other artifacts. There is, however, one drawback. My analysis has demonstrated that using a BCI, either with motor imagery or VEPs, demands a high degree of concentration which considerably limits their possibilities. But, the technology is still in its infancy and it is likely that the spatial resolution of the (invasive) electrodes and quality of the software will increase in the future, and that BCIs in general will become easier to use. A consequence may be that in the future a BCI could be used for multiple tasks, which is at the moment very difficult, if not impossible.

In case of persons who suffer from *locked-in syndrome*, a BCI may, for instance, be used for steering a wheelchair, spelling device and other artifacts in one's environment like a television, computer or microwave oven. And instead of using a cable between the BCI and the artifact to be controlled one could use a blue-tooth device. In this way a BCI can function as a highly advanced remote control. Also for healthy subjects a BCI may be used to control a diverse range of artifacts in one's environment. Hence, BCIs could turn out be a *multifunctional* technological system. One could argue that such a multifunctional BCI-system is a 'portal' for controlling other (electronic) artifacts in one's environment. This implies that our interaction with artifacts could be centralized in one technological system. A similar development has taken place with a multifunctional-remote-control for using one's television, stereo set and DVD-player. A consequence would be that we do not have to interact with our artifacts with our body anymore, but merely with our brain.

All this might seem like science-fiction, but if we consider the development of the computer - which started out at being a rather slow, room size processing unit to being a pocketsize PDA - this scenario seems not so far-fetched. Moreover, I am not claiming that the scenario I have just sketched out will be the case, I am rather speculating that it might be the case. Thus, if BCIs become more efficient and easier to use they could turn out to be a functional extension of our ability to interact with a number of electronic artifacts. They might even replace, or at least supplement – to speak in Brey's terms, our ability to bodily interact with technology. I have just speculated about the future functionalities of one-way BCI-systems. However, a next logical step in BCI-research may be designing two-way BCIs that would enable to the human brain and a computer system to exchange information in both directions. In the reflecting sections of chapters four, five and six, I will speculate about the consequences of such two-way systems.

4. The Epistemological Relationship Between Brain-Computer Interface Applications and Their Users

'A cognitive process is delimited by the functional relationship among the elements that participate in it, rather then by the spatial location of the elements.'

James Hollan, Edwin Hutchins & David Kirsh (2000, p. 176)

In the previous chapter I have analyzed the functional relation between BCI-applications and their users. It was demonstrated that they have functions that extend the means to realize the intentions of their users. The functional analysis showed that two types of BCI-applications extend the means to realize cognitive processes. First, linguistic applications extend the means to communicate. And second, the virtual application of interest here, Google Earth, extends the means to obtain information. Both communicating and obtaining information are cognitive, or epistemic, processes. In this chapter I will build on insights from the previous one and explore the epistemological dimensions of linguistic and virtual applications. I will do so by describing, evaluating and improving the epistemic quality of the cognitive processes regarding the use of linguistic and virtual applications. In my analysis I will draw from a number of thinker thinkers: Philip Brey, Alvin Goldman, Paul Thagard, James Hollan, Edwin Hutchins and David Kirsh.

We have seen that there is a cognitive relation between linguistic and virtual applications and their users. To describe this relation in more detail, I will employ Brey's functional perspective on human-computer relations. Concepts from Brey's perspective will be used to describe the cognitive, or epistemic, relation between linguistic and virtual applications and their users. The next step in this chapter is evaluating this relation. I will do so by making use of Goldman's five epistemic standards. These standards are the power, fecundity, speed, efficiency and reliability of epistemic practices. Thagard has used these standards to evaluate the epistemic quality of the printing press and the Internet. I will do the same for Google Earth: the virtual application of interest here. Note that these standards are not suitable to evaluate the epistemic quality of linguistic applications. After having described and evaluated the cognitive relationship I will try to improve it. Hollan, Hutchins and Kirsh developed some ideas about how to improve the epistemic quality of human-computer interaction. These ideas are based on a framework which is referred to as *distributed cognition*. The authors claim that what is important in effectively distributing cognition is the nature of the representations. The authors came up with a number of suggestions for how to make representations on computer screens more effective in terms of distributing cognition.

By drawing from Brey's perspective on human-computer relations, Goldman's five epistemic standards and Hollan's, Hutchins' and Kirsh's ideas about digital representations, I will describe, evaluate and try to improve the cognitive processes concerned with using linguistic and virtual applications and thereby try to answer the third research question:

- How can the epistemological relationship between BCI-applications and their users be described, evaluated and improved?

In the following four sections I will begin with presenting Brey's perspective on human-computer relations. Next, I will outline Goldman's five epistemic standards and Thagard's use of them. In the section thereafter I will briefly sketch out Hutchins' view on distributed cognition, followed by Hollan's, Hutchins' and Kirsh's ideas about how to effectively use representations on a computer screen. In the last section I will give a conclusion in which I argue to what extend the research question is answered and speculate about the future use of BCI-systems.

4.1 Brey on Human-Computer Relationships

In the previous chapter we have seen Brey's perspective on the functional relation between humans and technology. Brey (2005; 2008) further developed this perspective towards the particular relation between humans and computers. After doing so, he came to the conclusion that computers have two main functions for their users. A computer can be used as a cognitive device and as a simulation device. I will start out with outlining the computer as cognitive device and then as simulation device.

4.1.1 Cognitive Artifacts

In the previous chapter we have seen that McLuhan argued that computers extend cognitive functions like memory and information processing functions. Brey takes McLuhan's notion of the computer as extending cognition as point of departure and further develops it by asking *how* computers extend cognition. He answers this question by analyzing he functional relation between human cognition and computer activity[8]. In doing so, he draws from two concepts. The first is Donald Norman's concept of *cognitive artifact* and the second is Andy Clark's and David Chalmers' concept *the extended mind thesis*. Brey uses these two concepts as a basis for developing new concepts for better understanding the relation between humans and the computer as cognitive device.

Norman (1993) - a psychologist - introduced the notion of a cognitive artifact. He argues that a cognitive artifact distinguish itself from other artifacts by representing, storing, retrieving or manipulating information. Norman defines a cognitive artifact as being designed to maintain, display or operate upon information in order to serve a particular representational function. According to Brey, the keywords here are *information* and *representation*. Consider three examples of cognitive artifacts. A thermometer is a cognitive artifact, because its function is to represent and inform us about the temperature. Likewise, a clock has as function to represent and inform us about the time. And finally, a navigation system is designed to display geographical information. All three examples have representational functions. A hammer, in contrast, is not designed to serve a representational function, but to hammer nails in materials.

[8] Brey's perspective on human-computer relations presupposes a functionalist view on the human mind. Functionalism, a relatively new theory in the philosophy of mind, focuses on the causal relations between input, internal information processing and output. It emphasizes the functional relation and not the composition of the brain. A functionalist uses environmental input and behavioral output, but also insist that there is some essential information processing going on inside (Cunningham, 2000).

Memory, Interpretation, Searching and Conceptual Thought

Cognitive artifacts in general and computers in particular contribute to many cognitive functions like, for example, remembering, interpreting, searching or conceptual thought. Memory is the cognitive faculty whereby the human brain stores and retrieves information. A computer can extend our biological memory by encoding, storing and retrieving information. Computers can also extend our ability to interpret. According to Brey, ‘interpretation is the ability to assign meanings to input data, through the assignment of one or more concepts or categories’ (Brey, 2005, p. 386). To recognize objects in ‘raw’ perceptual data one needs to apply concepts to the perceptions in order to make a ‘fit’. The computer is capable of autonomously interpreting. For example, when properly programmed it can recognize objects and faces. However, most interpretation takes symbolic input like sentences and numbers and assigns categories to them. A computer could, for example, categorize names of animals as bird, mammal, reptile and so on. A third cognitive process which computers can extend is our ability to search. Internet search engines, for example, can help us find information on the Internet.

The most important human cognitive ability is arguably conceptual thought and in particular abstract thought. Conceptual thought often involves problem solving. For instance, finding a solution for a mathematical problem, determining how to furnish a room, translating a sentence from Dutch to English and so on. Computers are able of autonomous problem solving. When programmed properly, computers can solve mathematical problems, translate texts and even answer questions (think of the Turing test). However, computer intelligence, or artificial intelligence, has its shortcomings. Language and other informal domains are difficult for artificial systems.

The Extended Mind Thesis

We have just seen that the computer is a rather powerful cognitive artifact. A second concept which can contribute to better understanding the computer as cognitive artifact is Clark’s and Chalmers’ extended mind thesis (1998). In Brey’s interpretation of Clark and Chalmers, he writes that humans sometimes perform physical actions that contribute to a cognitive task. Measuring or searching for information, for example. Clark and Chalmers refer to such actions as *epistemic actions*[9]. They claim that if an epistemic action was performed in one’s brain we would see it as a cognitive process. Clark and Chalmers argue there is no logical reason not to see epistemic actions as part of cognitive processes. So, they claim, epistemic actions are part of cognitive processes. Clark and Chalmers then introduce the concept of a *coupled system*, which is in Brey’s interpretation defined as: ‘the linking of a human being with an external entity in a two-way interaction that includes information input from this entity and epistemic actions toward it’ (Brey, 2005, p. 389). A coupled system is a cognitive system because the entity, or cognitive artifact, is part of the information processing task.

Weak- and Strong Coupled Systems

Brey largely agrees with Clark and Chalmers view on cognition, but thinks their notion of a coupled system is too liberal. Consider Brey’s counterexample. If I merely look at a knife at the table there is no coupled system, because there is no epistemic action towards the knife. When I move the knife a bit to observe it, I do create a coupled system, because together with the knife I form the cognitive task of observation. In contrast, a cognitive artifact is different because it is not merely the object *of* cognition, but also contributes *to* cognition. This is so because it represents

[9] Epistemic actions are contrasted with pragmatic actions like, e.g., walking or taking the bus.

information and is therefore a more active contributor to the cognitive task. To overcome this, Brey distinguishes between *weak coupled systems* and *strong coupled systems*. In weak coupled systems objects are mere object of epistemic action (e.g., observing a knife). In strong coupled systems there is a relation between a human and a cognitive artifact which actively contributes to information processing by serving a particular representational function (e.g., reading of a thermometer or clock). According to Brey, only strong coupled systems are genuine cognitive systems, because in such systems the artifact serves a representational function. Computers serve representational functions and for this reason they form strong coupled systems with their users.

4.1.2 Computers as Cognitive Artifacts

We have seen that the computer is a cognitive artifact and forms a strong coupled system with its user. As cognitive artifact the computer is unique for two reasons. First, it can perform cognitive tasks autonomously. And second, it can actively manipulate representations. Most other cognitive artifacts are unable to autonomously perform cognitive actions or manipulate representations. Newell and Simon have argued that computers are *physical symbol systems*. Such systems manipulate physical symbols in virtue of their formal properties according to a set of rules. Due to this capacity, computers can support or perform almost any cognitive process. Brey argues that the functional relation humans have with computers as cognitive artifacts is that they extend cognitive processes.

To analyze the cognitive relation between computers and their users in more detail Brey uses a number of conceptual distinctions he made earlier. In the previous chapter we have seen that Brey made a distinction between *amplificatory* and *complementary* extensions. He argued that artifacts that *amplify* a human organ can have three different relations with that organ. The artifact can replace, supplement and enhance the functioning of that organ. An artifact replaces the functioning of an organ when it performs the function of that organ in a way that makes the organ redundant. When an artifact supplements an organ it performs a function the organ itself is performing as well. And an artifact enhances an organ when it cooperates with the organ in a way that enhances its functioning. In this way engaging in a symbiotic relationship with the organ.

The organ that computers extend is the brain and cognition is a function of the brain. So the question is does a computer replace, supplement or enhance cognition? According to Brey, a computer has all three relations with its users. A computer can function like an autonomous information processing system and can produce its own plans and solutions without human intervention. Expert systems, for instance, replace certain cognitive processes of experts.
When a computer supplements human cognition it processes information autonomously, but is limited to those tasks that are time-consuming or error-prone when done by humans. For example, doing complicated calculations, data searching in large databases and organizing and reformatting data. The distribution of cognition is that humans do the more creative and intuitive tasks and take care of the overall structure of the cognitive task, whereas the computer does the more time consuming task that are defined as *subroutines* within larger cognitive tasks.

When a computer enhances human cognition it does not perform cognitive tasks autonomously, but aids to a cognitive task and thereby enhancing our own cognitive abilities. So it does not perform a cognitive task itself but helps us to perform it. Brey writes: 'Our relation with the computer in this role is more symbiotic: the performance of a cognitive task depends on the information-processing abilities of both human and computer, and exchange of information between them' (Brey, 2005, p 392). For example, when we use a spreadsheet, word processor or

Web browser we perform cognitive tasks like doing calculations, producing well-formatted documents or navigating the Web in cooperation with the computer. Take the following example. When we use a spelling checker, this cognitive task depends on the ability of the spelling checker and on the ability of the user to decide whether the proposed alternatives are valid.

Brey argues that the distinction between supplementary and enhancement roles is not absolute. Even when computers enhance cognitive abilities, they still process information autonomously. The spelling checker, for instance, does not autonomously correct the spelling, but it does autonomously propose alternatives. In addition, when a computer supplements cognition it still needs a human to operate it, which makes it not completely autonomous. Thus, in both enhancement and supplementary relations, cognition is a distributed process depending on abilities of both computer and its user[10].

Hybrid Cognitive Systems

In enhancement relations the mutual dependency is the greatest, because then the computer operates *in tandem* with the human mind. Furthermore, cognitive functions are integrated in such a way that the human mind and computer can be best be seen as a single cognitive unit. Brey refers to such a cognitive unit as a 'hybrid cognitive system that is part human, part artificial, in which two semi-autonomous information processing systems cooperate in performing cognitive tasks' (Brey, 2005, p. 392). This notion of a hybrid cognitive system is stronger than Clark and Chalmers' notions of a coupled system and stronger than Brey's notion of a strong coupled system. In most strong coupled systems, the cognitive artifacts depend heavily on the human for their functioning and are unable to autonomously process information. Computers can autonomously perform information processing functions, so they are different from cognitive artifacts used in strong coupled systems (e.g., clocks or thermometers). Also, an important characteristic of computers is that 'they perform epistemic actions on symbols and images stored in memory or input by a user, in order to perform particular cognitive tasks' (Brey, 2005, p. 393). When a computer is programmed to ask for certain input of the user in order to perform information processing tasks, the user becomes object of epistemic actions of the computer (e.g., the Turing test).

4.1.3 Computing and World-Simulation

A computer can be used to make an artistic drawing, compose electronic music or play an adventure game. When making use of a computer in this sense, it is not a cognitive artifact, because the performed functions are not information functions. Making drawings, composing music and playing games are not information functions. These functions involve cognition, as almost any activity does, but it is not their primary goal. It may be argued that on an algorithmic level the only thing a computer can do is process information. This is true from the perspective of a computer programmer, but it is certainly not true from the perspective of a computer user. Brey is interested in the functional role of the computer for its user. The functions of a computer are not determined by the inner workings, but by the purpose assigned to them by designers or users. From the perspective of a user, a computer that plays music has a music playing function. This function is non-cognitive, because the purpose of playing music is aesthetic rather then informal or cognitive. So computers and software that support activities such as music playing, making drawings or gaming do not qualify as cognitive artifacts.

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[10] The distinction between replacement and enhancement is also not absolute. When a computer, e.g., replaces one memory it also enhances it.

