NEUROTECHNOLOGY AND DYNAMIC FLOW

THE INFLUENCE OF BRAIN STIMULATION TECHNOLOGIES AND NEUROFEEDBACK ON THE SELF AND SELF-UNDERSTANDING

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The Influence of Brain Stimulation Technologies and Neurofeedback on the Self and Self-Understanding

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ABSTRACT

In recent years, several technologies have been brought on the market that have the ability to increase or decrease brain activity in specific areas of the brain. Among these are brain stimulation technologies such as deep brain stimulation (DBS) and transcranial direct current stimulation (tDCS), but also neurofeedback training. Such neurotechnologies raise important philosophical, anthropological and ethical questions. Neurotechnologies can for example raise concerns in the areas of authenticity, responsibility or privacy.

In my research I focus on the self as one of the potential aspects of consciousness that can be affected by neurotechnology. With 'self' I mean in this research the organizational structure of consciousness that determines how experiences are perceived by an individual. In order to schematically analyze in what ways the self could be influenced via brain stimulation technologies and neurofeedback, I propose a theoretical apparatus that describes the self and exists out of some of the aspects through which the self is constituted. These aspects are first determined and explored on a phenomenological level, followed by supporting contemporary empirical findings and neurophysiological explanations. One aspect of consciousness that I discuss in particular is self-understanding, a post-reflective aspect of self that describes as what one understand oneself and one's brain.

The analysis shows that while neurotechnologies are already employed in clinical settings, much of the underlying neurological pathways are still unknown. Furthermore, neurophysiological research shows that activity in specific brain areas is can be associated with self-specific stimuli. This lends credence to the suspicion that neurotechnologies can influence the self by increasing or decreasing brain activity in these areas. On a phenomenological level, I exhibit how the self can be changed through influence on the various mechanisms that constitute the self. I suggest that it is important for practitioners to be aware of the effects of the information that is provided to subjects, and that these effects should also be included in the context of policy-making. I furthermore argue that it should be taken into account that on a societal level, neurofeedback and brain stimulation technologies can lead to a change in existing viewpoints towards the self and the brain.

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ADD	Attention deficit disorder
ADHD	Attention deficit hyperactivity disorder
BST	Brain stimulation technology
CB	Change blindness
DBS	Deep brain stimulation
EEG	Electroencephalography
FDA	Food and drug administration
fMRI	Functional magnetic resonance imaging
GW theory	Global workspace theory
IB	Inattentional blindness
LTD	Long term depression
LTP	Long term potentiation
MRI	Magnetic resonance imaging
NF	Neurofeedback
rt-fMRI	Real-time functional magnetic resonance imaging
tDCS	Transcranial direct current stimulation
TMS	Transcranial magnetic stimulation
WHO	World health organization

INTRODUCTION

"Concern for man... and his fate must always constitute the chief objective of all technological endeavors, in order that the creations of our mind shall be a blessing and not a curse to mankind."

- *Albert Einstein, 1933*

Imagine a device that has the ability to alter activity of the nervous systems in such a way that when attached to the head, a shift into a more energetic or relaxed state is enabled. This influence enables a shift to a state of calm, or gives a boost of energy. It takes five minutes for the device to bring about this shift. Feeling tired, anxious or depressed? One click on a button and you feel energetic and motivated for the rest of the day.

The description above may sound like surrealistic talk of something that lies far in the future, but this device has actually recently been released on the market and is now available for online purchase. A company in the United States of America is currently developing this technological device, called Thync (Thync, 2015). It uses neurosignaling to activate specific nerves to influence the balance between the sympathetic and parasympathetic nervous systems. Phrases on their website read "*Vibes are here. Feel calm or energy on demand*." and "*Conquer More*."

Thync is not the only technology that claims to directly or indirectly change the state of mind. In recent years, several technologies have been brought on the market that have the ability to increase or decrease brain activity in specific areas of the brain. Among these are brain stimulation technologies such as deep brain stimulation (DBS), transcranial direct current stimulation (tDCS) and neurofeedback. The effects of neurotechnology and their functioning is partly founded upon the imaging of brain activity, and partly upon behavioral studies (Giordano, 2015, p. 41).

Technologies such as Thync or other brain stimulation technologies that influence brain activity and the communication system of the brain, raise important philosophical, anthropological and ethical questions. In this research, I want to focus on one of the concepts that might be affected by neurotechnology. This concept is the self, which in this research stands for the organizational structure of consciousness that determines how experiences are perceived in an individual. This structure is called the dynamic flow of consciousness and exists out of several aspects, both on a neurophysiological and a phenomenal level. I will be investigating those specific aspects of consciousness that are deemed important in the constitution of the self, in order to explore via what ways the self can be influenced. One important aspect of consciousness that I will be discussing separately is self-understanding, this is because changes in self-understanding can lead to ethical and philosophical questions and concerns as well. The main research question in this research is:

"In what ways may brain stimulation technologies and neurofeedback influence the self and self-understanding?"

In order to answer the main question, both the concepts of self and self-understanding will be further explained throughout this research. The conceptual apparatus of self that I will discuss is built upon the idea of a dynamic flow of consciousness. Dynamic flow entails the idea that consciousness exists of an ever changing flow or self-transforming process of thought and experiences. Besides dynamic flow, an important aspect of consciousness is self-perspectival organization. Self-perspectival organization entails the idea that conscious experiences do not exist on their own, but belong to a conscious self or subject as 'states' or 'modes'. Experiences can shape the self in a way that is depending on the perspectival point *from which* the world is experienced. Both these aspects of consciousness are closely related to the self and self-understanding.

To go deeper into the defining the concept of self I will draw on Kant and Hume: both provide a helpful framework for discussing the relation between our sense of self and our experience of the world. This matters for the explanation of the self in this research because it helps understand how the way in which experiences are perceived determines the self. Both Kant and Hume are influential writers on the subject of self. For a conceptualization of self-understanding I will use Dweck, because her theory shows how beliefs can be of influence on patterns of action, which is relevant because this influence affects self-understanding. By defining this relation, the influence of neurotechnology on self-understanding can be problematized.

To prevent unforeseen and undesirable individual consequences to human users, or the occurring of undesirable societal changes, it is important that questions and concerns with regards to neurotechnology are researched and answered. Fundamental issues in neurotechnology can for example be related to authenticity and responsibility. These and other potential areas of conflict will be explained in more detail in chapter 1.2. They are examples of problems that can arise when it becomes possible to artificially influence the brain, consciousness or mental states, or when it can be *detected* that the brain is under influence (for example of a brain tumor or an epileptic seizure) that could affect behavior. Unnatural brain influence will be explained in chapter 2.2.

Self-perspectival organization, dynamic flow, the self and self-understanding are important concepts in this research that are all interconnected in the organization of consciousness. This entire organization will be explained in the first four chapters, forming a theoretical framework. In chapter 1, I will give a general introduction to the neurotechnologies that are most relevant for this research, because they could potentially influence brain activity and/or are already used in clinical settings. In chapter 2 I will look into the concept of neuroplasticity, make a comparison between neurofeedback and brain stimulation technologies and discuss the differences between neurotechnologies and drug use. I will also discuss when something can be called ‘unnatural’. This is because I will argue that influence with neurotechnology on the brain is unnatural in comparison to how the brain functions on its own, even in the case of neurofeedback, where there is no direct brain stimulation involved. All of the themes described above need clarification in order to understand the analysis of the possible effects of neurotechnologies on the self; and the consequences of these effects in a societal context. Chapter 3 outlines a philosophical account of consciousness and the self that provides a conceptual apparatus, which includes those aspects of self that are to be investigated. This conceptual apparatus will be helpful for further discussion with regards to possible influences on the self and self-understanding. In chapter 4, I will discuss the extent to which the philosophical framework is supported by state-of-the-art neuroscience. Chapter 5 then allows for an analysis of the possible implications of brain stimulation technologies and neurofeedback for this framework, the self and self-understanding in particular.

In this final chapter, I will show that the self can be changed through influence on the various mechanisms and aspects that constitute the self. I will also show that self-understanding can change by a change in beliefs of what we are, and through means of changes in beliefs with regards to the nature of personal qualities and character traits. Furthermore, the largest finding is that there is still a large gap in scientific knowledge when it comes to the underlying neurophysiological mechanisms that are involved in brain stimulation technologies and neurofeedback.

CHAPTER I

NEUROTECHNOLOGY AND ITS POTENTIAL TO CHANGE BRAIN ACTIVITY: A BASIC INTRODUCTION

To be able to investigate in what ways different types of neurotechnological applications influence consciousness and the self, first of all a basic understanding of each of these technologies is required. To give an idea of the present-day possibilities within the area of neurotechnology, I will discuss the advanced stage of development of these technologies, and various methodological issues that have already presented themselves.

I.1 A Basic Introduction to Neurotechnology

Neurotechnology describes the field of all tools, devices and applications that aim at repairing, improving or visualizing the brain and its functions. In this section, I will subdivide the neurotechnologies chosen for investigation into three main categories to maintain an accessible analysis and to be able to compare the impacts of each of them appropriately. These categories will be (1) brain imaging technologies, focusing on images of brain activity without external stimulation, (2) brain stimulation technologies, meaning techniques that influence natural brain activity and (3) Neurofeedback. The latter should in fact not be called a category but does deserve to be discussed separately, because it is the only neurotechnology during which the results of brain activity measurements of a subject are reported to him/her at the moment that this brain activity takes place in this subject's brain. For the subject, it will be like the conscious experiences that come with this activity occur at the same time as well. For this reason neurofeedback can be called a real-time procedure. Of the brain stimulation technologies that we have today, the following show the most promise of having a detectable (therapeutic) effect on human subjects: transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS) and deep brain stimulation (DBS) (Bolognini & Ro, 2010), (Millera, Bergera, & Sauseng, 2015) (Schlaepfer & Saviane, 2012). These three BST's are therefore selected to investigate besides the procedure of neurofeedback. There are more brain stimulation technologies, those will however not be discussed due to the scope of this research, to ensure that the three selected technologies can be studied in detail.

Depending on their purpose of use, two kinds of neurotechnological applications can be distinguished. When used for therapeutic goals they are considered medical devices and fall under the EU Medical Devices Directive (MDD) (Maslen, Douglas, Kadosh, Levy, & Savulescu, 2014). When they are not classified as such, they are categorized as neuroenhancement. Neuroenhancement describes application of neurotechnology on the brain of a person whose mental and physical state have given no indication of illness or disease with the intention of improving for example cognitive functions. In this research there is no particular focus on either the therapeutic goals of neurotechnology or neuroenhancement. This is because I want to investigate the individual and societal effects of neurotechnologies on the self and self-understanding in general, which might occur in an ill as well as a 'healthy' person.

Furthermore, in my discussion of each of the neurotechnologies involved in this investigation, I will neither include mechanical failure of mentioned technologies nor possible bodily harm. These factors are not included because the focus of this investigation lies on the influence and effects of the use of neurotechnologies on the self and self-understanding. This does not mean that risks of employment and health risks should not be taken into account when applying neurotechnology.