The non-cognitive functions of a computer depend on abilities to graphically represent, simulate or model interactive objects, structures and environments. Brey refers to these abilities as *simulation abilities*. Due to these abilities the computer is no longer merely a cognitive device, but also a *simulation device*. The two main functions of a computer: extending cognition and simulating interactive environments, are not mutually exclusive. For example, by making the desktop interface more graphical with icons representing documents, folders, trash cans, rulers and in and out boxes - the computer became more efficient for information processing activities. The first non-cognitive graphical computer application were computer games and creative software like Paint and music programs. According to Brey, these application are non-cognitive because their primary function is not to assist in information processing tasks. They rather extend our means for entertainment and creative expression by simulating physical environments, objects and events. The computer as simulation device functions less as an extension of ourselves, but more as an extension of our world. Virtual interactive environments provide new structures to experience, navigate and interact with. Therefore, they are an augmentation of the world and not of our body or brain. These virtual environments may not be physically real, but do have meaning for us and are certainly useful. For example, they can be used for cognitive tasks, entertainment and creative activities. Their functional role is as divers as the functional roles of the structures we encounter in the physical world.

Summary

Brey argued that computers have two main functions. They can be used as cognitive device and as simulation device. As cognitive device the computer can contribute to many cognitive processes, amongst which - remembering, interpreting, searching and conceptual thought. In addition, a computer can replace, supplement and enhance human cognitive processes. When a user is engaged in an enhancement relation the computer operates in tandem with the human brain and forms a *hybrid cognitive system*. Computers can also be used for non-cognitive functions like making drawings, composing music or playing games. These functions are non-cognitive, because there primary function is not to assist in information processing tasks. When computers are used for these purposes it becomes a simulation device. In short, computers can function as:

(1) Cognitive artifact

(a) Replace

(b) Supplement

(c) Enhance → Hybrid cognitive system

(2) Simulation device

4.1.4 Evaluating Brey's Theory

How plausible is Brey's functional view on human-computer relationships? His distinction between the computer as cognitive device and simulation device is insightful. Seeing the computer merely as cognitive artifact does not do justice to its diversity of functions. Computers indeed extend cognitive processes like memory, interpretation, search and conceptual thought, but can also be used for other purposes like making drawings, playing games and composing music. The latter functions cannot be captured as extending cognition. So including the notion of the computer as simulation device is useful.

However, as Brey also noted, the distinction between the computer as cognitive artifact and as simulation device is not always that clear. Brey wrote that a computer game is a non-cognitive graphical application and therefore a simulation device. But, although its primary function may be to entertain and is therefore non-cognitive, problem solving is an intrinsic part of many computer games. For instance, a player of an adventure game has to decide which weapons or strategy he or she has to use to concur enemy territory. The problem solving strategy is a cognitive process which is distributed across player and game. Remove one of the components and the problem will not solve itself. When solving problems in computer games, the computer is both a cognitive artifact and a simulation device at the same time.

Lastly, I have a remark concerning Norman's definition of cognitive artifacts. According to Norman, a cognitive artifact is designed to maintain, display or operate upon information in order to serve a particular representational function. In my evaluation of Brey's perspective on human-technology relations, I have argued that a telescope enhances visual perception, which is a cognitive function. Hence, by enhancing perception a telescope enhances a cognitive function. But in terms of Norman's definition it is not a cognitive artifact, because it does not serve a representational function. Also, a mobile phone enhances one's means to communicate, which is also a cognitive function. But, when calling, it does not serve a representational function. So there are artifacts that enhance cognitive functions but are, according to Norman's definition, not classified as cognitive artifacts, because they do not serve a representational function. One might argue that when using a mobile phone to send a text message it does serve a representational function. But when using it to make a phone call it does not serve a representational function.

I would like to propose a broader perspective on cognitive artifacts. One in which every artifact that contributes to cognitive processes is classified as a cognitive artifact, also if it does not serve a representational function. I define a cognitive artifact as an artifact that makes available (perceptual) information which would otherwise not be available. This definition includes artifacts that extend our perceptual apparatus (e.g., microscopes, telescopes, telephones) as well as the traditional cognitive artifacts (e.g., clocks, thermometers, calculators, computers). In case of the traditional cognitive artifacts, cognitive processes are distributed across brain and artifact. This is also the case with artifacts such as microscopes, telephones and so on, because perception and communication are processes that can be distributed.

4.1.5 Brain-Computer Interfaces in Terms of Brey's Perspective

In this section I will employ Brey's perspective on human-computer relation as a first step to answer the third research question. This means I will describe the epistemological, or cognitive, relationship between linguistic and virtual applications and their users.

Linguistic Applications

Linguistic applications restore the ability to communicate for persons who are unable to communicate, verbally or otherwise. These applications enable the user to select letters on a computer screen so that they can formulate words and sentences. In the light of Brey's distinction between the computer as cognitive artifact and as simulation device, a linguistic application is a cognitive artifact, because it serves a representational function. This is so because a linguistic application represents words and sentences – which are, or at least can be - representations of objects and phenomena in the world - on its screen.

Brey distinguished between *weak* and *strong coupled systems*. In weak coupled systems objects are mere object of epistemic action (e.g., when observing a knife). Whereas in strong coupled systems there is a relation between a human and a cognitive artifact which actively contributes to information processing tasks by serving a particular representational function (e.g., when observing a clock). In terms of this distinction, a linguistic application forms a strong coupled system with its user, because it has representations of objects and phenomena in the world (words and sentences) on its screen, which contribute to the cognitive task of communication. However, before someone starts spelling words there are only letters on the screen. Letters as such do not represent objects or phenomena in the world. So the strong coupled system comes into being when words are being spelled.

Brey has put forward four cognitive abilities - memory, interpretation, search and conceptual thought - which can be extended by computers. I would like to add communication to these cognitive abilities. Communication with language (or otherwise) is the process of transmission of information from a sender to a receiver with the use of a medium. In this process we assign meaning in an attempt to create shared understanding. Communication (with language) is for both sender and receiver a cognitive process. The sender has to formulate sentences and the receiver has to interpret what they mean. Computers can extend communication by facilitating email, websites, messenger programs and word-processors. In fact, extending communicating is arguably one of the most important functions of computers. A linguistic application also extends the ability to communicate for its user. Thus, a linguistic application serves a representational function and extends communication; a cognitive process.

In the previous chapter I have argued that in terms of McLuhan's and Brey's general views on human-technology relations, it was difficult to analyze the relation between a linguistic application and a person for whom the spelled words are meant. Now recall that I proposed a different definition of cognitive artifacts. I have defined a cognitive artifact as an artifact that makes available (perceptual) information which would otherwise not be available. In terms of this definition, a linguistic application is a cognitive artifact for someone who reads the spelled words, because it makes available information that would otherwise not be available. Note that in terms of Norman's original definition, a linguistic application is a cognitive artifact for someone who merely reads it as well, because it has a representational function. However, I have argued that the definition I proposed is a better way to describe cognitive artifacts.

Although in Brey's terms, linguistic applications do not enhance a cognitive process, some aspects Brey mentioned about the symbiotic dimension of enhancement relations between humans and computers do apply for linguistic applications and their users[11]. The cognitive task of communication is not performed by the linguistic application itself, but helps the user to perform it. Also, the performance of the cognitive task of communication depends on the information-processing abilities of both human and the linguistic application, and exchange of information between them. The application receives information from the participant (brain signals) and the user receives visual information from the linguistic application (letters, words, sentences). Brey wrote that in enhancement relations with computers we form hybrid cognitive systems. His definition of a hybrid cognitive system: 'part human, part artificial, in which two semi-

[11] In the previous chapter it became clear that for a person in need of a linguistic application, it is a complementary extension. For a person that is still able to communicate, it replaces his or her communicative functioning. So in Brey's taxonomy it does not enhance one's communicative abilities.

autonomous information processing systems cooperate in performing cognitive tasks' applies nicely to linguistic applications. The entire system, linguistic application and user, is part human, part artificial and has two semi-autonomous information processing systems which cooperate in performing a cognitive task[12]. So although there is no enhancement relation between linguistic applications and their users, the linguistic application and user do form a hybrid cognitive system. Note that in case of other cognitive artifacts with which we form hybrid cognitive systems (e.g., computers or navigation systems) we interact with them with our bodily, usually with our hands. A distinguishing feature of a linguistic application is that it forms a hybrid cognitive system with its user without bodily interaction. It is important to emphasize that this is due to the BCI itself.

Virtual Applications

The virtual application of interest, Google Earth, is in terms of Brey's framework both a cognitive artifact and a simulation device, because it provides geographical information by simulating a virtual environment. Brey wrote that the two main functions of a computer, extending cognition and simulating virtual environments, are not mutually exclusive, which was also pointed out in the evaluating of Brey's framework. Google Earth is a good example of this, because it has both an informational function and realizes this function by simulating a virtual environment.

In the previous subsection, we have seen that linguistic applications form strong coupled systems and hybrid cognitive systems with their users. A person using Google Earth with a BCI also forms a strong coupled system, because Google Earth actively contributes to information processing tasks by serving a particular representational function. But what cognitive process does Google Earth contribute to? It provides its user with geographical information. So it serves as an external memory and by doing so it extends the users memory. And in addition, it also contributes to searching abilities of its user. The user wants to search for geographical information. Google Earth contributes to that. A person using Google Earth with a BCI also forms a hybrid cognitive system. The performance of the cognitive task depends on the information-processing abilities of both human and Google Earth, and exchange of information between them. It is part human, part artificial, and two semi-autonomous information processing systems cooperate in performing a cognitive task. Furthermore, Brey wrote that the computer as simulation device functions less as an extension of ourselves, but more like an extension of our world. They are an augmentation of the world and not of our body or brain. Google Earth is certainly an augmentation of the world and by being so it is a cognitive artifact as well. And by being a cognitive artifact it is also an augmentation of our brain.

4.2 Goldman's Epistemic Standards

In the previous section the cognitive relation between linguistic and virtual applications and their users was described. In this section I will evaluate this cognitive relation. Epistemologist Alvin Goldman (1986; 1992) has proposed five epistemic criteria to evaluate the quality of epistemic practices. These criteria are fecundity, speed, efficiency, reliability and power. Philosopher Paul Thagard (1997) has used these standards to evaluate the epistemic quality of the printing press and the Internet. In this section I will do the same for the virtual application of interest here, Google Earth. Note that I will not evaluate the cognitive relation between linguistic applications

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[12] Actually in case of linguistic applications as well as virtual applications there are three information processing units, instead of two: the human brain, the signal processing unit which translates the brain activity and the application.

and their users, because Goldman's standards are not equipped to do so. Why this is the case will be explained in section '4.2.1 Evaluating Goldman's Standards'. In the previous section we have seen that Google Earth is a cognitive artifact and forms a strong coupled system and a hybrid cognitive system with its users. It extends the means to obtain information, which is a cognitive or epistemic process and will be evaluated in this section.

Although the five standards are evaluative in nature, it is difficult to precisely quantify the quality of BCI-systems in terms of these standards. After analyzing we cannot say that the speed or efficiency of a BCI-system is seven on a scale from one to ten. Despite this, we do need some kind of quantification. Otherwise we cannot evaluate. For this reason I will quantify the quality of BCI-systems for each of the five standards in terms of 'low', 'medium', 'good' and 'excellent'. In the following subsections I will start out with outlining the five standards, followed by briefly using the Internet to illustrate how the evaluation works.

Fecundity

The *fecundity* of a practice is determined by its ability to produce a large number of true beliefs for many persons. The Internet has made available immense amounts of true beliefs, or perhaps knowledge is a better word, for many people worldwide. Think of online dictionaries, newspapers, encyclopedia, databases of scientific articles and so forth. In quantitative terms, the fecundity of the Internet is excellent. But on the other hand, critics of the Internet emphasize that there is also a lot of information available which does not have a high truth value. Anyone with a website can post almost everything. But nonetheless, the Internet has made available many true beliefs for many persons which would otherwise not be available.

Speed

This epistemic standard is concerned with the *speed* with which true beliefs are gained. Getting a true answer sooner, rather then later is of course desirable and contributes to the quality of the process. In many cases there is a deadline after which information looses its value. So the faster problems are solved by a cognitive system, the more desirable it is. It is clear that the Internet has made available immense amounts of true beliefs. The speed with which these true beliefs can be gained is also rather impressive. An experienced Internet user can within minutes, sometimes even within seconds, find the desired true beliefs. In terms of quantifying, the speed of the Internet is excellent.

Efficiency

The *efficiency* of a practice is determined by how well it limits the financial costs of getting true answers. Although the Internet is costly because computers and information storage is needed, the efficiency is still rather good. Email, for instance, is cheaper then sending paper mail. And online newspapers are cheaper then paper newspapers. Also, the increasing amount of valuable information on the Internet, including scientific information, makes it a highly efficient source of true answers. In quantitative terms, the efficiency of the Internet is good.

Reliability

According to Goldman, 'an object (a process, method, system, or what you have) is reliable if and only if (1) it is the sort of thing that tends to produce beliefs, and (2) the proportion of true beliefs among the beliefs it produces meets some threshold, or criterion, value' (Goldman, 1986, p. 26). So the more *reliable* a process is, the higher the ratio of true beliefs it produces. Furthermore, in epistemology a distinction is made between error and ignorance. Error is false belief, whereas ignorance is the absence of true belief. A reliable process is an antidote to error, but not to ignorance. In general, searching for information on the Internet is not always a reliable practice. However, when done by careful and critical users it can be a reliable practice. Online journals, for example, certainly create a high ratio of true beliefs. In terms of quantifying, the reliability of the Internet in general is medium. But, the more critical the user, the more reliable the Internet is.

Power

We have seen that the antidote to error is reliability. The antidote to ignorance is (intellectual) *power*. So it is the antidote to the absence of true beliefs. Power is defined as 'the capacity of a process, (…) to produce a large number of true beliefs; or, slightly differently, the capacity to produce true beliefs in answer to a high ratio of questions one wants to answer or problems one wants to solve' (Goldman, 1986, p. 27). As Goldman's definition suggests there are several variants of the notion of power. Goldman's focus is on the one concerned with problem solving or question answering. Note that a cognitive system can be very reliable – create a high ratio of true beliefs - but not very powerful – produce answers to questions - or vice versa. In short, a powerful cognitive system is capable of getting a relatively large number of true beliefs. The Internet is rather powerful in helping persons find answers to questions that interest them. Also, it enables persons to find information which would otherwise not be available. In quantitative terms, the power of the Internet is excellent.

Summary

Goldman has proposed five epistemic standards to evaluate the quality of certain practices. These standards are fecundity, speed, efficiency, reliability and power. The fecundity of a practice is determined by its ability to produce a large number of true beliefs for many persons. The speed of a practice is concerned with how fast it leads to true beliefs. The efficiency of a practice is determined by how well it limits the cost of getting true answers. The reliability of a practice is determined by the ratio of truths to total number of beliefs fostered by the practice. And lastly, the power of a practice is concerned with the amount of true beliefs it produces. Thagard has used these standards to evaluate the epistemic quality of the Internet, which - in general, turned out to be rather good.

4.2.1 Evaluating Goldman's Standards

Although useful for evaluating the epistemic quality of the Internet, these standards are not useful for evaluating the epistemic quality of linguistic applications. This is so because all five standards are based on gaining true beliefs. However, the function of a linguistic application is extending the communicative means of its user, which has little to do with gaining true beliefs. So these standards are not of much use for evaluating linguistic applications. This is, however, not the case for the virtual application of interest here, Google Earth, which *can* be evaluated with these standards, because its function is to provide true beliefs about geographical information.

In addition, not all cognitive processes are concerned with gaining true beliefs. Deciding whether to buy an album of Coldplay or Radiohead, for instance, is not concerned with gaining a true belief. Communicating, to give another example, is a cognitive process that is not concerned with gaining a true belief either. Note that this is only so for someone who is the sender in the communicative process. The receiver may be concerned with gaining truth. In case of interacting with cognitive artifacts the goal is often to gain a true belief. The four cognitive abilities outlined in the previous section – memory, interpretation, search and conceptual thought – to which cognitive artifacts can contribute are all concerned with gaining true beliefs, or perhaps knowledge is a better word. For example, observing a clock or a thermometer contributes to interpretation. Using a calculator contributes to conceptual thought. And using an Internet search engine contributes to searching and perhaps to memory as well. All examples are concerned with gaining true beliefs. But, someone using a linguistic application, also a cognitive artifact, is not concerned with gaining true beliefs, but with communicating. This feature make linguistic applications a cognitive artifact that needs other standards to evaluate the quality of the cognitive processes concerned with using it.

In order to explain this feature it useful to look at John Searle's (2001) distinction between *mind-to-world direction of fit* and *world-to-mind direction of fit*. The belief that it is raining, for instance, is only true when it actually raining. In order to be true the belief has to fit a state of affairs in the world. The belief has the mind-to-world direction of fit. Beliefs have to fit the world in order to be true. Desires, on the other hand, have the opposite direction of fit. Desires do not represent how things are in the world, but how we would like them to be. Desires and intentions have the world-to-mind direction of fit. We do not say of desires and intentions that they are true or false. Instead we say that they are fulfilled or not fulfilled. In order to be fulfilled the world has to fit the desire or intention. Both linguistic and virtual applications are concerned with realizing intentions, as we have seen in the previous chapter. In that regard they both have the world-to-mind direction of fit[13]. However, someone using the virtual application Google Earth, is concerned with gaining true beliefs about certain states of affairs about the world. In order for these beliefs to be true they have to fit the world. Note that the beliefs gained are by definition true because Google Earth represents the world with a high isomorphism. This aspect of Google Earth has the mind-to-world direction of fit. And the epistemic quality of how those beliefs fit the world can be evaluated.

4.2.2 The Epistemic Quality of Brain-Computer Interfaces

In this subsection I will employ Goldman's five standards as a second step to answer the research question at hand. The virtual application of interest here is Google Earth. In the previous chapter it became clear that someone using Google Earth with a BCI forms a hybrid cognitive system. And that the performance of the cognitive task, obtaining information, depends on the information-processing abilities of both human and Google Earth, and exchange of information between them. One can argue that the function of Google Earth is to provide true beliefs about geographical information. When using Google Earth in general produces many true beliefs for many persons. So the fecundity would be excellent. This is also the case when Google Earth is being used with a BCI.

The speed with which Google Earth provides true beliefs is fast, almost immediate. But when using it with a BCI, there are two drawbacks. First, before one can use Google Earth with a BCI one needs training. And second, using Google Earth with a BCI requires intense concentration and therefore the process of steering Google Earth goes rather slowly. Taking the drawbacks into account I conclude that the speed to produce true beliefs is medium. The efficiency of a practice is determined by how well it limits the financial costs of getting true answers. The financial costs of using Google Earth with a BCI are high. It is much cheaper to do it with a mouse and a personal computer. So the efficiency is low. All the information Google Earth provides is true. It presents accurate satellite images of the world. Although some places in the world like military bases are censored, in general one can say that the reliability is excellent. A powerful cognitive system is

[13] All one-way BCI-systems have the world-to-mind direction of fit.

capable of getting a relatively large number of true beliefs. If it concerns questions about geographical information, Google Earth provides a large number of true beliefs. So its power is excellent.

4.3 Hutchins on Distributed Cognition

In the first section of this chapter we have seen that Brey used the extended mind thesis as a point of departure to develop new concepts like *strong coupled system* and *hybrid cognitive system*. In this section I will outline a framework which is related to the extended mind thesis, but has a more empirical side. This framework is referred to as *distributed cognition* (DC or DCog). The traditional view in philosophy and cognitive science sees cognition as a process which merely takes place in the brain. This traditional view is called *cognitivism*[14] and is still the dominant paradigm. According to the cognitivist view, the mind is some kind of computer, which does computations on mental symbols and mental representations (Anderson, 2003; McLaughlin, 2003). But in the last decades this traditional view is supplemented by DC[15] - developed by Edwin Hutchins and colleagues. This branch of cognitive science distinguishes itself from mainstream cognitive science by arguing that cognition should not be seen as a process that takes place merely in the brain, but should be seen as a distributed process. 'A cognitive process is delimited by the functional relationship among the elements that participate in it, rather then by the spatial location of the elements' (Hollan, Hutchins and Kirsh, 2000, p. 176)[16]. Cognition can be distributed in three ways. First, it can be distributed across the members of a social group. Second, it can be distributes across brain and artifact(s). And third, it can be distributed across time in such a way that products of earlier events can transform the nature of later events (Hutchins, 2001). In this section the focus will be on cognitive processes that are distributed across brain and artifact and in particular across brain and computer.

4.3.1 Distributed Cognition for Human-Computer Interaction

Hollan, Hutchins and Kirsh (2000) argue that DC is an effective framework for understanding human-computer interaction, and that it can be used for designing and improving cognitive artifacts. In their article they develop an integrated framework for understanding human-computer interaction (HCI). In this framework they try to integrate the principles of DC, experiment design, ethnographic observation and design of work materials and workplaces. Outlining in detail how these elements are precisely integrated would fall beyond the scope of this thesis. It suffices to say that the principles of DC are used as a basis to design experiments, work materials and workplaces - and that the outcome of the experiments can be used to refine the theory of DC. What is of particular importance here are the suggestions the authors make regarding how user interfaces should be designed in terms of effectively distributing cognition.

A key focus when distributing cognition across brain and computer is the nature of the representations and how these representations are used. Hutchins' cognitive ethnography has

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[14] In ethics the term *cognitivism* refers to the meta-ethical view that ethical sentences express propositions which can be true or false. A noncognitivist denies this.

[15] Other frameworks like *embodied cognition*, *situated cognition* and *wide computationalism* are also concerned with the notion of extended cognition.

[16] As like Brey's perspective on human-computer relations, DC also presupposes a functionalist view on the mind.

shown that people shift back and forth between attending to the properties of the representation itself and the properties of the thing that is represented. Or intentionally blur the two. Consider a concrete example. Hutchins' empirical research regarding the distribution of cognition in airline cockpits, revealed that when an engineer explained to the captain that there is a fuel leak, he interacts with the panel both as if it were the fuel tank it represents and sometimes as if was just a representation of the fuel tank. These shifts from representation itself to the thing which is represented provide a range of cognitive outcomes that would be impossible if representations were always seen as mere representations and not as things in themselves. These shifts are important for understanding HCI, because representations are ubiquitous and essential when interacting with a computer. Also, these shifts allow a person to do one kind of cognitive work on the representations itself, and another on interacting with the representations as stand-ins for the things they represent. In direct manipulation interfaces the icons on the screen are linked to the actual computational object, so that it feels as if we are manipulating the object itself and not its stand-in. For example, when dragging a document from one folder to another we do not think that we are moving mere icons but the actual document.

When using a computer we manipulate icons in *icon space* and it is possible to make use of the icons and the space in which they are placed in such a way that it simplifies the cognitive tasks. For instance, files may be left near the trashcan to remind us to delete the file. When building richer computational environments it is important to understand how humans are coupled to their environment. The authors argue that we must discover new models of active representations for HCI and explore three ways of doing so, which are presented in the next paragraphs.

History-Enriched Digital Objects

The first way is concerned with recording the use-history of digital objects and making this history available in such a way that it can inform tasks and facilitate interaction. When interacting with objects in the physical world, the use history is sometimes available to us in such a way that that it informs us how to interact with them. For example, a well-worn part of a door handle suggests were to grasp it. A book often opens at the place were we last stopped reading. And the most recently read essays are on top of the piles on our desks. So sometimes the use histories of objects in the physical world are perceptually available to us in a way that supports the tasks we are doing.

By recognizing the functions of use-history of objects in the physical world, we can now use this idea to create better digital objects. This means that digital objects should display graphical abstractions of their use-history as part of the objects themselves. The authors have explored the use of *attribute-mapped scrollbars* as a mechanism to make the history of interaction with documents available. They recorded who edited or read certain sections of a document as well as the length it took to read it. Histories of those interactions were presented in the scrollbar. These representations in the scrollbar identified and highlighted sections that had been edited and who did this. Using this kind of representations in the scrollbar made effective use of limited display real estate and made reading the document more effective. One can apply the idea of history-enriched digital objects to menus of collectively used computer systems. The use-history of the items in the menu of other users can be indicated by making often used items brighter or larger. Another example the authors mention is concerned with (news)websites. One can, for instance, direct readers to news items that have been read often by others[17].

[17] This idea is implemented in the Dutch news website www.nu.nl. The five most popular news items are presented in a prominently placed section of the site.

Zoomable Multiscale Interfaces

In the physical world we often move closer to objects we want to know more about. This observation can be used in digital interfaces. Hollan, Hutchins and Kirsh have made a piece of software (Pad ++) that creates a workspace that allows icons to be placed at any location and at any size. Furthermore, zooming is supported as one of the fundamental interaction techniques. The authors mention the following example. PadPrints is a Pad ++ application that functions as a navigation aid for web-based browsing. A multiscale map of all the websites a user visits is maintained by PadPrints. Websites that are visited longer are presented larger on the multiscale map. Displaying graphical representations of the visited websites is a good example of using history-enriched digital objects as a more effective way to interact with computers. The authors claim that zoomable multiscale interfaces are particularly useful for hierarchal information. This is so because items that are deeper in the hierarchy can be made smaller, but because they are still in view they can be accessed easily[18].

Intelligent Use of Space

Manipulating icons, objects and structures in Pad++ is part of the distributed cognitive process. Users of Pad++ leave certain portals open to remind them of useful information, they shift objects in size to emphasize their importance and they move important objects in and less important objects out of the workspace. Human beings are by definition spatially orientated. We are organizing our workspace to increase work efficiency. So space is a resource we must manage just like memory or time.

Summary

Distributed cognition is a branch in cognitive science that approaches cognition not as a phenomena that solely occurs in one's brain, but as a phenomena that is distributed across brain and environment. Researchers in this field argue that distributed cognition is an effective framework for understanding HCI and that it can be used for designing and evaluating cognitive artifacts. Of particular importance is the nature of the representations and how these representations are used. It is, for example, useful to record the history of use of digital objects and represent this use history as part of the objects themselves. Also, the importance or relevance of a digital object can be represented by the size of the icon. And zoomable multiscale interfaces are an efficient way to present hierarchal information.

4.3.2 Evaluating Distributed Cognition

There is a philosophical debate going on concerning the validity of distributed cognition and other related ideas and schools of thought such as the extended mind thesis and wide computationalism. Sketching out this entire debate would fall beyond the scope of this section. Instead I will focus on one point. By claiming that 'distributed cognition refers to a perspective on all of cognition, rather than a particular kind of cognition' (Hollan, Hutchins & Kirsh, 2000, p. 175) they seem to argue that all cognition is a distributed process. This claim can easily be falsified. I can close my eyes and do a calculation, visualize past events and remember the main arguments of my thesis. When doing so, I do not distribute cognitive processes across brain and environment, but have cognitive processes solely in the brain. This example demonstrates that cognitivism is difficult to reject in its entirety. My standpoint is that *some* cognitive processes are distributed across brain and environment, but not all. The cognitive processes concerned with

[18] A similar idea is used in the Dutch website www.ns.nl. The website presents hyperlinks which are used often larger than hyperlinks which are used less often.

using cognitive artifacts are, indeed, distributed across brain and artifact. So for the goal of this section: improving the epistemic quality of linguistic and virtual applications, distributed cognition does not loose its strength.

4.3.3 Distributed Cognition for Brain-Computer Interfaces

In this subsection I will try to answer the research question at hand. Bear in mind that I will employ three ways to improve digital representations: history-enriched digital objects, zoomable multiscale interfaces and intelligent use of space.

Linguistic Applications

We know that linguistic applications are cognitive artifacts that extend the communicative means of its user by enabling to select letters on a screen with a cursor. On the screen of a linguistic application, each letter of the alphabet is presented in the same size on the screen in *qwerty* style (Figure 6).

Figure 6. A person using a linguistic application.

The notion of history-enriched digital objects implies that digital objects should display graphical abstractions of their use-history as part of the objects themselves. For example, by making often used digital objects larger or brighter. In language use not every letter of the alphabet is used equally often. The letters q, x, y or z, for instance, are not used as often as the letters a, e, o, or i. The notion of history-enriched digital objects implies that often used letters should be presented larger or brighter on the screen. This idea is supported by the notion of zoomable multiscale interfaces, which is a way to present hierarchical information. More important information should be displayed with larger representations. Often used letters are more important. So they should be presented with larger icons then less important letters. In a way the BCI itself is also history enriched. It 'knows' that certain brain states 'mean' move cursor to the right or to the left. This is enabled by the neurofeedback method and the machine learning approach. The BCI has 'learned' what it has to do when it detects certain brain states. Furthermore, the notion of zoomable multiscale interfaces implies that we move closer and focus on objects in which we are interested. For someone selecting letters on a computer screen it might be more effective if the letter the person wants to select becomes larger when the cursor moves towards it. This makes the process of selecting letters go faster and easier[19].

[19] This idea is used in Apple interfaces, were icons become larger when the cursor moves towards them, or when the cursor moves over the icon.

The notion of intelligent use of space implies that digital objects are structured logically on the screen. Presenting the letters in qwerty style is for many persons logical and obvious[20]. However, for some (older) people who are not used to working with a typewriter or computer this way of presenting the letters might not be the most logical one. When we are interested in an object we focus on it and the object is usually in the middle of our perceptual field. For persons who are not used to the qwerty style, it might be logical to present the most often used letters in the middle and letters that are used less often in the periphery of the screen.

Virtual Applications

We have seen that the virtual application of interest, Google Earth, is both a cognitive artifact and a simulation device: it provides geographical information by simulating a virtual environment. Using the three ways to improving digital representations for Google Earth is not as easy as for linguistic applications. The digital representations in Google Earth display a high representational isomorphism with what they represent. One cannot change the representation of a country, city, village or neighborhood, because the function of Google Earth is to present images of the world which are as real as possible. The notion of multiscale zoomable objects is already implemented in Google Earth. One can zoom in on the object of interest. The notion of intelligent use of space is not really relevant here. If one changes the virtual space of Google Earth, the representation would loose their high isomorphism with what they represent and Google Earth would loose its value as cognitive artifact. But, the notion of history-enriched digital objects may be of interest. Google Earth may include the search-history of other users to show what was of interest for them. This can be done by making places which were of interest for other users brighter. Or perhaps also by making use of certain labels.

4.4 Conclusion and Reflection

In this chapter I have analyzed the epistemological relation between linguistic and virtual applications and their users in an attempt to answer the third research question:

- How can the epistemological relationship between BCI-applications and their users be described, evaluated and improved?

Brey

The epistemological relation between BCI-applications and their users can be described as follows. First, linguistic applications are cognitive artifacts, because they serve a representational function and extend communication, a cognitive process. Furthermore, a linguistic application forms a strong coupled system as well as a hybrid cognitive system with its user. Second, the virtual application of interest, Google Earth, is both a simulation device and a cognitive artifact, because it has an representational function and realizes this function by simulation a virtual world. Furthermore, someone using Google Earth with a BCI forms a strong coupled system as well as a hybrid cognitive system.

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[20] The qwerty style has its origins in the typewriter. If the letters of the alphabet were to be structured in alphabetic order the typebars would become intermingled and get stuck. Structuring the letters in qwerty style makes sure this effect is minimized.