In order to be able to problematize the effects of each the selected neurotechnologies, a basic neurophysiological understanding of the brain's communication system is required. For this reason, the following section briefly addresses the communication between neurons in the brain.

I.1.1 The Brain's Own Communication System; A Basic Explanation

Nerve cells or neurons are a very specialized type of cells. This means that they have a design which allows them to fulfill very particular functions (Byrne, Heidelberger, & Waxham, 2014). Nerve cells exist in the brain in groups, pathways or systems. These systems are called circuits and can be found in particular areas of the brain (microcircuits), or covering two or more different areas (macrocircuits). Nerve cells have two ways of communication, this happens either through chemical signaling or a process based on electricity (Communication Between Nerve Cells, 2015). These ways of chemical and electrical communication represent cell-to-cell and in-cell communication.

Generally speaking, the nerve cell exists of three parts: the cell body, the dendrites and an axon. The cell body and dendrites form a receiver for inputs, while the axon is responsible for conducting impulses in order to transmit neural information (Kiernan & Rajakumar, 2014). The information that the nerve cell receives may be either primary (in case of input from a sensory receptor), or information that was already processed and modified through various integrative steps.

The potential of a nerve cell involves a constant exchange of ions and can be measured by measuring the difference in voltage on the inside and on the outside of the nerve cell. Electrical signaling of nerve cells happens through means of conducting a flow of ions across the plasma membrane of the cells (Kiernan & Rajakumar, 2014). When passing through information, neurons generate a negative potential (depolarization) within the surface membrane. The electrical signal then travels along axons (or muscle fibers) to another place in the nervous system. Upon travelling to an adjacent cell, the signal is translated into a chemical signal, existing of so-called neurotransmitters. Because nerve cells are selectively permeable for different types of ions, specific kinds of action potentials can be fired.

This brief description of the types of communication within and between nerve cells will aid in understanding the workings of brain stimulation technologies and neurofeedback on the brain. In the following section, brain imaging, brain stimulation technologies and neurofeedback will be explained, in order to be able to investigate their influence on the consciousness, the self and self-understanding.

I.1.2 Brain Imaging Technologies

Brain imaging technologies are technologies that make it possible to visualize the brain without surgical investigation. I will briefly address some of the methods of brain visualization in this section, because many other neurotechnologies function in combination with one of these visualization technologies simultaneously, to be able to assess the acquired information directly. The visualization technologies described in this section are relevant because combined with a brain stimulation technology or neurofeedback, they may ultimately play a role in the influence of neurotechnologies on self and self-understanding.

Electroencephalography

One of the methods to measure brain activity, is to measure electrical activity along the scalp. This electrical activity is generated by brain structures, mostly large populations of active neurons (Teplan, 2002). When neurons are activated, local current flows are produced. An Electroencephalogram (EEG) can measure and record this electrical activity. During an EEG, electrodes consisting of small metal plates with wires attached to them, are placed on the scalp. These electrodes can detect very small electrical charges, from the ionic current flows within the neurons of the brain. The electrical activity that occurs in the brain takes place in different synchronized electrical pulses, that when recorded create different typical cyclic patterns which represent the communication of masses of neurons. These distinct cyclic patterns of synchronized pulses are called brain waves. After measuring brain activity with an EEG, the results are amplified by a computer and processed into a graph that demonstrates the activity as brain waves of varying frequency, amplitude and shape (Normal EEG Waveforms, 2014).

There are several types of brain waves that can be distinguished and seem to correlate with general mental states such as 'light sleep' or 'memory processing'. The table (table 1) below shows the five different types of brain waves that are employed according to the most widely used classification.

Table 1: Brain waves and their supposedly correlating mental states (Transparant Corporation, 2014).

Wave	Frequency	Correlating mental state
Gamma	27 Hz and above	Forming of ideas, language and memory processing and some types of learning.

Beta	12 – 27 Hz	Wide awake, no specifics. There are researchers that claim lack of beta waves can cause mental or emotional disorders such as depression or ADD, but this is strongly debated.
Alpha	8 – 12 Hz	Awake, relaxed and not processing a lot of information. Alpha waves have been associated with the ability to recall memories and reduce pain, stress and anxiety.
Theta	3 – 8 Hz	Light sleep or a very relaxed state.
Delta	0.2 – 3 Hz	A very deep sleep. In this state a subject does not dream and seems completely unconscious.

During the procedure the patient is asked to relax and sit in a comfortable chair or lie on a bed. The amount of electrodes can vary from 4 to 256 in current EEG systems and will be attached to the scalp with special paste or a cap (Lau, Gwin, & Ferris, 2012). During the EEG, attention is amongst other things paid to the basic waveforms, but also for example to short energy outbursts, and in some cases responses to external stimuli such as light. One of the goals of an EEG is to detect abnormalities in brain activity. These abnormalities present themselves for example as rapidly spiking waves, and can be a sign of a brain disorder such as epilepsy or brain lesions (Johns Hopkins Medicine, 2014).

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) uses nuclear magnetic resonance (NMR) to gather chemical and physical information on a molecular level. It started out as a tomographic imaging technique, that is to say, it produced images which represented thin slices of the body. At the present, it has advanced to image the whole volume of an object, a *volume imaging technique*.

The technology is based on the absorption and emission of energy by molecules within the body. The frequency that is used lies in the radio frequency of the electromagnetic spectrum. When electromagnetic waves of this wavelength form a magnetic field around the body, the direction (or *spin)* of protons of the atoms within the cells of human subjects is influenced. During the return to their original state, the protons that were affected send out magnetic waves (Berger, 2002). The detection of these signals is improved by receiver coils and after several complex processing steps eventually translated into cross sectional images by a computer. Each type of tissue within the body can be recognized by the kind of magnetic waves that are sent out. This way, an image of all tissue within the human body, even including tissue that is of microscopic size, can be visualized (UMCG, 2014).

Functional Magnetic Resonance Imaging

With functional magnetic resonance imaging (fMRI) scans, the same technique is used as with a regular MRI scan, except for the fact that subjects are now deliberately exposed to external stimuli or asked to perform motoric tasks while a scan of the brain is being made (Allen & Courchesne, 2003).

The basic principle of catching electromagnetic signals sent out by atoms within the body is the same compared to a regular MRI, except in case of fMRI it focuses on detecting changes in blood oxygenation and flow, since increased blood flow and the consummation of more oxygen are both indicators for neural activity (Blockley, Griffeth, Simon, & Buxton, 2013). This tactic is based on responses that are blood-level-oxygen dependent (BOLD). This means that magnetic resonance images are visualized based on the difference of signaling between oxygen-rich and oxygen-poor blood. The BOLD response to task-related neuronal activation is a function of the cerebral blood flow and cerebral metabolic rate of oxygen consumption. Changes in these underlying mechanisms can be detected with an MRI scan, through which neuronal activation can be detected.[1]

During a functional MRI scan, subjects can be exposed to stimuli or asked to perform for example cognitive tasks, for effect-measurements in the brain. The external stimuli to which the brain can be exposed during an fMRI, consist for example of visual stimuli, or performances such as finger movement tasks. The ultimate purpose of an fMRI is to visualize the brain under influence of such stimuli or cognitive and thought performances, to acquire insight in the functions of the brain. The fMRI is an imaging technology and not a stimulation technology because even though external stimuli are given during the procedure to influence brain activity, this influence is not meant to alter brain activity as an ultimate goal.

[1] It should be noted that relative changes in cerebral blood flow and cerebral metabolic rate of oxygen consumption say nothing in themselves. They are only valid against the baseline physiological state of an individual. For more information on BOLD responses, read (Blockley, Griffeth, Simon, & Buxton, 2013).

Real-Time Functional Magnetic Resonance Imaging

Real-time functional magnetic resonance imaging (rt-fMRI) is a technique with which results from an fMRI are immediately accessible, in fact at the moment that the data is acquired. This facilitates a number of applications, one of which is fast functional localization. Functional localization is a concept that allows defining of the location of specific brain activity in relation to the brain structure or anatomy as a whole. (Gholipour, Kehtarnavaz, Briggs, Devous, & Gopinath, 2007) This is comparable to what happens during an fMRI, only with this technique it is possible at the time it is occurring (hence *fast* functional localization). This allows for noninvasive manipulation of brain activity, to observe the effects it has on specific changes in behavior. Research has been performed to investigate brain-function relationships, and the implementation and application of rt-fMRI with an emphasis on the self-regulation of brain activity. Expectations are it will eventually lead to more insight into the causal role of specific functions in certain brain regions with regards to behavior (Caria, Sitaram, & Birbaumer, 2012).

I.1.3 Brain Stimulation Technologies

Brain stimulation technologies (henceforth referred to as BST's) are technologies that affect functioning of the brain directly using electrical currents, magnetic fields or pulsed alternating micro currents. The following section discusses the three brain stimulation technologies, which have been found relevant for this research. As explained, they are selected because they appear to have the most detectable (therapeutic) effect on human subjects.

Transcranial Magnetic Stimulation (TMS)

TMS is a method that is used to stimulate nerve cells in a certain targeted brain region, through means of generating activity by causing depolarization or hyperpolarization with a rapidly changing magnetic field. It was first developed in 1985 and is considered a possible treatment for mental disorders such as depression and psychosis (NIMH RSS, 2014). TMS was approved by the food and drug administration (FDA) in 2008 for treatment of migraine and major depressive disorder, which have been rendered untreatable through means of any other method so far (U.S. Food and Drug Administration, 2011) (U.S. Food and Drug Administration, 2013).

With TMS, an electromagnetic coil is placed at close proximity to the skull, at a specific location that is thought to have a connection to a certain mental state or mental illness. Small electrical pulses are given that can stimulate or suppress the activity of nerve cells. Sometimes TMS is used in combination with an fMRI or rtfMRI scan, to be able to measure the influence of TMS on brain activity. The combination of TMS and an fMRI/rt-fMRI scan can also aid in acquiring knowledge about the functions of specific brain regions by correlating changes in local brain activity to external bodily responses or behavioral changes.

Transcranial Direct Current Stimulation (tDCS)

TDCS uses small electrodes to deliver a constant, low current to a specific area of the brain. During this process spontaneous neuronal activity can be facilitated or inhibited. TDCS has an advantage over other brain stimulation techniques, in the sense that the device is relatively easy to fabricate and to apply (Flöel, 2014). There is a downside to this, because even though tDCS has not been approved by the FDA for any clinical application (Johns Hopkins Medicine, 2014), tDCS devices are already sold to the public by independent companies or as mentioned before, made at home by potential private users. This poses a risk, as laymen attempting to build similar devices in unprofessional conditions can result in harmful situations. This worries research institutions, as they are aware of the lack of knowledge of applications and lack of any international or even global regulatory adjustments with regard to these devices (U.S. National Institutes of Health, 2015).