Goldman

The epistemological relation between BCI-applications and their users can be evaluated with Goldman's five epistemic standards. When using Google Earth with a BCI one forms a hybrid cognitive system, which produces many true beliefs for many persons. So the fecundity is excellent. The speed with which Google Earth provides true beliefs is fast, almost immediate. But there are two drawbacks. First, before one can use Google Earth with a BCI one needs extensive training. And second, using Google Earth with a BCI requires intense concentration and therefore the process of steering Google Earth goes rather slowly. For these reasons, the speed to produce true beliefs is medium. The financial costs of using Google Earth with a BCI are high. It is much cheaper to do it with a mouse and a personal computer. Hence, the efficiency is low. All the information Google Earth provides is true. It presents accurate satellite images of the world. Although some places in the world like military bases may be censored, in general one can say that the reliability is excellent. A powerful cognitive system is capable of getting a relatively large number of true beliefs. If it concerns questions about geographical information, Google Earth provides a large number of true beliefs. So its power is excellent. Taking the outcome of all the five standards into account, I conclude that the epistemic quality of Google Earth as cognitive artifact is good.

Hollan, Hutchins and Kirsh

The epistemological relation between BCI-applications and their users can be improved as follows. Hollan, Hutchins and Kirsh's notion of history-enriched digital objects implies that often used letters should be presented larger or brighter on the screen. Their notion of zoomable multiscale interfaces implies that for someone who is selecting letters on a computer screen, it might be more effective if the letter the person wants to select becomes larger when the cursor moves towards it. Their notion of intelligent use of space implies that for people who are not used to the qwerty style, it might be logical to present the most often used letters in the middle and letters that are used less often in the periphery of the screen. These are insights that are valuable for BCI researchers as well as the users.

The function of Google Earth is to present images of the world which are as real as possible. One cannot change those images of the world, otherwise Google Earth would loose its value as cognitive artifact. The notion of multiscale zoomable objects is already implemented in Google Earth. The notion of intelligent use of space is not really relevant. If one changes the virtual space of Google Earth, the representation would loose their high isomorphism with what they represent. But, the notion of history-enriched digital objects can be used. Google Earth may include the search-history of other users to show what was of interest for other users. This can be done by making places which were of interest for other users brighter. Or perhaps also by making use of certain labels. But, whether this is really useful for improving Google Earth is rather doubtful.

Reflection

In this reflecting subsection I will develop some speculative ideas on the future use of BCIs as a means to interact with computers. We have just seen that I analyzed the epistemological relation between linguistic and virtual applications and their users. My analysis has demonstrated that they contribute to, or enable in the first place, certain cognitive processes of their users. I have claimed that due to the high amount of concentration needed to use BCIs, either with motor imagery or VEPs, the speed with which the cognitive processes are realized is rather slowly. We have also seen that Goldman has argued that the speed with which cognitive processes are realized contributes to the overall epistemic quality of the cognitive process. Using a linguistic application goes rather slowly. Of course, restoring the ability to communicate for someone who was previously incapable of doing so, even if it goes slowly, is still a huge step forward. But it would be desirable to augment the speed with which a linguistic application enables its user to communicate. Instead of using motor imagery or VEPs to select letters on a screen, a BCI may extract the brain activity (or brain states) related with thinking words. This would be like dictating words to a computer by merely thinking them. The spatial resolution of the electrodes and the quality of the software is currently not sufficient enough to extract brain activity related with thinking words. But, as was already mentioned in the previous chapter, it is likely that the quality of the electrodes and software will increase. So perhaps it might be possible to increase the speed of communicating with a linguistic application (and therefore the overall epistemic quality) by extracting brain activity related with thinking words.

Furthermore, my analysis has shown that contemporary BCIs as a means to interact with computers are rather limited for at least two reasons. First, before the BCI-system can be used the electrodes have to be placed and the system has to be installed, which is rather time-consuming. And second, using both motor imagery or VEPs as input signals have a low information transfer rate and are therefore rather slowly as well. At present, interacting with a computer goes much easier and faster with a mouse, keyboard, touch screen or speech or gesture recognition device. Note that this is highly speculative, but if BCIs were able to detect more complex cognitive processes, instead of motor imagery or VEPs, it would make mousses, keyboards, touch screens and so on, redundant. Directly 'downloading' cognitive processes into a computer would significantly augment the information transfer rate. I want to emphasize that I am not suggesting that the brain or parts of the brain can be downloaded in a computer as Hans Moravec and other futurists are claiming. I am merely theorizing that in the future a BCI may be able to extract cognitive processes, instead of motor imagery or VEPs, that could be used as input for a computer. This would increase the information transfer rate and for this reason the overall epistemic quality as well. And most importantly it would make a BCI a more promising device to employ for human-computer interaction.

Another issue which might be interesting to mention from an epistemological standpoint are two-way BCI-systems. Before doing so, it must be noted that although there is some research being done on two-way BCIs, at the present time they are not successfully implanted in humans or animals yet. Two-way BCIs would enable information to flow from the human brain to a computer system and vice versa. The two-way system could exchange information in both directions without making use of the senses. I am aware that such a BCI-system would not be easy, if not impossible, to design, and I agree that science-fiction scenarios like downloading memories into the brain seem rather far-fetched. However, one-way BCIs already exist and it is also possible to transmit electrical signals to the brain with a sensory prosthesis or a deep-brain-stimulation device. Furthermore, neuroscientific experiments have shown that when certain parts of the brain are stimulated it evokes religious experiences. BCI-researchers could combine and refine these technologies (and insights) and may try to induce, or evoke, certain brain states with invasive electrodes that correlate to certain mental representations (perhaps words). A series of such evoked brain states may then result in a series of mental representations and form a cognitive process[21]. Again, I want to emphasize that I am speculating here, but, if this was possible it would be a novel way to obtain and exchange information and would require a different epistemological perspective on human-computer interaction.

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[21] I am aware that this presupposes a physicalist conception of the mind.

5. The Phenomenological Relationship Between Brain-Computer Interface Applications and their Users

'Technologies transform experience, however subtle, and that is one root of their non-neutrality.'

Don Ihde (1990, p49)

In chapter three the relationship between BCI-applications and their users was analyzed from a functional point of view. Functions of the applications were related to abilities of their users and it was demonstrated how these functions extend the means to realize the intentions of their users. In the previous chapter the relation between linguistic and virtual and their users was analyzed from an epistemological standpoint. In this chapter I will analyze the relationship between BCI-applications and their users from a phenomenological point of view. In the past, philosophers like Merleau-Ponty and Heidegger have tried to conceptualize human-technology relationships from a phenomenological standpoint. The contemporary philosopher of technology, Don Ihde, does the same. He builds on traditional phenomenology and constructed a framework on human-technology relations that will be employed in this chapter to explore the relationship between BCIs, their applications and their users. And, in addition, I will make use of Brey's and Verbeek's refinement of Ihde's framework

In the previous two chapters BCIs were approached as merely functional entities. Indeed, they are entities with functions. There is, however, more to it. By having certain functions, a BCI mediates the experience of the world for its user. For example, the function of a BCI-controlled-wheelchair is to restore motor ability. By realizing this function, it opens up a range of new possibilities, such as, visiting family or friends or going to a movie-theater. This mediates how the user experiences the world. Through analyzing the relation between BCI-applications and their users from a phenomenological perspective I try to answers the fourth and last research question:

- How do BCIs and their applications mediate the experience of the world for their users?

In the remaining part of this chapter I will start with presenting Ihde's framework of human-technology relations. This is followed by an evaluation of Ihde's framework in which I draw from Brey's and Verbeek's refinement of it. Thereafter, I will use Ihde's framework as a lens to analyze the relationship between BCI-applications and their users. And this chapter ends with a conclusion in which I argue to what extend Ihde's framework answered the research question at hand.

5.1 Ihde on Human-Technology Relationships

Don Ihde - a North American philosopher of technology - tries to understand human-technology relationships from a phenomenological perspective. The term he uses is *postphenomenology,* because he builds on traditional phenomenology as developed by Husserl, Heidegger and Merleau-Ponty. In his book *Technology and the Lifeworld – From Garden to Earth,* Ihde (1990) developed a framework in which the relations humans have with technology are pointed out. Ihde takes as point of departure the way we experience artifacts and distinguishes four different ways we can do so. Note that these four relations should not be understood as absolute, but as a continuum.

5.2 Embodiment Relations

The first human-technology relation Ihde points out is the *embodiment relation*. It is called embodiment relation because the artifact is embodied and the world is experienced *trough* the artifact. Consider Galileo Galilei who is using a telescope to observe the moon. Galilei embodies his seeing through the telescope. This is schematized as follows: Galileo – Telescope – Moon. The technology is between the seer and the seen in a position of *mediation*. The same is true for someone who wears glasses. But both telescope and glasses must be *transparent* in order to see through. Without being transparent the technology is unable to become embodied. Furthermore, embodying is a process that must be learned. When I first put on my glasses, I perceive the world slightly different then before. I have to adjust to the new way of seeing the world. But once adjusted the technology becomes transparent and is taken into my perceptual-body self experience. This can be schematized as follows: (I – Glasses) – World. When embodied, the glasses *withdraw* from my experience. I have then actively embodied the technics of vision, which is the symbiosis of artifact and user within a human action. Embodiment relations are not restricted to visual relations. They can occur for any sensory dimension. A hearing aid does this for hearing and the blind man's cane for tactile motility. The same structural features of embodiment occur with a hearing aid and a cane. After a while the hearing aid and cane withdraw from attention and I hear the world through the hearing aid and feel it through the cane. The keywords here are 'mediation', 'transparency' and 'withdrawal'.

Glasses and hearing aids are both monosensory devices. However, embodiment relations can also occur with devices that entail whole-body motility like a car, for instance. A driver experiences the road and surroundings through the car. When a car is well embodied, the driver feels, rather then sees the distance between car and surroundings. In this way the drivers' bodily sense is extended to the parameters of the car. This is possible because one's *body image*[22] is not fixed but extendable or reducible. For example, when handling with radioactive material at a distance, one uses mechanical arms and hands to deal safely with the radioactive material. These arms and hands give the operator feedback. The closer to invisibility, transparency and extension of one's bodily sense the technology allows, the better it will be embodied. Embodied artifacts enhance or magnify our bodily powers and therefore change our capacities, which are therefore different from our naked capacities. By extending our bodily capacities, the technology also transforms them. For this reason, technologies are non-neutral and are more than mere functional entities[23].

Magnification and Reduction

Embodiment relations display a magnification/reduction structure. Embodied artifacts simultaneously magnify, or amplify, and reduce what is experienced through them. For example, when observing the moon with a telescope, we see the mountains on the moon through the magnifying capacities of the telescope, but at the same time it removes the moon from its context

[22] This term is derived from Merleau-Ponty's term body-schema.

[23] This aspect of technology is overlooked by theories on the functional relation between humans and technology.

in the sky. A telescope magnifies and reduces at the same time. The apparent size of the moon changes and the apparent position of the observer as well.

The same magnification/reduction structure also occurs with auditory technology like the telephone. When I use a telephone it withdraws from attention and I hear the person on the other side through the telephone, thereby engaging in an auditory embodiment relation. As a monosensory device, my phenomenal presence is reduced to that of a voice. The usually multidimensional presence of face-to-face communication disappears. Furthermore, optical technologies like telescopes or microscopes, bring the observed into a normal bodily space and distance. Planets and bacteria seem nearby and have the same apparent size.

5.3 Hermeneutic Relations

The second human-technology relation Ihde points out is the *hermeneutic relation*. In its broadest sense the term 'hermeneutic' means interpretation. In a more narrow sense it refers to textual interpretation. In Ihde's framework it is defined as an interpretative action within the technological context. This activity calls for special modes of action and perception, modes which are analogues to reading. Reading is a specialized perceptual activity and praxis. For example, when reading a navigational chart, the chart has an isomorphism with what it represents. Also, when reading the chart, the perceptual focus is on the chart itself. The chart becomes object of perception, while at the same time it refers to something beyond itself to what is not immediately seen like roads or coastlines. Now consider a thermometer which measures outside temperature. If one reads 2 ° C, one merely reads a number, but still one *hermeneutically* knows that it is cold outside. In Ihde's words: 'A hermeneutic relation mimics sensory perception insofar as it is also a kind of seeing as ___; but it is a referential seeing, which has as its immediate perceptual focus seeing the thermometer' (Ihde, 1990, p. 85). Ihde formalizes the hermeneutic relation as follows: I → (technology-world). Consider a technician who works in a nuclear power plant and reads a dial depicting levels of radiation. The technician merely has a dial between him or her and the nuclear pile[24]. Here the essential difference between embodiment relations and hermeneutic relations becomes clear. Although the technician reads the pile *through* the dial, the microperceptual focus is *on* the dial. Whereas in embodiment relations the partial symbiosis between myself and the embodied artifact is allowed *through* the perceptual transparency of the artifact. In short, in case of hermeneutic relations we look *at* the artifact and in case of embodiment relations we look *through* the artifact.

Ihde recognizes that it is important how the artifact(s) with which we have a hermeneutic relation are presented and structured. In case of a four-engined airplane, the four dials indicating the r.p.m. of the engines are structured in such a way that the pilot can at a single look see what the r.p.m. of each of the engines is. So technical design has to take perceptual structures into account[25]. Additionally, thermometers, radiation dials and r.p.m. dials all have a direct material connection with what they represent. Now consider a photograph which has a high representational isomorphism with what it represents. There is, however, no direct material connection between photograph and what is photographed. But there is, nevertheless, a hermeneutic relation with a photograph. Ihde calls it a *non-material* hermeneutic relation.

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[24] Artifacts with which we have a hermeneutic relation are cognitive artifacts. They present a representation of the world which has to be interpreted.

[25] This idea relates to Hollan, Hutchins and Kirsh's notion of intelligent use of space.

It was already noted that the four types of human-technology relations should be seen as a continuum. Ihde gives five examples of technologies that shift from an embodiment relation to a hermeneutic relation. Consider two of his examples. The first is a soldier who uses night-scopes to see the enemies' bodily heat radiation. The soldier embodies his or her night-scope, because it is taken into the body image and he or she perceives the world through it. But there is also a hermeneutic dimension to it. The technology makes visible aspects of the world which were not visible before. The bodily-heat signatures have to be interpreted as being human. The second example is a spectrograph. A spectrographic picture of a star does not resemble a star, but merely presents a number of different coloured lines. There is no perceptual isomorphism anymore and the lines have to be read as being a representation of a star. Both examples have embodiment and hermeneutic aspects. In the first the emphasis is on the embodiment and in the second on the hermeneutic dimension. The differences are between *what* is shown and *how* it is shown. In a hermeneutic relation the world is first transformed into a 'text', which is then read. In both embodiment and hermeneutic relations our perception is mediated by an artifact.

5.4 Alterity Relations

The third human-technology relation Ihde presents is the *alterity relation*. This relation is concerned with how we relate to or with technology, to technology-as-other. The question which is central in this relation is: How and to what extend do technologies become other, or at least *quasi-other*? Although technology can be seen as 'other', it must be noted that the otherness remains a quasi-otherness. It is stronger then mere objectness, but weaker then the otherness found with animals or other humans. Humans have the tendency to personalize artifacts. This is known as *anthropomorphism*. This anthropomorphism ranges from human-artifact analogues - like humanoid robots or characterizing computer 'intelligence' as human-like - to affections for artifacts - like being fond of an old car which one tries to keep going. When we enter into an alterity relation the technology becomes center of our focal attention and we see it as quasi-other to which we may relate. This occurs when playing a computer game. Ihde writes the following:

> 'In the actual use of videogames, of course, the embodiment and hermeneutic relational dimensions are present. The joystick that embodies hand and eye coordination skills extends the player into the displayed field. The field itself displays some hermeneutic context (…), but this context does not refer beyond itself into a worldly preference. In addition (…), there is the sense of *interacting with* something other then me, the technological *competitor*. (Ihde, 1990, p 100. Original italics).

The quasi otherness and quasi-autonomy of the game fascinates us. The more the technology is 'like' us, the more we are fascinated by it and the stronger the alterity relation is. Other media like film, cinema and television are technologies with which we relate and are fascinated by, but there is also a hermeneutic dimensions to it, because they refer in their unique way to a 'world'. They can make present events in the world and the perceptual focus is on the screen. Ihde argues that we have a wide range of alterity relations with computer technologies, which 'display a quasi-otherness within the limits of linguistics and, more particularly, of logical behaviours' (Ihde, 1990, p. 106). Ihde schematizes the alterity relation as follows: I → technology-(-world). The parentheses are placed around world to indicate that in alterity relations there may be, but need not be, a relation through the technology to the world.

Video Games and Virtual Reality

Additionally, in his book *Bodies in Technology*, Ihde (2002) has analysed a number of information and communication technologies (ICT) from a phenomenological viewpoint. Amongst those technologies are video games and virtual reality (VR) technologies. He argues that VR technologies with their nearby screens, bodysuits and wired gloves enclose the participant in a technologically encased envelope. But this enclosure is not neutral nor transparent. The participant is fully aware that he or she interacts with technology. Although we have an alterity relation with VR technologies as well as an embodiment and hermeneutic relation, its presence produces a sense of unreality and disorientation, which makes sure that the technology is still a quasi-other or quasi-world.

5.5 Background Relations

The fourth and last human-technology relation Ihde outlines is the *background relation*. The previous three human-technology relations all have in common that the technologies are in the foreground. This is – as the name already suggested – not the case with background relations. Such relations are concerned with technologies that remain in the background. Consider automatic and semiautomatic machines. In the context of our home there are many of such technologies like lighting, heating and cooling systems. The heating or cooling system is set and the system will operate independently of ongoing action. Once operating the technology functions as a barely detectable background presence. The technology does not call for focal attention and withdraws, but in a different way as embodied technologies do. The technology is, as it were, to the side. A background relation can be schematized as follows: I (-technology/world). Although the technology is both present and absent at the same time, it does become part of the immediate environment of the inhabitant. Washing machines, dryers, toasters or microwave-ovens are slightly more semiautomatic and need 'programming.' But when functioning they remain in the background. In background relations the technology does not receive focal attention, but does condition the context in which the inhabitant lives.

Summary

Ihde identified four human-technology relations. The first two, embodiment- and hermeneutic relations, mediate between humans and the world. The other two, alterity- and background relations, do not. In embodiment relations the artifact withdraws from our attention and becomes a (semi)transparent means through which the world is perceived. An example of an embodiment relation is looking at the sky through a telescope.

(1) Embodiment relation: (I-technology) → world

In hermeneutic relations the artifact provides a representation which has to be interpreted and tells us something about the world. An example of a hermeneutic relation is the use of a thermometer. In contrary of embodiment relations, artifacts in hermeneutic relations do not become transparent.

(2) Hermeneutic relation: I → (technology-world)

In alterity relations humans relate to or with an artifact and the artifact is seen as a quasi-other. Humans tend to project human properties on artifacts (anthropomorphism). An example of this is intelligent computers or humanoid robots.

(3) Alterity relation: I → technology (-world)

In background relations artifacts are not consciously experienced. This is the case with, for example, central heating systems or electric lighting.

(4) Background relation: I (-technology/world)

5.6 Evaluating Ihde's Framework

In my evaluating of Ihde's framework I will first focus on Brey's refinement of embodiment relations. After that, I will outline Verbeek's two additions human-technology relations based on Ihde's human-technology relations.

Brey on Embodiment Relations

In his article - *Technology and Embodiment* – Brey (2000b) points out that some examples Ihde uses for embodied artifacts, such as a car, a feathered hat and a hammer do not fit his definition of embodiment neatly. For example, a hammer is, according to Ihde, an embodied artifact, however, it is not used to perceive the world but to act on it. Although one does feel the world through the hammer, it is not used to better perceive the world, which is the case with, for example, telescopes and microscopes. The same applies for cars and the feathered hats. Both are not used - like the blind man's cane - to extend tactile feedback. In fact, a car driver and the woman who wears a feathered head try to avoid obstacles in the world. So, Brey claims, there appears to be a tension in Ihde's different notions of an embodiment relation.

To overcome this tension, Brey turns to Merleau-Ponty's original account of embodiment relations on which Ihde's notion of embodiment is partly based. Merleau-Ponty used the feathered hat, the car and typewriter not as examples of artifacts that mediate perception, but were brought up in a section on motor skills. Merleau-Ponty made a distinction between perceptual skills and motor skills, which – according to Brey - also leads to a distinction between two types of embodiment relation. There are two ways in which an artifact can be incorporated into one's *body-schema*: a structure contained in one's body which gives a unified understanding of the body. First, an artifact can become a means through which *motor skills* are expressed - and second - a means through which *perception* takes place. In Ihde's embodiment relations artifacts become means through which perception takes place. Three of the senses can be mediated by artifacts: seeing (e.g., telescopes, microscopes), hearing (e.g., stethoscopes, hearing aids) and feeling (e.g., blind man's cane, dental probes).

When an artifact mediates motor skills it becomes part of the body-schema. There are two ways in which artifacts can mediate motor skills. First, artifacts can be an appendage to the body which one uses to move in one's environment. The feathered hat and the car are examples. They enlarge one's body and have to be taken into account when moving through the environment. The motor skills required to do so are referred to by Brey as *navigational skills*. Second, artifacts can serve as tools to interact with the environment. An example is the typewriter. The key and typebar are an extension of one's finger. Also, when using a pen, trumpet or hammer one performs actions on the environment with an embodied tool. The motor skills required to do so are referred to as *interactive skills*.

The blind man's cane is an example of an artifact that mediates both motor skills and perceptual skills. When learning to use the cane, the blind man acquires motor skills. His cane is used to

interact with objects in his environment. By doing so, he navigates himself through the environment and at the same time he perceives objects in his environment with his cane.
In sum, Brey refined Ihde's notion of embodiment relations by making a distinction between artifacts that are means through which *motor skills* are expressed and means through which *perception* takes place. Three of the senses (seeing, hearing and feeling) can be mediated through artifacts. When an embodied artifact mediates motor skills, it can aid to navigational skills and to interactive skills. In overview, embodied artifacts can mediate:

(1) Motor skills

(a) Navigational skills

(b) Interactive skills

(2) Perceptual skills

(a) Seeing

(b) Hearing

(c) Feeling

Verbeek's Additional Human-Technology Relations

Peter-Paul Verbeek (2008) has developed two additional human-technology relations. In Ihde's four human-technology relations, technology moves away from the human. In embodiment relations the artifact is *embodied*, in hermeneutic relations the artifact is *read,* in alterity relations the artifact is *interacted with* and in background relations the artifact is merely a *background* presence. However, according to Verbeek, there is a human-technology relation prior to the embodiment relation. In this case artifacts *merge* with the body or brain, rather then merely being embodied. This happens with *bionic* devices like pacemakers, cochlear implants and retina implants, but also when one takes antidepressants to alter one's mood. These examples go beyond embodiment and a new hybrid entity comes into being, which can be called a *cyborg* or bionic being. In embodiment relations a distinction can still be made between a human and the artifact, which is no longer possible with bionic devices. They are not only incorporated in the body-schema, but are absorbed by the physical body and also physically alters the human body. Verbeek calls the relation we have with these bionic devices *cyborg relation,* which is schematized as follows: (I/technology) → world.

Verbeek's second human-technology relation is a refinement of Ihde's hermeneutic relation. Before outlining this human-technology relation it is useful to tell something about the concept *intentionality*. In phenomenology, intentionality is a core concept to understand the relation between humans and their world. In short, intentionality is 'aboutness' or 'directedness'. Humans experience has an intentional structure. This means that we are always directed towards reality. Our thoughts are always about something, we always perceive something and always feel something. So we are experiencing beings and we are always directed at the entities which make up our world. In Ihde's human-technology relations, human intentionality is either mediated (e.g., by a pair of glasses) or directed at technological artifacts (e.g., at a car). According to Verbeek, artifacts with which we have a hermeneutic relation, such as a thermometer, also have a form of intentionality, which he refers to as *technological intentionality*. A thermometer, for instance, is directed at the temperature, a spectrograph is directed at light frequencies and a sonogram is directed at how materials reflect ultrasound. When this directedness of artifacts is added to our own intentionality (or own directedness), *composite intentionality* comes about. This is a form of intentionality which results from an addition of technological intentionality to human intentionality. So humans are directed at the way in which an artifact is directed at its world. To schematize this composite intentionality, Ihde's formalization of hermeneutic relations, which is as follows: I → (technology-world), should be replaced with: I → (technology → world). This human-technology relation is referred to as the *composite relation*.

In sum, Verbeek has argued that there is a human-technology relation prior to Ihde's embodiment relation in which artifacts merge with the body our brain.

(1) Cyborg relation: (I/technology) → world

Furthermore, Ihde's hermeneutic relation was refined in a human-technology relation in which technological intentionality is added to human intentionality.

(2) Composite relation: I → (technology → world)

5.7 Brey's use of Ihde for Understanding Human-Computer Relations

Before we turn to an analysis of BCI-applications in terms of Ihde's framework I will briefly present Brey's use of Ihde's framework for understanding the relation between humans and computers. In the third chapter we have seen that Brey (2008) analyzed the relation between humans and computers in terms of functions. In the same paper he analyzed this relation in terms of Ihde's framework. Brey argues that all four human-technology relations can be established with computers. Bear in mind that Brey made a distinction between the computer as cognitive artifact and as simulation device.

Whenever using a computer we have embodiment relations with input and output devices like keyboard, mouse, joystick and monitor. But in addition, through these devices we can establish embodiment relations with virtual object such as paint brushes, avatars, guns and other virtual objects. Note that the world that is experienced through keyboard, mouse, joystick and monitor is a virtual world. When we use the computer as cognitive artifact, a hermeneutic relation is established. The computer then represents information about the world which is read by its user. A consequence of using the computer as a hermeneutic device is that our knowledge of the world is mediated by computers. We also have an alterity relation with computers. The computer – both as cognitive artifact and simulation device - can be experienced as a quasi-other and is interesting to observe and to interact with. And computers are anthropomorphized by humans. They are seen as and treated as persons. This is understandable because computers have similarities with humans. They can autonomously perform actions, have a high degree of interactivity, can respond to our actions and seem intelligent. Also, often we have an embodiment relation, hermeneutic relation and alterity relation at the same time. When one plays chess with the computer, for example, embodiment, hermeneutic and alterity relations are established. Finally, when using the computer as simulation device, when playing an adventure game, for example, we can experience virtual light sources within the game as background phenomena.

Brey argues that there is an ambiguity with virtual environments. On the one hand, we can see virtual environments as a computer-generated virtual artifact with which we can have embodiment, hermeneutic, alterity and background relations. On the other hand, we can see virtual environments as extensions of the physical world and should not be seen as complex artifacts but as *worlds* in themselves. Worlds are not artifacts with which we have relations, but set the scene within which these relations come into being. The first interpretation sees virtual environments as complex artifacts, whereas the second sees virtual environments as genuine worlds and as meaningful and real as the physical world.

5.8 Brain-Computer Interfaces in Terms of Ihde's, Brey's and Verbeek's Perspective

In this subsection I will try to answer the fourth and last research question. But before turning to an analysis of the relation between the applications and their users, I will present some aspects all BCIs have in common.

The BCI Itself

In chapter two I have written that BCIs can be used with invasive or non-invasive electrodes. If the BCI-system includes invasive electrodes (placed in the brain or on the surface of the brain) the user has a cyborg relation with the electrodes. The electrodes merge with the brain of its user, which can be schematized as follows: (I/electrodes) → world. The electrodes (and signal processing unit) are used to facilitate the relation with the application. So it might be better to schematize it as follows: (I/electrodes) → application.

Furthermore, all BCI users establish some structural features of embodiment relations with the BCI itself: the electrodes (both invasive and non-invasive) and signal processing unit. The BCI itself is taken into the body-schema of its user in order to act upon the application. In Ihde's notion of embodiment relations the world is experienced through the artifact. Galileo, for instance, experienced the moon through the telescope. This is, however, not the case with a BCI. Its user does not experience the application through the BCI, because the BCIs of interest in this thesis are one-way systems: the causal flow goes from the human brain to the artifact and not the other way around. But still, the BCI is in a position of mediation between the application and its user. And in addition, the BCI itself is to some extend transparent and withdraws from attention. So it satisfies all conditions of embodiment relations. It mediates between the user and the application, it is to some extend transparent and withdraws, after a long period of use, from attention. But one essential feature is different, though. In Ihde's notion of embodiment relations the world is experienced through the artifact. However, with BCIs it is the other way around. One can say that the application 'experiences' its user through the BCI. This unique feature distinguishes BCIs from other embodied artifacts.

Verbeek's concept *technological intentionality* is useful for describing this unique feature. Although this concept was developed for artifacts with which we have a composite relation, it applies for the embodiment dimensions of BCIs as well. Verbeek has argued that certain artifacts can be directed at something. A thermometer, for example, is directed at the temperature. This also applies for BCIs, because BCI-systems are directed at the brain. The system is designed in such a way that it detects brain activity. Or in other words, it is designed to be directed at the brain. This means that BCI-systems have, what Verbeek has referred to as, technological intentionality.

However, in case of Verbeek's examples, the artifacts are directed at the world. Thermometers are directed at temperature, spectrographs at light frequencies and sonograms at how materials reflect ultrasound. But, the technological intentionality of BCI-systems is directed at the brain of its user. So it is not directed at the world, but at its user. In contrast, the intentionality of the user is directed at the BCI. This implies that the technological intentionality of the BCI is directed at its user, whereas the intentionality of the user is directed at the BCI. Thus, the two types of intentionality which are involved here are opposed to each other. Otherwise put, they are directed at each other. This may be called *reciprocal intentionality,* because in a reciprocal construction each of the participants occupies both the role of agent and patient with respect to each other[26]. This relation can be captured as follows: (I ⇆ technology) – world. Or in the context of this thesis: (I ⇆ BCI) – world. This particular human-technology relation can be called the *reciprocal relation*. Note that this human-technology relation is not a refinement of Ihde's hermeneutic relation or Verbeek's composite relation, but a human-technology relation in itself developed to better understand the relation between BCIs and their users.

Reciprocal relation: (I ⇆ technology) – world

Note that there are other technological artifacts that can direct their technological intentionality at humans. Someone who is measuring his or her body temperature with a thermometer, for instance. In this case the technological intentionality of the thermometer is directed at the body temperature of its human user and the intentionality of the user is directed at the thermometer. However, it is important to see that these two types of intentionality are not directed at each other and are therefore not reciprocal. In the next subsection I will outline a human-technology relation in which technological intentionality is directed at humans but the technology is not consciously experienced and remains in the background.

Finally, in terms of Brey's refinement of embodiment relations, a BCI is a means through which motor skills are expressed, because it enables its user to act upon the application. However, and this emphasizes the uniqueness of BCIs, it does not realize this through actual motor skills, but merely by translating brain activity into input signals for the application. Acting upon the application is done without motor skills. So strictly speaking the BCI is not a means through which motor skills are expressed, but a means which replaces one's motor ability to interact with certain artifacts. A last point is that in all deliberate BCI-systems the users have to concentrate on the task at hand (e.g., moving a cursor or steering a wheelchair). This feature significantly reduces its transparency, because this makes sure that the user is always aware of the technology.