Deep Brain Stimulation (DBS)

DBS uses surgically implanted electrodes with wires attached to them, that deliver electrical impulses to alter irregular electrical brain activity. The DBS system exists of three parts, all of which, opposite of other BST’s, are underneath the skin. Electrodes are implanted in the brain, a pack with a battery (also called generator) is planted somewhere else in the body (usually in the chest, below the collarbone), and wires are connecting the electrodes to the battery. It is possible the patient receives two generators that are bilateral (one under each collarbone), each connecting to one of two electrode extensions (Brown University, 2014). The device can be placed and used based on every patient’s unique brain anatomy and symptoms so that it delivers electrical impulses exactly where they yield the desired results. It can also be adjusted with a wireless remote controller.

According to some researchers this is considered an effective method, showing that 70 percent of Parkinson’s disease patients show increased motor function and experience significant improvements in control of body movements (UCLA Neurosurgery, 2014). Of all patients with Essential Tremor (described below), 71 – 85 percent see improvement. Other researchers emphasize that, as with other brain stimulation technologies, results remain controversial and long-term efficacy and effects of DBS are not known yet (OCD-UK, 2011) (Vercruysse, et al., 2014).

I.1.4 Neurofeedback

Technically neurofeedback (henceforth referred to as NF) belongs to the BST's as well, because brain activity is stimulated under influence of an externally linked technology. However, the means through which the changes in brain activity are achieved, are so fundamentally different that it cannot automatically be assumed that the consequences of this procedure are the same as with any other BST.

With NF, brain activity is influenced using non-technological stimulation. That is to say, there is no direct electrical or magnetic stimulation to the brain. Changes in brain activity occur through means of 'training', that is possible because of the combination with immediate feedback from technological brain activity measurements. Sometimes this occurs through means of the brain's own reward mechanisms. The most prominent of these mechanisms is the psychological principle of operant conditioning, a term coined by B.F. Skinner in 1938 (Simply Psychology, 2015). Operant conditioning is the changing of behavior by using rewards or reinforcement after the desired response has been shown. In the case of NF, the 'reward system' is triggered by external stimuli such as a sound or a movie clip. The response to this stimulation can be detected in terms of brain waves.

The training of brain activity in a subject occurs while it is measured via an EEG and analyzed real-time. Before the training, the subject and practitioner discuss the desired mental state(s) and the correlating brain waves are determined. During training, the subject is (indirectly) asked to aim at producing these brain waves, through means of a specific focus, a computer game or other (thought) assignment. Whenever the subject is producing the desired brain waves, those correlating with the desired mental state, reward stimuli are send to the brain (in the shape of a sound or a short movie clip) (Neurofeedback Instituut Nederland, 2014). The mesolimbic dopaminergic system is considered to be amongst the most important reward pathways, and plays a central role in various types of reward, besides its role in motivated behaviors and cognitive processes (Alcaro, Huber, & Panksepp, 2007), (Icahn School of

Medicine at Mount Sinai, 2015).[2] In simplistic terms, a reward pathway causes an individual to be motivated to repeat the same action that caused the reward. It also communicates to memory centers in the brain that particular features of the experience should be remembered, so that an individual is more likely to repeat the action in the future (Icahn School of Medicine at Mount Sinai, 2015). After explaining the procedure of neurofeedback, I will elaborate on reward mechanisms, and the mechanism of operant conditioning in neurofeedback in particular.

After a while the changes in brain waves are not only invoked during training, but occur spontaneously in daily life as well. What must be kept in mind here is that neurofeedback may not have exactly the same kind of effect or measure of effectiveness in each person. There may be differences between groups such as children and adults or elder people, but also per individual. I will briefly consider this topic in section 1.3.3, where I will argue that there is a primal uniqueness in each individual that might be of influence on how brain stimulation technologies and neurofeedback affect the self. However, the question of what these influences are shall not be discussed, due to the scope of this research.

Procedure

Before the first neurofeedback training, an intake session takes place between subject and practitioner in which the symptoms of the subject are extensively discussed. After that, the subject undergoes an EEG scan in order to determine the brain waves associated with the symptoms that the subject has a desire to change. Based on the findings from this EEG, it is discussed what goals are realistic and desired, and a treatment schedule is set up (Neurofeedback Instituut Nederland, 2014).

At the beginning of treatment, the subject is seated in a chair that is supposed to be comfortable, in front of a screen. The subject undergoes another EEG, but this time the EEG is connected to a neurofeedback machine that processes information from the EEG and displays it on a screen. It is aimed to receive information on the brain activity specifically for places in the brain that correspond with the discussed symptoms. The subject is often situated in front of the screen, watching a representation of his or her own brain activity. This representation can

[2] For a more detailed explanation of the mesolimbic dopamine system, read: "Behavioral Functions of the Mesolimbic Dopaminergic System: an Affective Neuroethological Perspective" (Alcaro, Huber, & Panksepp, 2007).

be displayed in the form of brain waves, but also things such as temperature on a thermometer, an emotional face or a virtual reality showing a fire (Weiskopf, 2012). Sometimes the activity is observed only by the practitioner. The subject may be asked to focus on a specific thought or mood that correlates with the desired state of mind (such as relaxation). It is also possible that the subject is asked to participate physically active, for example by pushing buttons or controlling a computer. Each time the brain produces the frequency of the desired brain wave, positive feedback is sent to the subject in terms of a sound or short movie clip to trigger a reward system in the brain. When positive feedback is sent to the brain, it will associate the reward with the desired wavelength (this differs per goal/brain area) (Sherlin, et al., 2011). According to providers of neurofeedback, the desired 'state of mind' (corresponding with the desired brain activity) will eventually be reproduced by the subject automatically, without any equipment.

Because during this procedure, positive feedback is sent in direct response of the subject actively and consciously producing the desired brain activity, neurofeedback has a self-regulatory aspect (Strehl, 2014). This aspect is associated with personal effort, and is therefore considered to be a skill. This differs from other brain stimulation technologies where a technology changes brain activity directly and independently from the thoughts or mental state of a patient or subject, by sending electrical pulses to the brain.[3]

Besides this self-regulatory aspect of personal effort in neurofeedback, there are a couple of other fundamental differences between neurofeedback and the BST's. It is important to outline these differences, because the procedure, means and methods might be of influence on the outcome of either brain stimulation or neurofeedback training on the self or self-understanding. Thus, a comparison between brain stimulation technologies and neurofeedback might tell us more about the possible effects for each of them. The following six statements show the most prominent differences between neurofeedback and brain stimulation technologies that were selected as relevant in this research:

1. A subject has perception of a projection of their own brain wave pattern at the moment of neurofeedback training (only NF)

[3] It should be noted that there may also be a difference between brain stimulation technologies and neurofeedback with regards to effectiveness, because they are such different methods. However, this research focuses primarily on the differences between effects with regards to the *types* of means and method, and possible consequences thereof for the self and self-understanding.

2. While making an effort, the subject has knowledge of the fact that both subject and trainer can have real-time perception of the type of brain activity that is produced (only NF)
3. To an extent, a subject receives information regarding the correlation between a subject's mental state and the type of brain waves, at the moment of being in this mental state, for the purpose of influencing that mental state (only NF)
4. There is effort (NF) vs. no effort (BST) expected during the procedure, which means active participation (NF) vs. passive participation (BST).
5. There is a difference in the technological aspect in both procedures. Where brain stimulation technologies make use of electrodes for directly *influencing* of brain activity, the technological aspect in NF is limited to the attachment to an EEG for *measuring* brain activity, for the purpose of giving feedback
6. The way in which the method of the technology is presented to a subject; 'aggressive' (BST) vs. 'passive' (NF)

Each of these six differences will be further explained in chapter 2.3. The consequences of these differences for the self and self-understanding will return throughout the following chapters, and will be taken up in the analysis in chapter 5.

Operant Conditioning

The following section will discuss the process of operant conditioning. It is important to clarify this concept because during neurofeedback training the neurological mechanism of operant conditioning can be used to adjust amplitude, frequency or coherency of the neurophysiological dynamics of the brain (Thatcher, 2000).

Operant conditioning was investigated extensively by B.F. Skinner (Simply Psychology, 2015). It concerns the changing of behavior by using rewards or reinforcement after a certain kind of behavior has occurred. Skinner's theory of operant conditioning was influenced by psychologist E.L. Thorndike, who suggested the principle of *law of effect* (Cherry, 2015). This principle entailed that actions that are followed by a desirable response are strengthened, are more likely to be repeated. Skinner named his theory 'operant' conditioning because he aimed to refer to 'active behavior that operates upon the environment to generate consequences' (Skinner, 1953). Operant behavior is also described as behavior that is under conscious control. When occurring under conscious control, it can still be either spontaneous or purposely, but its consequences determine whether or not it is behavior that is likely to be repeated. Operant behavior is in contrast with respondent behavior, e.g. pulling back ones hand when it is burned. There are some important concepts present in Skinner's theory, they are as follows (Cherry, 2015):

- Reinforcement: Any event that will strengthen or increase the behavior that preceded it.
    - Positive reinforcer: Any favorable or in any way positively experienced event that is presented after specific behavior, of which an effect is that it strengthens this behavior. This can something like a praise or a direct reward.
    - Negative reinforcer: The removal of an event that is experienced as negative or unfavorable, after a specific type of behavior. The removal must have the effect of strengthening a certain desirable response.

- Punishment: The presentation of an unfavorable event that is experienced as negative, and causes a decrease in the behavior that preceded it.
    - Positive punishment: An unfavorable event that has as purpose to weaken the behavior it followed.
    - Negative punishment: The removal of a favorable event that was experienced as positive, after display of a specific behavior.

The mechanism of operant conditioning is not restricted to the scientific area, as it is also a learning mechanism that occurs in daily life. Children respond to the effects of operant conditioning by adjusting their behavior, for example when they are promised (and given) candy after display of desired behavior (positive reinforcement). The reward is associated with the behavior and the behavior is therefore more likely to be repeated. But the effects are visible in adults as well. This can take form in promotions at work (positive reinforcement) or the prospect of being fired (negative punishment). It can even occur on a basic level as the response someone gets after telling a joke. The more people think it is funny and laugh about it, the more one is stimulated to tell another one, or to tell the same joke to a different audience (Cherry, 2015). However, when employed in neurofeedback in combination with direct feedback, the mechanism of operant conditioning can possibly have other effects than as a mere gradually occurring learning mechanism. I will return to this question in chapter 5.

I.2 Fundamental issues in Neuroscience

Now that I have discussed the neurotechnologies that will be investigated, I will illustrate some fundamental affairs that arise in the contemporary scientific debate. These are examples of the individual and societal values and qualities that are stake *if* the self indeed can be changed due to neurotechnological developments. They will help give a clearer idea of what we are dealing with and support the relevance of this investigation.