Non-Deliberate Applications

Non-deliberate applications use brain signals that are not deliberate or consciously regulated. The application of interest here is a BCI-system that monitors the concentration of a physician who is operating a patient. When installed - the physician does not consciously experience the technology. This means that in Ihde's terminology of human-technology relations, users of a non-deliberate application have a background relation with the technology. A non-deliberate application is a semiautomatic system, which - once operating - functions as barely detectable background presence. The technology does not call for focal attention and withdraws from attention. This relation can be schematized as follows: I (-non-deliberate application/world).

[26] This definition of reciprocal relations is used in linguistics. For example, the English sentence 'John and Mary cut each other's hair', contains a reciprocal structure: John cuts Mary's hair, and Mary cuts John's.

Furthermore, a non-deliberate application is simultaneously both present and absent, but does become part of the immediate environment of the user. Note that artifacts in background relations do not mediate between the user and world.

In the previous subsection I have outlined the reciprocal relation. In this relation, the human and technological entity both occupy the role of agent and patient with respect to each other. However, the reciprocal relation does not apply for non-deliberate applications, because the element of human intentionality is lacking. This is so because non-deliberate applications withdraw and do not call for focal attention. And in addition, they do not involve conscious and deliberate thought (which are required to have human intentionality) to control the application. Note that the participant has conscious and deliberate thought while using the BCI-system, but it is not used for controlling the application. So what we have here is a human-technology relation in which technological intentionality is directed at its user, but there is no human intentionality involved. Hence, it appears that the background relation established with a non-deliberate application needs refinement. In order to schematize this, Ihde's formalization of a background relation, which is as follows: I (-technology/world) may, in this case, be replaced with: I (← technology/world). Or in the context of this thesis: I (← BCI/world). So the BCI-system remains in the background while its technological intentionality is directed at its user. This human-technology relation may be referred to as the *unidirectional relation*.

Unidirectional relation: I (← technology/world).

A unidirectional relation may also be established with certain medical technologies that, for example, monitor hart rate, respiration or blood pressure while being hospitalized. These technologies direct their technological intentionality at respectively hart rate, respiration and blood pressure while they remain in the background. More complex unidirectional relations may occur with certain ambient intelligence systems that use profiling to personalize and adapt to particular user behavior patterns. The technological intentionality is in this case not directed at one particular variable of the human body but at behavioral patterns. Thus, technological intentionality in unidirectional relations can be directed at different aspects of the human body, brain or behavioral patterns.

Bodily Applications

Bodily applications restore motor function by steering a motorized wheelchairs or prosthesis. In my analysis I will first focus on BCI-controlled-wheelchairs and then on BCI-controlled-prostheses. A BCI-controlled-wheelchair is taken into the body-image of its user in the same way as Ihde argued a car is taken into the body-image of its driver. The users' bodily sense is extended to the parameters of the wheelchair. In addition, it also mediates between its user and the world. For these reasons, users of a BCI-controlled-wheelchair have an embodiment relation with the wheelchair. Ihde argued that embodiment is a process, it has to be learned. This is clearly the case for a BCI-controlled-wheelchair. Embodying this artifact is a difficult process. The user has to learn that regulating specific neural activity is causally linked to steering the wheelchair. After a number of training sessions the wheelchair becomes to some extend embodied and it taken into the perceptual-body self experience. This can be schematized as follows: (I – BCI-controlled-wheelchair) – world.

Although there are similarities between driving a car and using a BCI-controlled-wheelchair, there are differences as well. A driver who embodies his or her car well can have a conversation with a passenger, make a phone call or think about going to the supermarket. A user of a BCI-controlled-wheelchair has to concentrate very hard on regulating the specific neural activity linked to the wheelchair. This person cannot have a conversation or do other things then concentrate. This means that the user is always aware of the wheelchair and therefore the transparency is rather limited. Ihde wrote that the closer to invisibility, transparency and extension of one's bodily sense the artifact allows, the better it will be embodied. The transparency of a BCI-controlled-wheelchair is limited and the invisibility is limited as well, because the user is painfully aware that he or she is sitting in a wheelchair which has to be steered with one's thoughts. Using a BCI-controlled-wheelchair demands a high degree of concentration and awareness which makes embodying this technology rather difficult.

Remember that Brey has refined Ihde's notion of embodiment. He made a distinction between artifacts that mediate between motor skills and perception. A BCI-controlled-wheelchair is an artifact that mediates motor skills. It is an appendages to one's body and it is used to move in one's environment. It enlarges one's body-image and has to be taken into account when moving through the environment. Brey made a further distinction within the artifacts that mediate motor skills. Artifacts can aid to navigational skills and interactive skills. A BCI-controlled-wheelchair aids to navigational skills.

BCI-controlled-prostheses are taken into the body-image of its user in the same way as Ihde argued mechanical arms and hands - used to deal with radioactive materials - are taken into the body-image of their user. This means BCI-controlled-prostheses are embodied. This can be schematized as follows: (I - BCI-controlled-prostheses) – world. Ihde argued that these mechanical arms and hands give the operator feedback. This is also the case for BCI-controlled-prostheses. They give tactile and visual feedback. But the degree of transparency and invisibility is rather limited. Using a BCI-controlled-prosthesis demands a high degree of concentration and its user is always aware that he or she is using a prosthesis. But the extension of one's bodily sense the prosthesis allows is greater than with a wheelchair, because a prosthesis has more similarities with the original body part it replaces.

In terms of Brey's refinement of embodiment relations, a BCI-controlled-prosthesis is an artifact that mediates both motor skills and perceptual skills in the same way a blind man's cane does. During the neurofeedback sessions, the participant acquires new motor skills, which are used to interact with objects in the environment. At the same time the participant can - due to the tactile feedback - to a certain extend perceive/feel those objects with which he or she interacts.

In both Ihde's and Brey's view on embodiment relations the person interacts with the embodied artifact either with their body or senses. However, in case of a BCI-controlled-wheelchair, the person interacts with the artifact merely with their brain. And in case of a BCI-controlled-prosthesis, the participant interacts with the artifact with both his of her mind and body (stomp). This unique feature (that one interacts with one's mind with an artifact) distinguishes BCIs from other embodied artifacts.

Ihde described that in embodiment relations a magnification/reduction structure is present. In this description he focused on monosensory devices like microscopes, telescopes and telephones[27]. However, structural features of this magnification/reduction structure can also be

[27] By focusing on monosensory devices Ihde implicitly emphasizes the need for a distinction between artifacts that mediate motor skills and perceptual skills.

present in what Brey has called artifacts that mediate motor skills (e.g., cars, cane's or hammers). In chapter three, we have seen that artifacts can extend or amplify human abilities. A person who is driving a car magnifies or amplifies his or her motor skills. However, this person only magnifies one type of motor skills (locomotive motor skills) and thereby simultaneously reduces other motor skills like writing or painting. Now consider a person who is using a bodily application. This person has to concentrate on steering the wheelchair or prosthesis and thereby magnifies, or amplifies, his or her motor skills. But due to the high degree of concentration needed to steer the artifact, this person at the same time reduces both his or her mental/cognitive capacities to steering the artifact, and reduces - or at least transforms - options for other motor functions. This example demonstrates that there is a conceptual distinction between what can be reduced. Ihde argued that by enhancing perception with a telescope or microscope it can also be reduced. However, when using bodily applications, mental/cognitive capacities are reduced as well as other options for motor skills. It is important to distinguish between what bodily or cognitive abilities can be reduced.

To end with, bodily applications are not only embodied but also considerably change the lifeworld for their users. A BCI-controlled-wheelchair, for example, enables a previously paralyzed person to be mobile (again). This opens up a range of new possibilities; someone can visit friends or family, go to a movie theater or do groceries. By opening up new possibilities a BCI-controlled-wheelchair increases one's independence as well as autonomy, because a user is not reliant anymore of someone else to push the wheelchair. All this significantly changes how that person experiences the world. Moreover, this also has a psychological impact on one's self-image and self-esteem in a positive way. So by mediating between its user and the world a BCI-controlled-wheelchair changes *how* the world is experienced. One could say that they *expand* the lifeworld of its user. These effects also occur with BCI-controlled-prostheses but in a lesser degree, because they restore less motor functions. Furthermore, one could argue that the BCI itself mediates between the user and the application, and the BCI-system in its entirety mediates between the user and the world.

Linguistic Applications

Linguistic applications restore the ability to communicate by selecting letters on a computer screen with a cursor. In the third chapter we have seen that a linguistic application is a cognitive artifact and serves a representational function. The relation between a linguistic application and its user shows some features of a hermeneutic relation. There is an interpretative dimension to it, because the spelled words have to be interpreted. And when doing so, the perceptual focus is on the application. Most examples Ihde mentioned of artifacts with which we have hermeneutic relations, such as, thermometers, radiation dials and r.p.m. dials have a direct material connection with what they represent. This is not the case with linguistic applications, because they represent words and sentences, which do not have a material connection with way they represent. In fact, it may even be so that they do not have any connection with the world. Additionally, one structural feature of embodiment relations is also established. A linguistic application is in a position of mediation between its user and the world. But, it is not transparent nor does it withdraw from attention, and it is highly doubtful whether it will taken into the body schema of its user.

Furthermore, someone using a linguistic application merely *reads* the words he or she has spelled. The user is not concerned with interpreting representations that tell something about the world. The user produces those representations on the screen him- or herself to communicate with someone else. So this relation may have some features of a hermeneutic relation, the most essential one: that the artifact tells its user something about a state of affairs in the world – is absent. This means that this relation may be captured as hermeneutic in the original sense of the word, but not as hermeneutic in Ihde's sense of the word. The same is true for someone who reads the spelled words. There is hermeneutic dimension to it, but not in the sense of Ihde's hermeneutic relation.

Ihde has argued that we have a wide range of alterity relations with computer technologies. In case of VR technologies, he has argued that it encloses the participant in a technologically encased envelope. But this enclosure is not transparent. The participant is fully aware that he or she interacts with technology, which makes sure that the technology is still a quasi-other. In addition, Brey has also argued that the computer can be experienced as a quasi-other, because it is anthropomorphised and interesting to observe and to interact with. A linguistic application is a computer system that is also interesting to interact with and may to some degree be anthropomorphized. In parallel with VR technologies, the participant is enclosed in a technologically encased envelope: the electrodes, signal processing unit and application - and is fully aware that he or she interacts with technology. It therefore remains a quasi-other. Nonetheless, there is an alterity relation between linguistic application and its user, which can be schematized as follows: I → linguistic application-(-world).

We have seen that bodily applications expand the lifeworld of their users, because they extend one's action horizon, increase one's independence as well as autonomy, and have a positive impact on one's self-image. All these consequences also take place with linguistic applications. Restoring the ability to communicate for someone who was previously incapable of doing so has a tremendous impact on his or her lifeworld. Being able to interact with others and to communicate how you feel or what you think not only significantly increases one's autonomy and dignity, but, it also includes a user of a linguistic application in the lifeworld of others as well in a more invasive way then before.

Virtual Applications

The virtual application of interest here is Google Earth. In chapter three we have seen that it is both a cognitive artifact and a simulation device. A cognitive artifact has a representational function which has to be interpreted. When doing so, the perceptual focus is on the application. This implies that a user of Google Earth enters into a hermeneutic relation with the device. Ihde has used a navigational chart as an example of an artifact with which we have a hermeneutic relation. Both Google Earth and a navigational chart are object of perception, while at the same time they refer to something beyond themselves to what is not immediately seen like roads or coastlines. Both have the same function, which is to provide geographical information. Although there is no direct material connection with what it represents, there is a high representational isomorphism. This relation can be schematized as follows: I → (Google Earth-world).

We have seen that there is an alterity relation between a linguistic application and its user. This is also the case with Google Earth: it is interesting to interact with and observe how it works. In parallel with VR technologies, the participant is enclosed in a technologically encased envelope: the electrodes, signal processing unit and application - and is fully aware that he or she interacts with technology. It therefore remains a quasi-other. Nonetheless, there is an alterity relation between Google Earth and its user, which can be schematized as follows: I → Google Earth-(-world).

Furthermore, because a virtual application is in the center of the perceptual field of its user, one could say that the application, while using it, becomes the lifeworld of its user. This feature relates to the magnification/reduction structure. When using the application one's visual awareness is reduced to the application, while at the same time the application itself magnifies, or perhaps better, enhances cognitive abilities of its user. Also, since using the application demands a high degree of concentration, one could say that one's awareness, and lifeworld in general, is reduced to the application. As soon as one is distracted one cannot use the application anymore. Note that this also takes place when using a personal computer, but in case of BCIs the degree of concentration needed to use the application is much higher. So the reduction aspect is stronger. All this implies that a virtual application reduces the lifeworld of its user, but it simultaneously opens up a new virtual lifeworld for their user. Perhaps it is interesting to mention that within the virtual lifeworld the magnification/reduction structure can also take place. When using a gun to shoot an enemy, for instance, an avatar magnifies, or enhances, its bodily capacities while at the same time options for other motor skills are reduced.

5.9 Conclusion and Reflection

In this chapter I have analyzed the relation between BCIs, their applications and their users from a phenomenological perspective in an attempt to answer the fourth research question:

- How do BCIs and their applications mediate the experience of the world for their users?

As a first step to answer this question, it must be noted that invasive electrodes have a cyborg relation with its user. Furthermore, the relation between the BCI itself: the electrodes and signal processing unit, and its user – display some structural features of embodiment relations. The BCI itself is taken into the body-schema of its user in order to act upon the application. It is between the application and its user in a position of mediation, and is to some extend transparent and withdraws from attention. However, BCIs have a unique feature that distinguishes them from other embodied artifacts. In Ihde's notion of embodiment relations the world is experienced through the artifact. But in case of BCIs it is the other way around. One can say that the application 'experiences' its user through the BCI.

Verbeek's concept *technological intentionality* turned out to be useful for describing this unique feature. BCI-systems are directed at the brain, which implies they have technological intentionality. The technological intentionality of the BCI is directed at its user, whereas the intentionality of the user is directed at the BCI. Thus, the two types of intentionality are directed at each other and are reciprocal, which may be called *reciprocal intentionality*. This relation can be captured as follows: (I ⇆ technology) – world. Or in the context of this thesis: (I ⇆ BCI) – world. In the third chapter it was concluded that there is a symbiotic relation between BCIs and their users, because there is a close interaction and cooperation between BCI and user to realize a particular function. The reciprocal relation explains this symbiotic dimension from a phenomenological angle.

Furthermore, acting upon the application is done without motor skills. So strictly speaking the BCI is not a means through which motor skills are expressed, but a means which replaces one's motor ability to interact with certain artifacts. This being said, I will now sum up the relation between the application and their users. First, a non-deliberate application is a semiautomatic

system, which - once operating - functions as barely detectable background presence. The technology does not call for focal detection and withdraws from attention. As a result, users of a non-deliberate application enter into a background relation with the artifact. However, the background relation established with a non-deliberate application needs augmentation. We have seen that there is a reciprocal relation between BCIs and their users. But, the reciprocal relation does not apply for non-deliberate applications, because the element of human intentionality is lacking. So there is only technological intentionality involved here. This novel human-technology relation may be referred to as the *unidirectional relation* and can be captured as follows:
I (← technology/world). Or in the context of this thesis: I (← BCI/world). Also, it is important to mention that non-deliberate applications do not significantly change the lifeworld for their users, because they remain in the background.