1. Authenticity

The first issue to be discussed is that of authenticity, which can also be exposed as a threat towards the authenticity of a person, or at least of their minds' contents (Giordano, 2012). For example, neurofeedback practitioners emphasize that they can detect 'deviating' brain waves that an individual possesses, by claiming: "With an EEG we can determine very accurately where the deviating brain waves are with you." (Neurofeedback Instituut Nederland, 2014). Giordano argues that neuroenhancement has the ability to violate 'being true to oneself'. This becomes even more difficult when the symptom or quality that is treated in a patient or subject, is seen by the subject as being a part of their self. If this quality is threatening for a patient's health (for example in anorexic patients), this can lead to complex complications (Maslen, Pugh, & Savulescu, 2015).

2. Responsibility

Besides several other neurotechnological applications outside of health care, the use of neuroscience is also gains prominence in legal purposes. It has already occurred that a legal punishment was decreased due to medical findings (e.g. the presence of a brain tumor). When more and more neurotechnological applications will become possible, the general judgment of when an individual carries responsibility for an action could be pulled into question. This might occur, while at this moment it is still unclear and undecided to what extent neuroscientific evidence should be counted as relevant (Vincent & Lokhorst, 2010).

3. Equality

Equality can become an issue in the field of neurotechnology since the establishment and enforcement of neurotechnological applications carry a certain normativity that inscribes Western neurocentric values into the notion of life. Application of these technologies can then disregard (minor) groups of the population, for which reason it carries harmful potential. In addition to this, if the goal is to 'protect' the population in the future, this goal can justify unethical decision-making, which in the case of neurotechnology especially, can be dangerous as well (Giordano, 2012). This does not even take into account a misbalance in equality between members within a population, e.g. individuals with certain benefits in position, financially or otherwise, that are deemed fit for a neurotechnological treatment where others are not.

4. Abuse in Economy and Privacy

Another example of an issue is abuse of neurotechnology that is directed towards the public. In neuroeconomics for example, it is researched what brain mechanisms are involved in economic decision-making. This information can be used and manipulated by neuromarketeers, that try to identify a so-called 'buy-button' and use it to steer the public's buying behavior. There is also the matter of privacy, because in the near future it might become possible to use brain imaging evidence for recruitment purposes, breaching privacy of individual quite drastically.

5. Military Applications

It is also being considered to use neurotechnologies for military purposes. This can concern treatment of PTSD and other disorders after traumatic experiences. For example, the erasing of unconscious emotional memories (Glannon, 2007). One of the consequences of this possibility might be that having soldiers experience traumatic events is no longer considered an obstacle. But it can also be used as neuroenhancement, for example by using DBS to suppress neural activity in the amygdale, which processes emotions such as fear (DNews, 2015).

The issues above show the implications that the neurotechnologies that were discussed in this chapter could have, and why it is important to research as many of these areas as possible before this technology is applied. Both the self and self-understanding are concepts that are related to the points described above, and also play an important role in everyday life, on an individual as well as a societal level.

I.3 Neurotechnological Implications: Two Exemplary Cases and the Questions They Raise

In the following section, I will provide two examples of how close some neurotechnologies are to being available to users and to illustrate the impact that the public availability of such devices could have. The first of these examples is a case in which real-time neuroimaging shows that individuals can learn voluntary control over specific brain areas. It concerns the area that is assumed to be related to pain processing. The second example is Thync, the neurotechnological application of tDCS that was mentioned in the introduction, and that can be controlled via an application on a smartphone. Thync was released on the market in 2015, and the company that developed it claims it can alter the state of mind.

I.3.1 Real-Time Neuroimaging

In 2005, an article was published on control over brain activation and pain by using real-time neuroimaging with a functional MRI scan (deCharms, et al., 2005). Research was performed to examine how watching one's own real-time brain activity of pain during the experience of pain, was of influence on how this pain was perceived. An individual may be able to learn control over activation of certain regions in the brain, thereby controlling neurophysiological mechanisms that mediate behavior and cognition. DeCharms et al. claim that ultimately, this could provide an alternative way to the treating of diseases.

For this research, healthy volunteers were compared to chronic pain patients. The subjects in this research project were told that during the project, they would be attempting to enhance control over activation in localized regions of their brain, those regions associated with pain. They were told to alternately increase and decrease brain activity in this area during a training, by using the following strategies:

- Attention toward the painful stimulus vs. 'away from it', to imagine it would go to the other side of the body
- An attempt to perceive the pain stimulus as a mere sensory experience instead of something that could actually damage them
- Imagining the stimulus to be either low or high
- Making an effort to control the painful experience

In addition to this they were (amongst other things) informed of the fact that during the attempt, they would view real-time feedback of their success. They also received the information that random noise can occur in the rtfMRI information they would see, and that a delay exists between brain events and the display of brain activity on the screen. The goal for the subjects was to learn to enhance control over this activation of the brain in the pain perception area, during a rtfMRI scan. Four independent control groups were trained in a similar way, only without viewing the valid real-time fMRI feedback information from their own brain activity. Instead, they only received autonomic biofeedback, which regulates the functions of the heart, stomach and intestines.

The results of this investigation indicated that individuals can learn to have control over the brain area that is assumed to be related to pain processing. The fMRI signal in a brain region could be controlled, which involved engagement with the associated neurophysiological mechanisms, and led to the predicted cognitive results of the investigation. This result was a significant decrease in the perception of pain in chronic pain patients. The four independent control groups that only received autonomic biofeedback, did not learn enhanced control over pain, indicating that real-time neurofeedback was essential to the learning process.

I.3.2 Thync

The second example is a tDCS device and is called “Thync”. Thync is an upcoming neurotechnology that has recently been released on the market. The developers of Thync are former Harvard students, who proposed the idea of combining biology with technology to create the ability of having different mental states on demand and ‘dialing up’ a ‘best self’ – as they call it – when desired (The Daily Dot, 2015) (Thync, 2015). The headline on their website greets you with “Shift your state of mind. Conquer life.”, presupposing you do not conquer life yet, but will be able to with their product. The company claims to bring forth a new category of wearable products that function at the intersection of neuroscience and consumer technology. However, under the headline ‘products’, there is talk of “A groundbreaking wearable device that enables you to shift your state of mind in minutes”, coming in 2015. It claims to make use of neurosignaling; the coupling of an energy waveform to a neural structure in order to modulate its activity. The possible states of mind that it claims to choose have been updated to ‘calm’, ‘energy’ and ‘focus’.

The device exists of two patches that are attached to the head (this concerned a prototype that was tested). After the device has been attached, it is controlled via an application that can be installed on a smartphone. Through means of the application, one of the three states of mind mentioned above can be chosen. A graph on your smartphone shows the amount of electric shocks that is send to your brain. In the article, the test person describes the electric shocks as ‘tingles’ that create a certain ‘tightness’ around the head, but no pain.

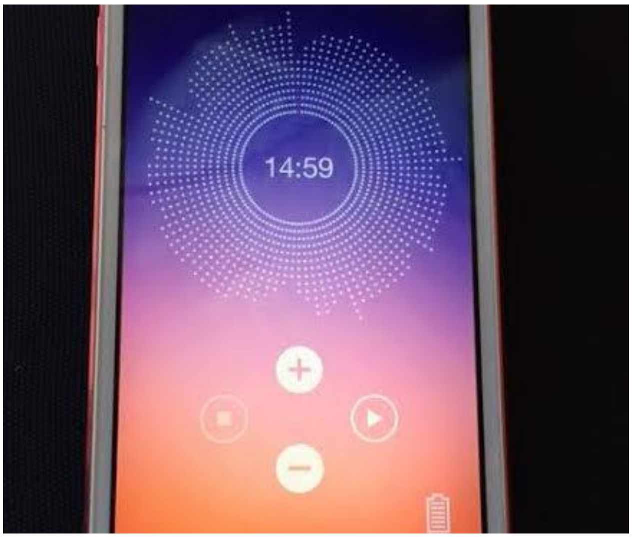

Figure 1: The graph shown in the application

What is notable is that the Executive Director of Thync himself outlines the difference between their own device and ‘most of what you see in wearables today’ (The Daily Dot, 2015), thereby emphasizing that Thync belongs to the more ‘invasive’ technologies (due to direct stimulation). He described other devices as those that give you feedback and ‘ask you’ to change yourself or your behavior, in order to get to a desired result. Neurofeedback is one such technology that would fall under this category. According to the executive director, the Thync device would be different in the sense that the ‘right’ parts of the nervous system and nerves that go into the brain are activated, *actually* changing your mental state. As opposed to trying to change behavior based on feedback, he claims that their device “just does it”, which is comparable to brain stimulation technologies.

There is also the question of whether people would view it as a drug. In despite of their claim to be developing the product following the guidelines of the FDA, it still concerns an alteration of mental state through means of technology. The company compares Thync to alcohol or caffeine, because they both chemically alter the brain. This seems a strange comparison however, because there are some significant differences even between alcohol and caffeine. For example, it is allowed to drive after drinking caffeine, but not after consummation of too much alcohol. What the company does say is that Thync can be used to replace taking chemical drugs on some occasions, such as coffee or anxiety medicine, without the negative health implications that those drugs might bring about. However, even if Thync was not categorized as chemically altering, other issues may arise that carry even heavier moral, ethical and health implications. Examples of these are questions with regards to authenticity, safety or equality issues, in addition to the possible influences on self and self-understanding as discussed in this particular research. In chapter 2.4 I will bring special attention to the differences between neurotechnologies and drug use, in order to create awareness of some of the problems that could arise if they would carelessly and thoughtlessly be considered to belong in the same category, and should thus be treated the same.

I.4 Can we Believe the Promised Effects of Neurotechnologies?

Methodological controversies can change the use and effects of a technology, and bring about a change in perspective and attitude towards how the results of the technology should be evaluated. In this section some of the possible methodological controversies with neurotechnology will be discussed, to show that a skeptical attitude towards these developments is necessary. The issues to be discusses are the placebo effect, media hype and the differences between individuals.

I.4.1 The Placebo Effect

Research with tDCS has shown that the placebo effect plays a large role in the results (Palm, et al., 2013). The placebo effect or placebo response is a psychobiological phenomenon that is understood to be supported by a variety of learning processes (Schambra, Bikson, Wager, DosSantos, & DaSilva, 2014). These learning processes can be both conscious and unconscious. For example in depression, undergoing a therapeutic process creates the conscious expectation of a form of therapeutic benefit. This benefit may guide motivation, affective responses and learning. What is interesting about the placebo effect is that inert clinical features (such as pill color) are associated with eventual behavioral improvement. In pharmacological studies, these inert features can lead to a significant placebo response (Schambra, Bikson, Wager, DosSantos, & DaSilva, 2014). The placebo effect results in short-term improvement of the symptoms of depression, that match the results of improvement of the drug that is being studied. With tDCS, functional specific stimulation without parallel interpersonal therapy has shown symptomatic improvements in patients with depression. These beneficial effects have been attributed to the activation of several neurophysiological pathways. However, when sham stimulation with tDCS is used, depression scores improve (relative to baseline) in the first few weeks.[4] When sham stimulation was performed in combination with a placebo pill, the changes were even more pronounced. Of course these improvements could have several explanations, e.g. spontaneous disease remission, but one of these explanations is the placebo response. Regardless of having received active or placebo medication, clinical responders shared very specific metabolic activation. This pattern was not seen in non-responders, and reflected the expectation of therapeutic benefit. This suggests an explanation for tDCS that corresponds to the placebo response; tDCS reinforces the brain networks that were activated by the expectation of therapeutic benefit alone, and thereby fortifying the placebo response to which it contributes.

I.4.2 Media Hype

One of the problems of a relatively new technology such as Thync is the media hype that it is often accompanied by, that carries exaggerated and unrealistic promises. While discussing Thync in chapter 1.3.2 I already touched upon this subject by giving a few examples of the claims and promises that are portrayed on the website of the facilitating company (Thync, 2015). Technologies are presented in a way that benefits the company that wishes to promote their products. At the same time, developments that are new and have seemingly unknown and revolutionary effects inspire viral threads in the media and on social websites such as Facebook. This way, the public is informed of new technological devices and possibilities in a populist and unrealistic way, creating 'false' expectations and conceptions of the technology. The way such an upcoming technology is viewed, and the conceptions, beliefs and expectations about the effects that it will have, can cause at least two problematic effects.

The first is uninformed and overhastened use of such a technology. The media are often exaggeratingly positive, emphasizing that given technology is easy to use and merely beneficial. The threshold for fabricating, buying or utilizing the technology becomes so low, that people are inclined to decide they want to use it, before they have become aware of the realistic long-

[4] There are various methods for providing sham stimulation. In general, sham stimulation is regarded valid as such when participants cannot tell it apart from actual stimulation beyond chance rate. For a detailed explanation and used methods, read (Palm, et al., 2013).

term effects. This can generate feelings of regret and dissatisfaction in users. Neurologists at Yale University have emphasized that devices such as Thync are based on research that is not ‘ready for the world’, and that the science behind these technologies is not meant to be utilized for the commercial market (Hogenboom, 2015).

Second of all there is the effect of disappointment in users. This is different from dissatisfaction, because it arises upon self-reflection and as a consequence of expectations that were set too high. When the technology does not meet what it promised (or in fact was not promised by the technology, but the media, social media and the developing company), especially in the case of neurotechnology, users might self-reflect and blame themselves. This is because promises with regards to neurotechnological devices in particular, are made with regards to mental states and behavior. When mental states and behavior do not change as much as was expected, users might feel that they do not feel ‘good’ enough or as if they have failed themselves. As a consequence they might blame themselves for this ‘failing’.

I.4.3 Cultural Factors and Uniqueness per Individual

Uniqueness of an individual can be ascribed to several factors such as age and gender, environmental and cultural influences. All of these factors can be the basis for deviating expectations and a variation in response to the existence and capabilities of neurotechnologies in general. But even if such factors as age and gender did not play a role in creating a difference between each individual, there would still be a fundamental uniqueness to each person, a uniqueness that might affect how neurotechnologies influence the self. Stern called this ‘primal uniqueness’. In his introduction to Person und Sache (Vol. 2), he wrote: “Despite any similarities by which persons are identified as members of humankind, a particular race or gender tec., despite any broad or narrow regularities which are involved in any personal events, a primal uniqueness always remains, through which every person is a world of its own with regard to other persons.” (Stern, 1906, p. I).

This primal uniqueness is what makes neurotechnology in particular a difficult area of research, because it influences an organ that functions in a different way in each individual. In discussing the influence of neurotechnology on aspects of the self and self-understanding, uniqueness of the self may be responsible for specifics concerning *how* the self is affected and changed. It will not be possible to discuss each of the factors of uniqueness separately and research each of the possible roles they play in the influence on the self, because that would not fit the scope of this research project. It would not fit the goal of this research either, since its focus lies on the influence of neurotechnologies on a more general level, namely the dynamic organization of consciousness of the human being in general and the various aspects out of which consciousness consists.[5]

The issues of the placebo effect, the media hype that surrounds neurotechnology and primal uniqueness in individuals show that results and conclusions in literature with regards to empirical data in neuroscience should be carefully evaluated. In this investigation, the possible influence of these points should be kept in mind. They may return and be discussed separately throughout this research if their influence is deemed relevant for the analysis with regards to the self and self-understanding.

I.5 Conclusion

In this chapter, I have briefly explained the workings of the neurotechnologies that I named as most relevant to this research, in order to create an understanding of the ways in which they might affect the brain and brain activity, cognitive functions and phenomenal aspects such as consciousness. Furthermore, I have given examples of two scenarios in which such technologies already seem to have the ability to have an impact on (daily) life by influencing brain activity. In the last section I discussed three methodological issues that should be taken into consideration when discussing and evaluating neurotechnology, because they can be of influence on the results of neurotechnological application and the way in which these results should be evaluated.

The following chapter will go deeper into the workings of the brain, explaining the concept of neuroplasticity in particular. This concept will help understand the meaning and possibilities of influence with neurotechnologies on the self. I will also briefly enter the debate on what can be considered ‘natural’ in the case of brain influence. Furthermore I will present an overview of the differences between neurofeedback and brain stimulation technologies, and also on the differences between neurotechnology and drug use, because in both cases I want to emphasize that they should not be regarded and – as a consequence of that – be treated the same.

[5] Although primal uniqueness cannot be investigated in this research as a determining factor in how neurotechnologies influence the self and self-understanding, it should be kept in mind that it can still play a role in contemporary empirical data. The issue of primal uniqueness furthermore stresses the importance of more research before improvident application of neurotechnological devices.

These analyses will provide insight in the specifics of brain stimulation technologies on one hand and neurofeedback on the other. For this reason the final analysis regarding influences on the self and self-understanding in chapter 5 can also be executed and yielding results on a more detailed level.

CHAPTER II

HOW NEUROTECHNOLOGY CAN BE UNDERSTOOD IN VIEW OF EXISTING NEUROSCIENTIFIC ISSUES AND CONCEPTIONS

In this chapter, I will address some of the contextual issues that arise in the discussion around neurotechnology. First the concept of neuroplasticity is explained, which is necessary in order to understand in what sense neurotechnology can be considered unnatural, explained secondly. In addition to this, I will point out the distinction between brain stimulation technologies on one hand, and neurofeedback on the other. This way, the possible differences between consequences of both types of neurotechnology will be better understood.

Finally, I will make a comparison between neurotechnology and drug use, because in research talks and media they are often referred to as having comparable functions and effects. By showing five fundamental differences between them, I will emphasize why the application of neurotechnologies poses a unique case. I will then argue that it is therefore it is necessary to investigate the effects of neurotechnologies separately and independent from the known effects of drug use.

II.1 Neuroplasticity

As said, in order to understand in what sense and in which cases the application of neurotechnologies could be considered unnatural, it is necessary to explain the particular function of the brain called neuroplasticity. Neuroplasticity can be described as the brain's ability to reorganize itself through changes in connectivity between nerve cells and neural circuits in the brain due to environmental influences and internal demands (McCullumsmith, 2015). It is considered to be of utmost importance for normal brain function, as it is recognized as a major physiological basis for the adaption of cognition and behavior (Kuo, Paulus, & Nitsche, 2014). Generally speaking, there are two types of neuroplasticity. Functional plasticity refers to the brain's ability to move functions from one brain area to another (Greenwood, 2007), for example in case of brain damage, while structural plasticity describes the brain's ability to change the physical structure under influence of learning (Lamprecht & LeDoux, 2004).

Neuroplasticity occurs through two mechanisms; long term potentiation (LTP) and long term depression (LTD). LTP and LTD are enduring changes in the connections between nerve cells, that are induced by specific patterns of synaptic activity (Bliss & Cooke, 2011). LTP describes the enhancement of the synaptic transmission ability between two nerve cells, while LTD suppresses this synaptic transmission ability. What this basically means is the strengthening (LTP) and the weakening (LTD) of the bond between two neurons. The patterns of synaptic activity that cause LTD and LTP can occur under the influence of experiences, as said above. This causes the dynamic structural reorganization in connectivity between nerve cells in the brain.[6] If however these changes in the brain that allow for example for connectivity between nerve cells to enduringly and significantly change can also be induced by neurotechnologies, it would become a different case. It would then be through technology that the physiological structure of the brain would change, with the accompanying consequences for cognition and behavior. What is more, if brain stimulation technologies or neurofeedback can indeed influence the capacity of neuroplasticity itself, this could mean that neurotechnology can change the way in which the brain reorganizes, restructures, and thus changes, itself. In the

[6] Thus a complex interplay between the activity of kinases and phosphatases, enzymes which can also either directly or indirectly cross-modulate each other's activity, determines the polarity of synaptic plasticity. Persistent activation of these mechanisms initiates a cascade of signaling events that culminate in gene expression and the production of new proteins (Bliss & Cooke, 2011).

case of functional plasticity, this could mean for example that functionality is organized differently after for example having had a stroke. Perhaps brain functions will return differently in other brain areas, or faster than without neurotechnological interference. With regards to structural plasticity, the changes that would normally be occurring as a consequence of regular learning processes in daily life, could for example be enhanced or compromised because the brain's capacity to bring about such changes is altered.

The meaning of these possible influences of neurotechnologies will become clear in the following chapters. In chapter 5, I will discuss what consequences this might have for selected aspects of the self and self-understanding. For now, this section has shown how influences that cause changes in the brain are nothing special in itself – since this occurs on a daily basis through experiences and bodily processes. This becomes a different matter when it becomes possible to intentionally achieve such changes in a very direct and aimed manner. Why this is what makes influence with neurotechnologies unnatural, will be explained in the following section.

II.2 The Unnaturalness of Neurotechnological Applications

The debate concerning what is regarded as 'natural' as opposed to unnatural is a global ongoing debate, but generally focuses on findings in various scientific disciplines or biological interventions such as genetic manipulation (Bird & Tobin, 2015). What should be kept in mind in the discussion surrounding the unnaturalness of manipulation of brain activity, is that both the methodology and the outcome should be taken into account. Certain mental states or achievements that are brought about through means of neurofeedback or neuroenhancement can also occur without technological interference. This does not automatically mean that they should be considered 'natural' upon occurring through means of neurotechnology. At the same time, the fact that the methodology *is* considered natural, does not mean that it is natural to apply it, even if the result is regarded as a natural state.

In discussing what is unnatural with regards to neurotechnology, we need to first answer the question of what the term unnatural stands for in this investigation. James Giordano has discussed this topic, with regards to neuroenhancement (Giordano, 2012, p. 199). This will shed some light on the difficulty of the topic before I turn to what I will consider as unnatural within the context of this research.