Second, a BCI-controlled-wheelchair is taken into the body-image of its user and mediates between its user and the world. They are for these reasons embodied. But, using the device demands a high degree of concentration and awareness which makes embodying this technology rather difficult. In terms of Brey's refinement of embodiment relations, a BCI-controlled-wheelchair is an artifact that mediates motor skills and aids to navigational skills. BCI-controlled-prostheses are taken into the body-image of its user and also mediate between its user and the world. They are therefore embodied. Using it also demands a high degree of concentration and its user is always aware that he or she is using a prosthesis. But the extension of one's bodily sense the prosthesis allows is greater than with a wheelchair, because a prosthesis has more similarities with the original body part it replaces. In terms of Brey's perspective on embodiment relations, a BCI-controlled-prosthesis is an artifact that mediates both motor skills and perceptual skills. And finally, someone using a bodily application reduces his or her mental/cognitive capacities to steering the artifact as well as reducing options for other motor functions.

Third, a linguistic application has a representational function which has to be interpreted. When doing so, the perceptual focus is on the application itself. But, there is no hermeneutic relation between a linguistic application and its user, because the most essential feature - that the artifact tells its user something about the world – is absent. Also, there is an alterity relation between linguistic application and its user, because it is anthropomorphised and interesting to observe and to interact with. And lastly, the virtual application of interest here, Google Earth, has a representational function which has to be interpreted. When doing so, the perceptual focus is on the application itself. All this implies that a user of Google Earth enters into a hermeneutic relation with it. Additionally, there is an alterity relation between Google Earth and its user, because it is anthropomorphised and interesting to observe and interact with.

To end with, we have seen that deliberate applications considerably change the lifeworld for their users. By restoring abilities for paralyzed persons BCIs extend one's action horizon and increases one's independence, autonomy and self image, thereby significantly expanding the lifeworld of its user. However, due to the high degree of concentration needed to use a BCI-application, they can also reduce the lifeworld of their users. In case of virtual applications, they reduce the lifeworld of their users, but simultaneously open up a new virtual lifeworld for their users in which the magnification/reduction structure can occur as well.

Reflection

In this subsection I will try to develop some speculative ideas on the phenomenological consequences of the future use of BCIs. In the reflecting section of the previous chapter, I have theorized that two-way BCI-systems would enable a human brain and computer system to exchange information in both directions. Two-way BCIs may induce, or evoke, certain brain states with invasive electrodes that relate to certain mental representations (perhaps words). A series of such evoked brain states may then result in a series of mental representations and could form a cognitive process. I have speculated that if this was possible it would be a novel way to obtain and exchange information and would require a different epistemological perspective on human-computer interaction.

We have seen that Ihde's point of departure for his phenomenological analysis of human-technology relations was the way we *experience* technological artifacts. From a phenomenological perspective, obtaining information by directly stimulating the brain with electrodes is fascinating for at least two related reasons. First, because it is a completely new way to interact with and experience an artifact. Traditionally, we do so with our body and senses, but in case of a two-way BCI we do so solely with our brain. This asks for a new phenomenological perspective on human-technology relations. And second, because it is a novel way of obtaining and exchanging information. Normally we acquire information with our senses; we listen to others, read a book, watch a documentary and so forth. But if it becomes possible to evoke cognitive processes and thereby directly transmit information to the brain we do not need our senses anymore to obtain information.

Note that I am not arguing that possible developments in BCI-research will make our senses obsolete, but, rather, I am speculating that in the future it may be possible that two-way BCIs could function as an addition to our senses by providing us with information. Two-way BCIs could function as a 'sixth sense', so to speak, which would have rather drastic consequences for the (re)structuring of our cognitive system, not to mention the societal consequences this would bring. From a phenomenological viewpoint, having an additional sense is captivating, because it will rather drastically change the way we experience acquiring information. In the final chapter I will speculate a bit more about the consequences of two-way BCI-systems for the restructuring of our cognitive apparatus.

Describing the experience of having your brain stimulated by invasive electrodes and thereby evoking cognitive processes is in phenomenological terms a real challenge. Ihde's, Verbeek's and my own human-technology relations are unable to account for this feature, because the underlying idea in these human-technology relations is that we interact with artifacts with our body and senses. So they presuppose that we bodily-sensory experience artifacts. However, if there is only a relation between the brain and a computer, and the senses and body are circumvented, this will result in a different way of experiencing an artifact and the experience of obtaining information. This will be fundamentally different then interpreting a representation provided by a cognitive artifact, which is the case in Ihde's hermeneutic relation or Verbeek's augmentation of it. Note that I am speculating here, but it may be possible to not only evoke cognitive processes - but also images, emotions or other experiences. This feature will open up a whole different lifeworld for their users, a lifeworld that is deeply different then the one we are used to. Developing a human-technology relation from a phenomenological perspective which can account for this captivating feature would be interesting material for future research. In the reflecting section of the past chapter, I will theorize more on the restructuring of our cognitive system and on societal consequences of two-way BCI-systems.

Let's theorize a bit more about the consequences of a BCI-system that can evoke images, emotions or other experiences by briefly relating it to Robert Nozick's thought experiment *the experience* *machine,* outlined in his book Anarchy, State and Utopia (Nozick, 1974). The experiment roughly goes as follows. Neuroscientists have figured out a way to connected the brain to a machine which is able to give you the most pleasurable experiences. One is not able to tell whether the experiences are real or produced by the machine. The question ‘what is real?’ is left out for sake of convenience. Nozick asks: if we were given the choice, would we choose the experiences the machine provides us with over real life? So it boils down to a choice between a (hedonistic) simulated life and a real authentic life.

Nozick provides us with three arguments why not to ‘plug in’ into the experience machine. First, most humans want to actually ‘do’ certain things, rather than simply have the experience of doing them. The basic idea of this argument is that real experiences have a higher worth than experiences which are simulated. Second, he points out that we value being (as well as becoming) certain kinds of persons. This is one of the ways how we get to earn our (self)respect. And dealing with misfortunes and problems in life builds character. Furthermore, virtues like dedication, persistence and willingness to strive hard for one’s goals may disappear if one only has to plug in to get what one desires. And third, Nozick argues that we value contact with reality in itself, independent of any drawbacks such contact may bring. We want to know we are experiencing the ‘real thing’. In sum, Nozick thinks that it is important to most people, often in a rather deep way, that we are the authors of our own lives and that this necessarily involves interacting with the real world. Thus, one could argue that such a Matrix-like scenario is from the view of certain conceptions of the good life not desirable. There is more in life than pleasure alone. Furthermore, in the reflecting section of chapter six, I will provide some more moral considerations of two-way BCI-systems.

6. Conclusion and Reflection

'The ghost in the machine.'

Gilbert Ryle (1949)

In this thesis I have analyzed the relationship between BCIs, their applications and their users from three philosophical perspectives in an attempt to answer the overall research question:

- What is the functional, epistemological and phenomenological relationship between BCI-applications and their users?

In the next four sections I will demonstrate to what extend I have answered the four sub-questions which are derived from the overall question. But before doing so, it must be made clear that in this conclusion I will not sum up each of the particular relation between the four BCI-applications and their users. Instead I will try to extract some general features which apply for all BCI-systems. For a detailed summing up of the particular relation between the four BCI-system and their users I refer to the concluding sections of chapters three, four and five. Lastly, in the fifth section of this conclusion I will reflect on my research, place it in a broader framework and provide some moral considerations.

6.1 Brain-Computer Interfaces

As an initial step to answer the overall research question I have tried to answer the first sub-question:

1) What are BCIs, what are their distinguishing features and possible applications?

BCIs are an emerging technology that extracts brain activity and translates it into command signals for external devices. The most distinguishing feature of a BCI is that it establishes a direct communication pathway between the brain and an artifact. Neurofeedback, machine learning algorithms and evoked potentials are three distinct methods for controlling a BCI. Furthermore, brain signals are extracted with invasive or non-invasive electrodes, processed by a processing unit and used as command signals for an application. Furthermore, I have conceptually analyzed different types of applications, which resulted in a taxonomy in which all applications with similar features are grouped. In this taxonomy I have distinguished between four possible BCI-applications, which can de analyzed on two levels. On the first level, a distinction was made between *deliberate* and *non-deliberate applications*. Deliberate applications require conscious, deliberate thought to control the application. There are two distinct ways to do this. The first is based on motor imagery and the second is based on evoked potentials.

In contrast, non-deliberate applications extract brain signals which are not deliberately or consciously regulated. On the second level, which is a further distinction within the deliberate applications, I have distinguished between *bodily*, *linguistic* and *virtual applications*. Bodily applications are devices which restore motor functions like, for instance, a motorized wheelchair or prosthesis. Linguistic applications restore the ability to communicate by enabling its users to select letters on a computer screen. And finally, virtual applications control a virtual environment like, for instance, a computer game or Google Earth.

6.2 The Functional Relationship

In the next step to answer the overall research question I have tried to answer the second sub-question:

2) How do functions of BCIs and their applications relate to abilities of their users and how can they extend these abilities?

I have tried to answer this question by employing McLuhan's and Brey's perspective on human-technology relationships. I have used their views to analyze functions of BCI-applications, relate them to abilities of their users and analyze how they extend these abilities. As a point of departure I used McLuhan's framework in which he argued that technological artifacts extend human organs, senses or functions. In terms of this taxonomy, all BCIs literally extend the central nervous system, which is an organ in McLuhan's framework. Furthermore, in my analysis I have focussed on the function of the application, because the user primarily has a functional relation with the application, rather than with the BCI itself: the electrodes and signal processing unit. However, the functional relation between the BCI-applications and their users is largely determined by the BCI itself. We have seen that all BCI-systems extend the central nervous system, which is realized by the BCI itself. McLuhan's concept *accelerated interplay of functions* was useful for including the BCI in the functional equation. Electrodes, signal processing unit and application all cooperate to accelerate a certain function or organ of a BCI user.

Brey's framework made clear that BCI-applications extend the means to realize the intentions of their users. This is a better (and more abstract) way to describe the functional relation between BCI-applications and their users then saying that they extend organs or functions of their users. In addition, there is a *symbiotic relationship* between the users' brain and the application in all BCIs, because in each case the brain and the application *cooperate*. This cooperation is facilitated by the BCI itself, or better, largely determined by the BCI itself. So in essence each BCI builds on faculties of the brain to extend the means to realize intentions of its user. Also, an important conclusion is that linguistic and virtual applications extend the means of their users to realize certain cognitive processes.

6.3 The Epistemological Relationship

As a third step to answer the overall research question I have tried to answer the third sub-question:

3) How can the epistemological relationship between BCI-applications and their users be described, evaluated and improved?

In the functional analysis in chapter three it became clear that linguistic and virtual applications extend the means of their users to realize certain cognitive processes. In order to describe the cognitive, or epistemic, relation between those applications and their users in more detail, I have employed Brey's perspective on human-computer relations. After doing so, it turned out that both linguistic and virtual applications are *cognitive artifacts* and form *strong coupled systems* as well as *hybrid cognitive systems* with their users. I then went on to evaluate the epistemic relation between one type of virtual application, Google Earth, by making use of Goldman's five epistemic standards. Taking the outcome of all the five standards into account, it was concluded that the epistemic quality of Google Earth is good.

And finally, after having described and evaluated the cognitive relation between linguistic and virtual applications and their users, I have tried to examine how to improve the epistemic quality. This was done by employing Hollan, Hutchins & Kirsch's view on digital representations. Their notion of *history-enriched digital objects* implies that often used letters should be presented larger or brighter on the screen of a linguistic application. Their notion of *zoomable multiscale interfaces* implies that for someone who is selecting letters on a computer screen, it might be more effective if the letter the person wants to select becomes larger when the cursor moves towards it. Their notion of *intelligent use of space* implies that for persons who are not used to the *qwerty* style, it might be logical to present the most often used letters in the middle and letters that are used less often in the periphery of the screen. These three suggestions for improvements are valuable for designers and for the users as well.

In case of Google Earth, the notion of zoomable multiscale interfaces is already implemented. The notion of intelligent use of space is irrelevant. And the notion of history-enriched digital objects may be employed to include the search-history of other users to show what was of interest for them. This can be done by making places which were of interest for other users brighter. Or perhaps also by making use of certain labels. However, whether this suggestion is really helpful for making Google Earth more effective in terms of distributing cognition is doubtful.

6.4 The Phenomenological Relationship

As a final step to answer the overall research question I have tried to answer the fourth sub-question:

4) How do BCIs and their applications mediate the experience of the world for their users?

I have employed Ihde's postphenomenological perspective on human-technology relationships to answer this question. Ihde has distinguished between four types of human-technology relations: the embodiment relation, hermeneutic relation, alterity relation and background relation. In an embodiment relation artifacts mediate between a human and the world. All BCI-systems display some structural features of embodiment relations and therefore *mediate* between its user and the world. The BCI itself is taken into the *body-schema* of its user in order to act upon the application. It is between the application and its user in a position of mediation, and is to some extend transparent and withdraws from attention. Moreover, BCIs have a unique feature that distinguishes them from other embodied artifacts. In Ihde's notion of embodiment relations the world is experienced through the artifact. But, in case of BCIs, it is the other way around. One can say that the application 'experiences' its user through the BCI. So strictly speaking the BCI is not a means through which motor skills are expressed, but a means which replaces one's motor ability to interact with certain artifacts.

Verbeek's concept *technological intentionality* was useful for describing this unique feature. BCI-systems are directed at the brain, which implies they have technological intentionality. The artifacts that, according to Verbeek, have technological intentionality are directed at the world.

But, the technological intentionality of BCI-systems is directed at its user. In contrast, the intentionality of the user is directed at the BCI. This implies that the technological intentionality of the BCI is directed at its user, whereas the intentionality of the user is directed at the BCI. Thus, the two types of intentionality are reciprocal and directed at each other, which may be called *reciprocal intentionality*. This new human-technology relation may be called the reciprocal relation and can be captured as follows: (I ⇆ technology) – world. Or, in the context of this thesis: (I ⇆ BCI) – world.

Lastly, the background relation established with a non-deliberate application needs refinement. We have seen that there is a reciprocal relation between BCIs and their users. But, the reciprocal relation does not apply for non-deliberate applications, because the element of human intentionality is lacking. So there is only technological intentionality involved here. This novel human-technology relation may be referred to as the *unidirectional relation* and can be captured as follows: I (← technology/world). Or in the context of this thesis: I (← BCI/world).

6.5 Reflection

As was mentioned in the introduction of this thesis, the underlying idea which ties the functional, epistemological and phenomenological approaches to human-technology relations together, is based on a philosophical anthropological understanding of human beings, and how technology relates to this. One of the aims of philosophical anthropology is trying to better understand what characterizes or defines human beings. An essential characteristic is that we are tool using beings. And our relation with these tools largely determines who we are. Therefore, a better understanding of the relation with our tools contributes to a better understanding of what characterizes human beings. If the relation with our tools largely determine who we are, and our tools develop into ever more complex technological systems, it implies that human beings become more complex as well. BCIs are a good example of this development and need special anthropological attention, since they can have rather far reaching consequences for the evolution of our cognitive system. Our cognitive abilities are important from an anthropological viewpoint, because they largely define who we are. In the next paragraphs I will try to place possible developments in BCI-research and their anthropological consequences in a broader perspective, which is followed by touching upon some moral considerations on these possible developments.

Historical Anthropological Perspective

In order to frame the human-BCI relation in a broader historical and anthropological perspective, it is useful, as a point of departure, to look at what philosophical anthropologist Jos de Mul (2002) has written about the development of our cognitive system. The evolution from *Homo Sapiens* to *Homo Sapiens Sapiens* (modern humans) was characterized by the introduction of external symbols like cave paintings, other artistic representations and written language. When we read a book, for instance, we form a strong coupled system with it and therefore it is part of our cognitive system. Written language has, according to de Mul, transformed our cognitive system. By distributing our cognition we have developed new skills like reading and writing, which – after a long evolutionary process – eventually led to philosophy and science. Our use of the computer will – as with written language – result in a restructuring of our cognitive system, de Mul claims. In case of written language we have only *distributed* cognitive processes. However, as we have seen with Brey's perspective on human-computer relations, we have now entered a stage in which computers can *replace, supplement* and *enhance* human cognitive processes. We heavily rely on our computers and other cognitive artifacts to perform cognitive tasks for us. This has far reaching consequences for the restructuring of our cognitive apparatus. Physically connecting the human brain to a computer system takes this development even further and might be the next step in the evolution of our cognitive system.