II.2.1 Naturalness of Suitability and Familiarity

The first of Giardano's arguments to distinguish naturalness that I will be discussing, is 'naturalness of suitability'. (Giordano, 2012) In this argument he describes how certain capacities belong or are suitable for certain species, so-called *species-typical capacities*. The terms 'suitable' and 'belonging' are ambiguous as well, because they are related to socially accepted norms and forms of behavior. Nevertheless, they can still say something about the naturalness of actions or entities. Giordano points out how an example of this is the possibility of changing human nature with neuroenhancement in general. He claims one could argue that such procedures as neurofeedback, neuroenhancement and their possible outcomes do not belong in human nature at all. [7] What can be considered natural, is the way that something was supposed to be, something it was developed or designed for. When it is used for something that was not there from the beginning, such as adult human beings walking on hand and feet, this looks unnatural. The same can be said about the brain, in which case one could consider what would be a natural process and what would not be that. From an evolutionary viewpoint, the brain has not been adapted to direct electric stimulation, so from this perspective it would seem brain stimulation technologies can be claimed as unnatural based on suitability grounds.

This argument can be applied to neurofeedback as well, but there it already becomes more difficult. Neurofeedback is a method to teach a subject to stimulate his or her own brain, by monitoring them via an EEG and rewarding them when the 'right' brain waves are produced. According to the argument of suitability, neurofeedback would not be considered natural because the brain was not intended to be attached to an EEG to monitor its activity. What is more, the technology allows in some ways for quantification of mental states by associating them with the amount of brain activity in specific brain areas. However, if we imagine a child getting candy each time it performs desirable behavior, triggering the brain's reward system, a similar process is described, only in this case, the brain is trained 'naturally'. Therefore it might be argued that neurofeedback can be considered natural as well, because brain activity is altered by employing 'natural' reward systems in the brain. So even though it gives an idea of the ways

[7] Human nature in this case is describes as "a set of characteristics that are common to all humans and that distinguish humans from other kinds of beings" (Buchanan, 2009, p. 142). The characteristics in this set are essential in the sense that if one of them is missing, one is no longer a human being. This does not mean that nothing unnatural can be added to this state of human nature.

in which neurotechnologies could be natural, the argument of suitability still proves problematic in identifying the unnaturalness of neurofeedback specifically.

Giordano introduces another approach, suggesting naturalness as familiarity. (Giordano, 2012) This claim has more to do with what humans are accustomed to, what they are familiar with. This argument approaches unnaturalness from a more personal perspective, since there is much more variety amongst human beings as to what they are accustomed to in their lives. If not per individual, there is great variety amongst cultural customs. In case of neurofeedback, the argument would claim it is unnatural, because features of the procedure such as having patches with electrodes attached to the head and sitting in front of a screen while attached to an EEG are not every day acts. Most people have never experienced these particular ways of treatment in their lives. This goes for brain stimulation technologies as well. The complication that arises with this argument however, is the fact that for something to become familiar, the only factor essentially required is the time it takes for subjects to get used to such a procedure. Therefore, even if considered unnatural, it would not stand as an argument in the debate because utilizing this technology would render it natural in due time. However, it could still be debated that this is not enough reason to allow for employment of the technology, from the viewpoint of the precautionary principle. The precautionary principle in relation to neurotechnology will be discussed in more detail in chapter 5.1. I will now turn to my own reason to consider the way in which neurotechnologies change the brain unnatural.

II.2.2 Unnatural Neuroplasticity: Increased Speed and Directedness

Previously described categorizations and arguments show the difficulty of classifying the different types of neurotechnologies into one of these categories. For this reason, and to show an additional way in which neurotechnology could be classified as unnatural in general, I will point out two main differences between changes in the brain due to environmental influences or internal demands, and changes in the brain that were induced via brain stimulation. This will aid in explaining the unnaturalness of neurotechnologies that alter brain activity one way or another, so it will include neurofeedback training.

As described earlier, neuroplasticity is the ability of the brain to reorganize and restructure the connectivity between nerve cells due to experience, environmental influences and internal demands. As such influences take place each time an individual experiences something, feels something or undergoes environmental input, changes in the brain as a consequence of neuroplasticity occur constantly, gradually and unavoidably throughout an individual's entire life.

It is known that brain stimulation technologies can influence cognitive, affective or motor brain functions (Frontiers, 2007-2016). One of the proposed mechanisms of action for technologies that alter brain activity to such an extent (such as TMS, tDCS and possibly others) is induction of LTP and LTD (Brasil-Neto, 2012) (Bliss & Cooke, 2011) (Ruffini, et al., 2013). These technologies initiate the same neuronal mechanisms that occur as a consequence of the daily activities and experiences that induce structural plasticity, the type of plasticity that allows for organizational changes in the brain due to learning processes. Because such changes in the brain occur as a consequence of everyday experiences as well, it is a difficult task to define what it is exactly that make the changes in neurophysiological structure as a consequence of neurotechnological procedures unnatural.

I suggest at least two major differences can be distinguished between everyday induced organizational changes and changes induced with the neurotechnologies discussed in this research. The first is that with neurotechnologies, direct brain stimulation is possible that artificially triggers the same mechanism over and over again, causing structural changes in the brain at a pace that would be impossible in everyday life. That is why the most important difference that occurs between 'natural' everyday stimulation and stimulation with neurotechnologies, is the *speed* with which it can happen. This is why changes in the brain, when induced directly with neurotechnology, can still become an unnatural phenomenon. Due to artificial inducing of LTP and LTD, dynamic neuronal structures and pathways could be formed that would not occur as a consequence of experience and internal demands alone. This unnatural speed is what makes the stimulation unnatural, and it is what I will call direct and unnatural stimulation. Another possible reason for an increase in speed is not only that the process itself is sped up, but can also arise as a consequence of steps in the underlying neurological process that can be avoided or become unnecessary with neurotechnology. This might for example occur in the establishment of neural circuits, if brain stimulation technologies were to be applied to increase synaptic connections between nerve cells (Hattori, Millard, Wojtowicz, & Zipursky, 2008).

The second difference between everyday induced organizational changes and changes induced by neurotechnology is the focused and precise aim with which stimulation can take place, in comparison with everyday experiences of which it is believed they have a positive effect on the general state of mind, for example walking in nature. This is also where neurotechnology differs from for example psychological therapy. In the cases of tDCS, TMS and DBS stimulation can be directed at a specific location and intensity can be varied in order to achieve a specific desired result. In case of neurofeedback training as well, the training can be adjusted based on detailed feedback about the subject's brain activity that allows the training to be steered in a specific direction. In addition to this, the more knowledge is gained in the area of relating specific brain areas to mental states, processes and cognitive functions, the more directed stimulation can be in order to achieve a specific result. It would seem that the more precise and instantly a specific mental state can be achieved via artificial stimulation, the more unnaturally brought about this mental state may be, and the more unnatural the mental state itself might be regarded as in this particular moment and person. To return to the discussion of unnaturalness, both speed with which changes in the brain's structural organization can be brought about and the specific directedness of brain stimulation technologies and neurofeedback are the main reasons of why I call their effects on the self and self-understanding unnatural. To make this even more clear, the unnaturalness of neurotechnology can be compared with the use of pharmaceutical drugs. In that case, increased speed in brain mechanisms and increased directedness can also be achieved, for which reason these drugs can also be considered unnatural. There are also some differences between drug use and neurotechnologies, these will be discussed in chapter 2.4.

Now you may think that calling something unnatural does not make it undesirable or harmful. For this reason, I will provide a few reasons why a critical view towards unnatural effects of neurotechnology is desired. Below I point out some ways in which unnatural stimulation with neurotechnologies could be considered unintended, harmful or regarded as undesired. Both individual and societal consequences can occur.

First of all, there is the problem of long-term effects. Since neurotechnology is relatively new, not much is known about changes in behavior or cognition that occur more than a few years after influence of neurotechnology. As I explained while discussing tDCS in chapter 1, there have been some indications that stimulation of one cognitive ability with this technology, reduces another cognitive function. (From a study published in the journal Behavior Brain Research, (DNews, 2015)).

Second of all, while many of the underlying neuronal mechanisms that take part in neuroplasticity are still unclear or unknown, these mechanisms are used in brain stimulation. Research has shown that changes in some neural pathways can influence downstream neural elements (Hamilton, Messing, & Chatterjee, 2011). However, the pathways and downstream neural elements that would be influenced are unknown. This means that the exact physiological influences of stimulation with these technologies on the brain are difficult to predict, especially on a molecular level.

Thirdly, as mentioned in chapter 1, many of the research data is based on behavioral studies, or on results based on reports from subjects. However, with neither of these methods of inquiry it is possible to find out what happens in the brain on a molecular level. Subjects themselves may be capable of reporting certain feelings and shifts in mental states that they are aware of, but they could not themselves sense what neuronal pathways have led to which states of mind. The same goes for behavioral studies, where motoric and social output is studied. It would be very difficult to retrace changes in behavior or cognition to LTP or LTD between neurons, and even if done so, it is not possible to find out what other neuronal pathways or mechanisms may have been influenced.

The fourth argument of why unnatural effects could be bad or harmful is an example of how an intended and well-performed adjustment in brain function could still be seen as a negative consequence. This has to do with the ability of an individual to cognitively control emotions being critical for mental health. It is speculated that brain stimulation might someday be used to lessen the relatively normal minor negative mood states that occur in psychologically healthy individuals. To many, this might seem as a positive development, because it offers a prospect of (slightly) less mental suffering. However, it is also being researched that the ability to endure mental discomfort plays a fundamental role in psychological development, such as in the development of patience and determination (Hamilton, Messing, & Chatterjee, 2011). Evidence suggests that painful experiences also may play a role in empathy, because observing pain in others generates the same patterns of neural activation as when an individual experiences pain him or herself (Hamilton, Messing, & Chatterjee, 2011). This is why the question remains whether unnatural stimulation such as manipulation with BST's will be beneficial in the larger sense in the end, or that it will come at the expense of other valuable psychological abilities.

II.3 The Differences between Neurofeedback and Brain Stimulation Technologies

In order to be able to make a proper analysis of the influence of brain stimulation technologies (BST's) and neurofeedback (NF) on the self and self-understanding, the main differences between the two types of technology will be pointed out in this section. Contemporary developers such as the directors of Thync recognize the difference between neurotechnologies that aim for a subject that can train their own mental states through means of feedback that is given, and devices that directly and 'actively' stimulate brain activity. This difference was also already briefly discussed in chapter 1, and it shall be elaborated upon in this section, including the meaning of these differences for the effects that each of these technologies will have.

1. A subject has perception of a projection of their own brain wave pattern at the moment of neurofeedback training (only NF)

With neurofeedback, a subject is often seated in front of a screen. As described in chapter 1, the screen usually displays a projection of the subject's brain activity, in the form of brain waves or something like a thermometer or an emoticon. There are also cases where the subject is asked to play a game on the screen to achieve the desired state of mind. In any case, the purpose of this display is to stimulate the subject to think in the 'direction' that was previously determined as the desired direction (such as a relaxed state, involving calming thoughts). Besides this purpose of the display of the projection of brain waves however, the subject receives information about how they are doing (for example the temperature on the thermometer slowly rising). This may be experienced as a sense of how *well* they are doing, since an effort is made to reach a set goal, even if the reaching of that goal is only in their own interest. There are some neurofeedback centers that claim "the subject does not have to do anything 'actively', it is the brain that is training the brain" (Neurofeedback Instituut Nederland, 2014). However, this would presume that it does not matter what the subject is thinking of, since it all happens on its own, without any involvement of the subject himself. But even without motoric activity, if a subject is asked to do something, (like concentrating on a relaxed state of mind), this may give rise to a sense of effort and control in the subject. This is not the case for brain stimulation technologies, as the process described above does not occur with those technologies. With TMS, DBS and tDCS the brain is stimulated no matter what the subject is thinking at that time. The only sense of control, is because for example in the case of DBS, stimulation can be controlled via a remote controller. However, this gives a sense of controlling what happens *to* their brain, as opposed to sense of having to control what might happen *in* their brain as a consequence of their own thinking. The difference is between having to push a button, and forcing oneself to have a certain state of mind. This difference is important for this research, because feelings of effort and control are related with the concepts of self and self-understanding. In chapter 5, I will explain what such feelings of control and effort can mean for these concepts.

2. The subject has knowledge of the fact that both subject and trainer can have real-time perception of the type of brain activity that is produced (only NF)

The following difference between neurofeedback and brain stimulation technologies is actually a consequence of the one just explained. It builds upon the information that subjects receive on how well they are doing. Besides senses of effort and control, the subject may experience feelings of pressure with regards to their performance. Before the procedure, they usually are told that the practitioner can keep track of brain wave patterns real-time via the EEG. The fact that a subject has knowledge of the practitioner following their brain wave pattern may cause feelings of pressure or anxiety, even though it would be far from possible for the practitioner to know what the subject is thinking. These feelings may also influence or compromise the measurements of brain activity during the feedback session, or the results of the training itself. This is different with stimulation with BST's, because even though the practitioner might have knowledge of the subject's brain wave pattern in that case as well, there is no "thought performance" necessary. The activity in the brain is stimulated or decreased independent of the subject's present thoughts or mental state. In the same way as the previously described difference, the effects in relation to the self and self-understanding will be discussed in chapter 5.

3. To an extent, a subject has knowledge regarding the correlation between a subject's own mental state and the type of brain waves, at the moment of being in this mental state or focusing on a specific way of thinking (only NF)

The following difference concerns the 'feedback' part of neurofeedback specifically. The subject's brain 'gets rewarded' when it produces the right type of brain waves. In some cases, the subject plays a game (for example moving something to a specific part of the screen by concentrating on it) and the reward system is triggered when the subject is ‘winning’. The point with this procedure is that sometimes, it is presented as a procedure in which the subject receives information on how *their brain* is doing, as opposed to how *they* are doing instead (About Neurofeedback, 2014). It is not you that is rewarded for example by getting candy; the brain is, by triggering a system. This gives the idea that the subject is *not* in control, and they might perceive it as such as well. A result is that the procedure is more similar to BST’s this way, in which case the brain is stimulated separately from the subject’s present thoughts as well. However, in the case of NF, this occurs while the subject is making an *effort* with their thoughts. This is why subjects undergoing neurofeedback may feel an increased sense of dissociation towards their brain when they are being told that their *brain* is functioning a certain way, as if the brain was functioning completely separated from their thoughts. This consequence may be of influence on the self as well, which will be explained in chapter 5.

4. There is effort (NF) vs. no effort (BST) expected during the procedure, which means active participation (NF) vs. passive participation (BST)

Previously mentioned differences already touched upon the difference in sense of control and personal effort. One effect of the effects of neurofeedback, is that a subject consciously experiences their own mental influences on their mental states in a very concrete and quantified manner (as opposed to gradually ‘feeling different’ when mental states or behavioral aspects are changed due to neuroplasticity). With neurofeedback, skills can be *trained*, for example self-regulation (Strehl, 2014). This is not the case for BST’s, because a subject is not required to influence their mental states using mental focusing or thought. This difference is important, because a subject’s awareness with regards to their own concrete influence on their mental states can give rise to feelings of failure or success, but also of responsibility. This gives another dimension to the procedure, because it can also cause a shift in the subject’s feelings with regards to the nature and amount of influence they have had on the result. In turn this may influence aspects of the self and/or self-understanding, which will be discussed in chapter 5.

5. The use of electrodes for *influencing* of brain activity (BST) vs. attachment to an EEG for the purpose of *measuring* brain activity (NF)

With brain stimulation technologies, brain activity is changed with an electrical current that has its source outside of the human body. Nerve cells in the brain are externally influenced by neurotechnology. With neurofeedback, this is not the case. The subject still gets electrodes attached to their head, but this is only for *measuring* brain activity, not to influence or change it. The changing of brain activity is done by the subject himself, but by tracking brain activity via an EEG, the neurotechnology is what makes this changing possible. This is important because the difference in methods may cause variable effects on the subject. The idea of having electricity run through ones brain is different from the idea that one is trained to adjust their own thinking pattern, even if they would be causing the same end results objectively.

6. The way in which the method of the technology is presented to a subject; 'aggressive' (BST) vs. 'passive' (NF)

What should also be mentioned is that this difference in means actually exists of two dimensions. On one hand, one could say that BST's are more aggressive, since they directly stimulate or reduce brain activity in specific areas of the brain by electrically stimulating it. However, where BST's may employ a more aggressive procedure, it is passive for the subject because the results of the procedure are not in any sense dependent on effort or involvement of the subject. The procedure of neurofeedback on the other hand may seem less aggressive than those of BST's, because neurofeedback merely indirectly triggers the reward mechanisms (through a sound or short movie clip). But because of the involvement of the effort and concentration from subjects in the results, and the sense of responsibility that this may inspire in these subjects, neurofeedback requires a more 'active' attitude. Therefore, it should be kept in mind that even if neurofeedback is perhaps considered a less invasive procedure, it can be experienced as more intense.

While it may not be the case that each of these differences proves that NF and BST's are fundamentally different technologies, together they show that there is enough reason to believe that application of NF as opposed to BST's can have significantly different consequences. Therefore, they are discussed separately in chapter 5.

II.4 A Comparison between Neurotechnologies and Drug Use

A topic frequently discussed in relation to neurotechnology and neuroenhancement is drug use. In the following section, some of the most important differences between drugs and neurotechnology will be explained. This will give insight in the effects that neurotechnologies could have and emphasize in what ways the influence of neurotechnologies are possibly more substantial than those caused by drugs, and why the effects should not be carelessly compared.

Up until now, I have mainly focused on the medical use of neurotechnology and not neuroenhancement, or improvement of the 'healthy' brain. There is a large difference between these discussions when it comes questions of ethics, authenticity and whether or not either neurotechnology or neuroenhancement goes against human nature. This is because neuroenhancement crosses a border that medical use of the technology does not, improving the healthy brain has as purpose to improve human functioning, whereas medical use merely intends to bring a subject's brain function back to its original state. The focus of the comparison to drug use and medicinal use of substances will still lie on medical use of brain stimulation technologies and neurofeedback, but also mentions cases of neuroenhancement at times, for the purpose of comparison of possible effects and social consequences.

Developers and supporters of neurotechnologies attempt to imply that altering a state of mind or invading in brain processes is not such a big deal. They often compare it to drug use, especially in the case of neuroenhancement, but medical use of neurotechnologies is often compared to the use of pharmaceutical drugs as well. It is introduced as a new method, but compares the results to those of drug use with a medical purpose or present neurotechnologies as a 'handy tool' to make someone feel or function better. As Maarten Frens, low tension current researcher in Rotterdam pointed out, BST's such as tDCS are promoted on the market as though they only have benefits and that they will easily improve many aspects of your life in an instant (TEDxDelft, 2013). Of course, this attracted many critics, expressing their concern and posing questions with regards to the underlying more philosophical matters. Examples of these are the national or global gaps between the 'rich' and the 'poor', rewards for effort vs. results, and whether or not such technologies will ultimately lead to more happiness and well-being in individuals and society as a whole. These questions are more relevant in neuroenhancement, because neuroenhancement gives much more opportunities. However, they are important in the case of medical applications of neurotechnology as well, because these applications can still have a large impact on both individuals and society.

Ethicists have also compared neuroenhancement with plastic surgery or cosmetics, but critics argue that both neuroenhancement and medicinal applications of neurotechnology influence mental states in a much more direct way (Schepers, 2015). One could even imagine claiming neurotechnology should be classified as one step ‘further’ than drugs, in the sense that the level of directness, duration and unpredictability are more prominent in case of the former. However, in some cases, drugs and neurotechnology can have the same effect on body and/or mind. For this reason, the difference between them is then for a large part a question of means.

For all of these reasons it is important to look at the classification of neurotechnologies, and the ways in which they differ from chemical drugs and their effects. Maarten Frens’s talk focuses on neurodoping, the idea to use electrical current in professional sports accomplishments. So where exactly lies the boundary between chemical enhancement as it has been known until now, or healing and enhancement with electrical brain stimulation? And what exactly are the differences?

1. Nature of Stimulation

First of all, there is the difference in electrical and chemical stimulation. Even though electrical stimulation that changes brain activity has chemical effects, it is different from being directly chemically stimulated. When taking pharmaceutical drugs, there is a chemical process that follows, that can be traced. Even though not all pathways of this process are perhaps known, it can to some extent be predicted how and with what these drugs will react in the body. Electrical stimuli alter brain activity on a different level, because they influence the electrical part of cell-communication (see chapter 1). This is not merely an objective difference but also a subjective difference, in the sense that subjects can perceive employing each of these methods in a different way (taking a pill containing substance vs. putting electrodes on the head or having them inside the brain, knowing these electrodes will send out an electrical current).

2. Duration of the Effects

Second of all, there is the duration of the effects. Of course this varies largely within each discipline, but there are some fundamental differences. The duration is partly determined by the degradation process of the drug. Chemicals are degraded in the body into decomposed products that no longer have neurological effects. For example in case of consumption of alcohol, a correlation has been made between the amount of alcoholic parts per milliliter of blood (per mil) and a ‘drunk’ state of mind. This includes measurable factors such as reaction times, motor coordination and reduced blood pressure. When the alcohol is broken down into acedic acid by the liver, less and less alcoholic parts are measured circulating in the blood system. This shows that it can be measured to what extent a person is under influence of the drug and also that it can be made certain that a person is no longer under influence at all. In the case of neurotechnology that makes use of direct electrical stimulation, there is no chemical compound that is broken down and leaves the body. Therefore, it is much harder to detect (undesired and unmonitored) lasting neurological and mental effects.

In addition to this, there is difference in the effects lasting after termination of application or consumation. Where the intended effects of pharmaceutical drugs (this excludes permanent physical damage) no longer appear when the drugs are no longer taken, expectations and contemporary research findings indicate that the effects of neurofeedback and brain stimulation technologies can last for weeks or months and longer, especially in the case of neurofeedback (Bewernick, Kayser, Sturm, & Schlaepfer, 2012) (Vestito, Rosellini, Mantero, & Bandini, 2014) (Kouijzer, de Moor, Gerrits, Buitelaar, & van Schie, 2009). In fact, they are *supposed* to be long-term or permanent, for the benefit of the subject.