To put strength to the claim that BCIs could be the next step in the evolution of our cognitive system, it is useful to relate it to Merlin Donald's book *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition*. Donald (1991), a psychologist, has argued that the human cognitive system has evolved over three stages. This evolutionary process took place over several million years. For sake of convenience I will leave out all the evolutionary concepts like selection pressure and genetic make up, and focus on the three transitional stages of cognition. Center stage in his analysis is the memory system. Each of the three stages is characterized by a change in the memory system. As point of departure Donald uses apes. According to Donald, apes have *episodic memory,* which is the ability to store perceptions of specific episodes. However, apes have poor recall of their memories, because they cannot self-trigger their memories.

The first cognitive transition resulted in the development of *Homo Erectus*. This creature was able to make tools and had a very rudimentary form of communication based on the ability of facial, verbal and whole-body expressions. This ability allowed Homo Erectus to have some degree of *quasi-symbolic* communication. These representations can be learned by imitation and constitute a cognitive mechanism for creating a unique communal set of representations. Learning these representations would have placed an increased memory demands on the individual. Moreover, these skills are a preadaptation for the later evolution of language and allowed tool use and social organisation.

The second cognitive transition is, amongst other things, based on the capacity for lexical invention, grammar and neuronal and anatomical adaptations for speech. This has led to the development of *Homo Sapiens*. I will not outline in detail how words, the meaning of the words and grammar are formed. It suffices to say that over time a vocabulary with grammar is formed. The ability to speak depends on the mimetic (imitation) ability to rehearse and retrieve vocal acts. Language is by definition build on top of our mimetically skilled phonological system. Furthermore, in order to actually speak words, the anatomical (vocal cords, tongue, etc.) and neurological systems had to evolve. The development of the vocabulary has put an even more increased demand on the memory system, because Homo Sapiens had to remember its vocabulary.

The third cognitive transition is based on the externalization of the memory system and has led to the developed of *Homo Sapiens Sapiens*. The externalization of memory started out with the development of written language which was subsequently used to record events (and stories) and eventually resulted in forming theories about reality. These developments introduced radical new properties into the individual and collective storage and retrieval systems of humans. This has changed the human cognitive architecture in general and in particular the role of biological memory. Externalizing memory and thereby distributing cognition, has huge advantageous. Biological memory has only a limited amount of 'data-storage', which is now drastically extended with external memory systems. Information can now not only exponentially cumulate, but it is also made increasingly available - by books, newspapers and computers - for many people. Perhaps the Internet is the most recent (and powerful) example of the development of the externalization of our memory system. All three transitions took place with a restructuring of the cognitive and neurological system. The neurological restructuring is largely made possible by the *plasticity* of the brain. In short, this means that neurons, the buildings blocks of the brain, are able to make new connections with other neurons, which enables new cognitive abilities.

In sum, Donald has argued that the human cognitive system has evolved over three stages. The first stage was characterized by the ability to use facial, verbal and whole-body expressions to communicate. The second stage was characterized by the ability to use spoken language. And the third stage was characterized by the ability to use written language and other technological means to externalize memory. This evolutionary process has led to the following three types of humans:

(1) Homo Erectus:	Facial, verbal and whole-body expressions
(2) Homo Sapiens:	Spoken language
(3) Homo Sapiens Sapiens:	Written language and externalization of memory

I would like to propose that two-way BCIs could induce, enabled by the plasticity of the brain, the fourth transitional stage in the evolution of our cognitive system. In the reflecting sections of chapters four and five, I have theorized that two-way BCIs would enable a human brain and computer system to exchange information in both directions. This would be a radical new way of obtaining and exchanging information. If this becomes possible and we can directly transmit information to the brain, a two-way BCI could function as an additional sense and can provide us with vast amounts of information with a high information transfer rate. This would induce a radical restructuring of our cognitive apparatus and could lead to the evolution of a different type of human being, which may be referred to as the *Homo Informaticus*[28].

(4) Homo Informaticus:	(Re)internalization of external memory system

Note that this is highly speculative, but if a two-way BCI would connect the brain to a digital information system, it would (re)internalize a part of our external memory system. A consequence would be that this digital information system (perhaps the Internet), could largely replace, or at least significantly supplement, our biological memory, because they could make information available instantly. Moreover, *merging* our cognitive apparatus with a digital information system would give the notion of distributed cognition a different meaning. However, a drawback of such a development could be that Homo Informaticus depends to much on the artificial memory system. What happens if the memory system malfunctions, gives invalid information, or worse, shuts down? This could have disastrous consequences. A contemporary example of an external memory system that sometimes malfunctions are navigation systems. I can say from my own experience that at times they do not function properly, which can have negative consequences like being too late for appointments, getting lost and so forth. This is can be very annoying, to say the least. But, if Homo Informaticus' entire external memory systems malfunctions, and he or she depends heavily on it, it has disastrous consequences.

The evolution of Homo Sapiens Sapiens into Homo Informaticus would result in a transhuman being. It can therefore be placed in the *transhumanism* debate. Transhumanism, sometimes called posthumanism, is a school of thought that advocates the enhancement of human beings by supporting the use of new technologies for the enhancement of the human body and cognitive

[28] The term 'Homo Informaticus' is not novel. Broadly defined, Homo Informaticus is a human being that increasingly absorbs more digital information due to developments in information and communication technologies (ICT). My conceptualization of this term adheres to a more narrow definition. I define Homo Informaticus as a being that has (re)internalized his or her external memory system by employing a two-way BCI to interact with a digital information system.

abilities. It is a controversial intellectual and philosophical movement, which goal is to erase human diseases, handicaps, augment bodily and cognitive functions and prevent or at least slow down the aging process. Transhumanism can be seen as an extension of humanism. Humanists acknowledge that we are not perfect, but that we can improve ourselves with rational thinking, freedom, tolerance, democracy and concern for others. Transhumanists agree with all this, but also want to employ science and technology to improve the human condition. They see the enhancement of the human organism as the next step in the human evolution (Bostrom, 2003). Thus, a transhumanist would see the evolution of Homo Sapiens into Homo Informaticus[29] as desirable.

Moral Considerations

I will end this thesis with touching upon some moral considerations on the desirability of BCI-systems. The aim of this subsection is not to argue in favor or against any moral position, rather, its goal is to merely touch upon some moral and societal issues which could result from the developments in BCI-research. In case of BCIs that restore functions for paralyzed persons it is difficult not to see them as desirable. But, in case of BCI-systems that allow a healthy person to sit to still and interact with technology merely with his or her brain, one might wonder whether this is desirable. Albert Borgmann (1984) has argued that artifacts deliver *availability*. A central heating system, for instance, delivers warmth. It makes the warmth instantaneous, safe, ubiquitous and easy to obtain. In earlier times, in order to get warmth, one had to go into the forest to chop wood and the fire had to be lit and had to be kept going. So in earlier times, warmth is not instantaneous, could be dangerous (one could hurt oneself when chopping wood), is not ubiquitous nor easy to obtain. The point of this example is that modern technology brings commodities without bodily engagement with our environment; contemporary technology reduces us to passivity and does not engage the body. Virtual applications, and perhaps other future applications as well, do not engage the body of healthy persons. Do we really want this? Do we want to become such ‘couch potatoes’?

Furthermore, I have theorized that the next logical step is designing two-way BCI-systems that would enable information to flow in both directions. One can question the moral and societal desirability of such a development. What happens to us and society if we employ a two-way BCI to interact with a digital information system that makes available a vast amount of information instantly? From a moral perspective there are two issues which are interesting to discus. The first is how such a two-way BCI-system relates to the treatment/enhancement distinction. And the second relates to the moral and societal consequences the cognitive enhancement a two-way BCI will bring.

One could argue that employing a two-way BCI to interact with a digital information system that makes available a vast amount of information instantly, significantly enhances one’s memory and therefore one’s cognition in general. Enhancing cognitive abilities goes beyond treating cognitive impairments and is according to some not desirable. However, the distinction between enhancing and treating cognition is not always that clear (Turner & Sahakian, 2006). If there is a difference between treatment and enhancement, there should be a clear conceptualization of the point when

[29] The concept Homo Informaticus can also be related to Luciano Floridi’s (2006) concept *inforg* (acronym of informational organism), which is shortly defined as a connected informational organism. It is important to note that an inforg will not directly connect his or her brain to an informational system. Instead, an inforg will increasingly delegate or outsource his or her decisions, memories and routine tasks to artificial systems. Also, all this will change how an inforg sees his or her agency.

treatment becomes enhancement. This point is based on the definition of normal human beings. The concept normal can be defined as not deviating from a standard. However, differences in culture, wealth, genetic make up, economic status, education and upbringing make it difficult to define what normal human cognition is in a global environment. So who determines the standard from which not to deviate? Furthermore, consider someone who suffers from *Korsakoff's Syndrome* and has an extremely bad memory. If this person was to be given Ritalin or another substance that increases one's memory, it would enhance his or her memory, but, still, that person's memory would not even be close to the memory of a 'normal' person. So it is possible that a particular trait is enhanced, in this case memory, but that trait is still far from being 'normal'. Thus, if it is difficult to determine what normal is, and the treatment/enhancement distinction presupposes the definition of being normal, it implies that this distinction is difficult to uphold.

Although the treatment/enhancement distinction is hard to uphold, many ethical considerations regarding cognitive enhancements in general and memory enhancements in particular are based on this distinction. Neuroethicists from the British Medical Association (2007) have argued that certain enhancements of our cognitive system might threaten our authenticity and personal identity[30]. They argue that native or achieved excellence has a higher worth than cognitive abilities which are bought. If cognitive abilities can be bought with an external aid like a two-way BCI, it would reduce their value and make them less admirable. Virtues like dedication, persistence and willingness to strive hard for one's goals might disappear if it only requires money to buy a two-way BCI. Furthermore, invasive BCIs could cause moral issues concerning safety as well. Invasive BCIs would probably change the structure and functioning of our brain, which may change the personal identity of its users. We have no idea how the brain might respond to the restructuring of the neural system. It could cause undesirable side-effects, such as, cognitive impairments, memory loss, personality changes and so on. Moreover, cognitive enhancements in general might change power relations and interpersonal relations between humans. If a person all of a sudden becomes more intelligent than another, it might change how that person sees others who are less intelligent. A cognitively enhanced person may not be seen in his or her environment as the same person anymore (Hansson, 2005).

Furthermore, if two-way BCIs become widespread, there will be situations in which people might feel pressured to plug in. Employers will see the advantages of someone who has better memory and will prefer someone who is cognitively enhanced (Farah et all., 2004). To give a concrete example, research has shown that pilots taking Donzepezil performed better than pilots who took a placebo. Should pilots be expected to take this substance? Can airline companies require this of pilots? So individuals might feel coerced to plug in. Also, researchers and doctors might feel coerced to meet patient demands. Perhaps even governments might feel coerced if they know what the societal advantages of a population with an enhanced memory are. The argument against coercion is that autonomy is highly priced in contemporary society and if pressuring someone to plug in against their will can be seen as unethical (British Medical Association, 2007).

Two-way BCIs could also cause issues regarding distributive justice. It is likely that two-way BCIs, like most other things, will not be fairly distributed. For instance, Ritalin (a memory enhancer) use for healthy subjects is highest under college students, which are mainly middle class and a privileged segment of the society. There will undoubtedly be financial barriers and possibly also

[30] The moral discussion on cognitive enhancements can, just as the evolution from Homo Sapiens Sapiens to Homo Informaticus, be placed in the transhumanism debate.

social barriers for certain groups to have access to two-way BCIs. These barriers could weaken the already weak socio-economic position of certain groups in society (Farah et all, 2004). There are other moral considerations which may be relevant here. What will happen if we employ a two-way BCI-system to transmit information to the brain which is invalid, or worse, meant to manipulate someone? Can someone be held responsible for acting on the basis of invalid or manipulative information? Also, who has access to the information one has asked for, or more importantly, who has access to your brain? In principle, two-way systems could also be used to have a peak into the brain which will cause problems concerning one's privacy. Could two-way BCI-systems lead to an Orwellian society? All these moral concerns raise the question whether we want to be hooked up to information systems in order to enhance our memory capacities. Thus, the developments in BCI research have to be encountered with prudence.

However, on the other hand, there are also advantages with using two-way BCIs to enhance our memory, because it will cause individual and societal benefits. Modern society is highly competitive, young children are judged on the basis of tests, students compete for places in universities, applicants compete for well paid jobs and there is a societal pressure to succeed in one's chosen pursuit. It does not come as a surprise, that enhancing one's memory is seen as a benefit in such an environment, because it gives one a competitive advantage. This is known as a *positional good* or *positional benefit*. An enhanced memory system also has *instrumental* benefits. For example, when growing older we tend to forget things. This can, depending on the degree, seriously impede our quality of life and can be rather frustrating. Trying to make life easier with a better memory has an instrumental value. Additionally, companies also have an instrumental benefit with workers who work, through their improved memory system more efficient and faster.

Additionally, society undoubtedly benefits from the success and happiness of its members. For instance, skilled politicians, scientists and doctors use their cognitive abilities for the benefit of the whole society. We collectively benefit from these skills. If we could have more intelligent people in society – through enhanced memories, everyone benefits from this. Moreover, universal access to enhanced memory systems would increase the average IQ of our society, which can be seen as desirable (British Medical Association, 2007). It could also give a society a competitive advantage over other societies who do not use cognitive enhancements.

In addition to the societal benefits, there are also moral arguments in favour of enhancing our cognition. John Rawls has argued that inequalities are allowed only when they maximize the position of the least-off in society. This idea is referred to as *the difference principle*. Inequalities can maximize the position of the least-off, because without inequalities people have no incentives to prefer one job over another or to excel in particular fields. Society needs people who excel like doctors, professors, CEO's and so forth. If the overall size of the pie - to use Rawlsian terms - increases the worst-off also get more (Swift, 2005). So, one can argue that the least-off in a society benefit from cognitive enhancements, because cognitively enhanced persons – who are smarter and more efficient - make sure that society as a whole progresses faster then without people who are cognitively enhanced.

To end with, in the reflection of chapter five we have seen that Nozick's thought experiment *the experience machine* could be used to argue against a two-way BCI-systems that induces certain images, emotions or experiences. However, in case of a two-way BCI that enhances one's memory the same Nozick, a libertarian, would argue that the state should not meddle with the distribution of resources. It should rather protect its citizens of intrusions by others. According to Nozick, people own things because they have worked for them. He opposes all redistributive taxation. There are three ways to get property in a legitimate way, which are: initial acquisition, voluntary transfer and rectification. In Nozick's view, justice is about respecting people's property rights. Everybody should be left free to do what they want with what is theirs. Although this can lead to (huge) inequalities, if the initial distribution of resources was just, the trade is also just as well as the inequalities it creates. According to Nozick, the body and the self are ours. He acknowledges that the talents people have is a matter of genetics and up bringing, which is a matter of luck. But, nevertheless, the talents are theirs. This is the same for our body, it's ours and we can do what ever we want with it (Swift, 2005). In terms of Nozick's libertarian view, there is nothing unjust about buying enhanced memory systems, even if they are only affordable for the rich and create inequalities.

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Figures

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