3. Invasiveness

The third aspect that differs is the invasiveness of the technology, meaning to what level the effects permeate the body. As said, drugs such as alcohol or medicinal drugs are quantifiably measurable within the body after consummation or administration. Electrical stimulation that induces or reduces brain activity brings about responses that are of an electrical nature as well. Even though brain activity can be measured to a certain extent, it is harder to trace what actual consequences arise, especially on the long-term, partly because of its electrical nature.

There are two ways for drugs to interfere with the communication system. The first way for drugs to interfere with the system is that chemicals in drugs mimic the chemical structure of naturally present neurotransmitters. This triggers a response from nerve cells, but because they do not active nerve cells the way neurotransmitters would, this leads transmission of messages that would otherwise not have been released (Sanyal, 2012). The second way for drugs to influence the communication system of the brain is by producing greatly amplified messages. This can happen due to abnormal release of neurotransmitters under the influence of the chemicals in drugs. Ultimately, this will disrupt communication channels.

Both of these ways in which drugs interfere with the communication system of the brain, can usually be traced measuring blood levels. This is not the case for neurotechnologies, because they interfere with the brain on a different level. This can happen very locally, so that only a specific part of the brain that supposedly correlates to a specific mental state is influenced. However, since brain stimulation technologies cause increase or reduction of sponteanous cell firing (tDCS) or directly increase or decrease neuronal activity (TMS) or blocking nerve signals (DBS), it is harder to predict the ways and areas in which electrical stimulation will react. It is no longer the case that chemicals react with other chemicals, and only those specific chemicals. The subcellular and subatomic level of reaction of electrical stimulation, may therefore heighten the chances at unintended and undesirable reactions and thus effects.

4. Risk of Addiction

Then there is the fourth aspect, the risk of addiction. After the research on drug use in the past decades, the National Institute on Drug Abuse now considers drug addiction a brain disease, because drugs change the brain, its structure and its functioning (The National Institute on Drug Abuse, 2014).[8]

Most drugs target the brain’s reward system, by directly or indirectly causing abnormal release of the neurotransmitter dopamine. Dopamine has been known to be involved in regulations concerning movement, emotion, motivation and feelings of pleasure. When activated, this functions as a reward for some of our ‘natural behaviors’, the process described as operant conditioning in chapter 1.1.4. Overstimulation of the system can cause euphoric effects that give a strong urge to repeat the behavior that caused this feeling – in this case taking the drug (The National Institute on Drug Abuse, 2014).

This can happen because the connections in the brain are wired to ‘remember’ this euphoric effect, and ‘teach’ drug users to repeat their behavior without thinking about it. One of the effects of most drugs is the diminishing of feelings, when the brain is no longer under influence of the drugs. This is another reason to take the drug again, and to take more each time to accomplish the same desired effects.

[8] The use of the word “addiction” in this research can be considered as the brain’s specific inclination to retrigger a specific pathway or reproduce a certain type of brain waves.

There is a difference between neurofeedback and BST's with regards to risk of addiction. With brain stimulation technologies the dopamine system is not 'used'. This is different for neurofeedback, where in fact one part of the procedure is to trigger this exact system in the brain through means of operant conditioning. What is interesting is that this is purposefully done, to cause repetition of a specific train of thought, with as consequence a consistent change in a specific pattern of behavior. A subject may even presume that by using the reward mechanism the brain is being *made* addicted to these specific trains of thoughts and patterns of behavior. On neurofeedback.com, originally started in 2006 by Mike Cohen of the Center for Brain Training, it even reads that "It's amazing how motivated people are to keep it beeping", referring to the beeping sound that the client receives upon producing the desired brain wave pattern and that triggers the reward mechanism in the brain (About Neurofeedback, 2014). Apart from the ethical questions this might arise that this research does not address, it may have interesting consequences, especially for self-understanding. The thought that one's brain is made addicted to a specific type of thought and behavior, offers a perspective that can change the way a subject feels about this behavior. These possible consequences will be addressed more elaborately in chapter 5.

5. Question of Means

The following aspect of neurotechnology as opposed to (therapeutic) drugs concerns the difference in means between the different types of neurotechnologies on one hand, and drugs on the other. Whether or not the purely physical consequences of employment of each of these methods are the same, is in this case irrelevant. Let's compare for example the Thync device with a cup of coffee. Imagine a person feeling tired and wanting to be more mentally active. It is generally known that coffee contains caffeine, a chemical component that is taken up in the body, circulates the blood stream and arrives in the brain, where it causes a reaction that can cause this person to feel more active. The cup of coffee can be consumed by drinking it, a method used since prehistoric times to nourish ourselves. After this it is processed and digested by the gastro-intestinal tract, a process known by the consumer as a consequence of centuries of studies.

On the other hand there is Thync. The same person feels tired and in want of higher mental activity. Now, they make use of Thync, a device that they know can influence brain activity. They install the application for Thync on their mobile phone, a technical device that exists no longer than a couple of decades. Furthermore, a two-patched futuristic-looking device is placed on the head. The consumer pushed the screen of their mobile phone on the top, the ‘button’ for mental activation. Then after a minute or five, the consumer is supposed to feel more active. While Thync is used, a slight itching sensation or tightness can be experienced. It is likely that the consumer does not know what happens in the brain during stimulation, or if any other effects will arise. Nor is it clear when the effects will have worn off, except for the experience.

What makes this an important difference between neurotechnology and drug use, is the fact that means can influence subjective experience, something that is often not realized. This can lead to significant differences in the ultimate outcome of application. Especially in the case of influence on those aspects of consciousness that will be discussed in this research and self-understanding, the difference in means can play a large role. This will become clear in the following chapters.

In light of all of the above, we can conclude that there are some important differences between neurotechnologies and drug use. Because of the potential of neurotechnologies for longer lasting or even permanent results, they could be considered more dangerous in this respect as opposed to drugs, of which the effects often will wear off in a few hours after consumption. The fact that the effects of neurotechnologies are less quantifiable, adds to this danger because the (potentially undesirable) changes would be more difficult to trace. The issue of addiction, especially in the case of neurofeedback, will be discussed separately in chapter 5. While there are some comparable factors between them, the reasons above show that it is important to keep in mind that (pharmaceutical) drugs and neurotechnology are two separate categories that should not readily be compared.

II.5 Conclusion

In this chapter I have explained that neuroplasticity can be described as the brain’s ability to change itself through the reorganization of for example the connectivity between nerve cells in the brain, due to environmental influences and internal demands. I explained that the neurophysiological changes brought about via neurotechnology can be regarded unnatural due to the speed and directedness with which such changes can be brought about, as opposed to ‘natural’ everyday occurring plastic changes. Furthermore I have outlined what appeared to be the most prominent differences between NF and BST’s to be able to make a comparison between these two types of neurotechnology with regards to their effects. Finally, I compared neurotechnology to drug use and found the differences discussed sufficient to say that the two cannot be regarded the same in way of application, functioning, consequences.

In the following chapter I will approach this concept from a philosophical perspective and explain what I mean by ‘self’ in relation to consciousness. This will constitute a conceptual apparatus that will be helpful in analyzing the effects of neurotechnology. In chapter 4 I will then compare this conceptual apparatus to contemporary neurophysiological findings.

CHAPTER III

CONSCIOUSNESS AND THE SELF

In order to investigate the effect that neurotechnologies can have on the self, and ultimately self-understanding, the concepts 'self' and 'self-understanding' should be conceptualized first. In this chapter, several views with regards to aspects the self and consciousness will be discussed, in order to form a conceptual apparatus of the self.

In her research on "Brain technologies and the self"; Brenninkmeijer describes reports from subjects of how the self can change in psychological terms after having received brain stimulation. These are captured in phrases like: "I am a better version of myself", "I am becoming a completely new human being", or statements as "this is really me" (Brenninkmeijer, 2013). Such descriptions question the relationship between neurotechnologies and what human subjects think of as their selves. But how to schematically analyze in what ways this 'self' can change after the brain has been exposed to neurotechnological applications? In order to do so, a philosophical conceptual apparatus of the self must be developed, that can be supported by contemporary neuroscientific findings. In this chapter, such a conceptual apparatus of the self will be composed. I will use the theories of three philosophers that have written influential literature on the subject. These three are David Hume, Immanuel Kant and William James. The concept of self as it will be investigated in this research, is best described in relation to consciousness, since consciousness plays a crucial role in its constitution. James' ideas on the organization of consciousness will be the starting point in discerning those aspects of the self that seem likely to be influenced by both brain stimulation technologies and neurofeedback.

Before discussing James' theory of consciousness, I will explain the self as it is used in this research, through means of philosophical insights by Kant and Hume. Although their theories may not be entirely in agreement with recent neuroscience, they provide a conceptual apparatus of the self which will allow for a schematic analysis of influence of neurotechnology on the self on a phenomenal level. The various aspects of self described by James, Kant and Hume will be explained in further detail in chapter 4, and discussed from a contemporary neurophysiological perspective.

In order to properly discuss the various views on consciousness and the self, first of all a brief general conceptualization of consciousness will be presented.

III.1 A Conceptualization of Consciousness

The debate that comes with different conceptualizations of consciousness, has for a long time focused on the mind-body problem. The mind-body problem concerns the relation between mind and matter, or in some cases more specifically the relationship between consciousness and the brain. It questions how materialistic entities such as molecules and atoms (for example light particles or hormones) can give rise to conscious, subjective experiences. The gap between the material on one hand, and the subjective experiences on the other, is sometimes referred to as 'the explanatory gap'. One of the solutions to the mind-body problem is that the explanatory gap results from 'qualia' (explained below). David Chalmers has developed an interesting theory concerning this explanatory gap that also aids in clarifying the difficulty with defining consciousness.

Qualia (singular: quale) is a term for the phenomenal aspects of mental life that are accessible via introspection. Introspection means the observation or examination of one's own mental and emotional states and processes. This is not merely 'looking within' and wondering at what one is experiencing at one specific time, but should be seen as a process, that can also be trained (Gertler, 2009). The topic of introspection will return in 3.2.2, "Kant and the Self". Qualia may encompass feelings and experiences such as the feeling of pain or the emotion of anger, or the specific sensation one experiences when seeing a certain color. It is often described as 'what it is like' to undergo a certain feeling or state. The 'hard problem' of consciousness is to find a materialistic explanation for these qualia to bridge the explanatory gap. This will be discussed in the following section.[9]

III.1.1 How to Approach the Explanatory Gap: A Solution to the Hard Problem of Consciousness

David Chalmers offers an interesting view on consciousness by suggesting a rather unique connection between mind and matter, but not taking an outspoken dualistic or materialistic point of view. His explanation will contribute to a general understanding of consciousness at the level that is required to understand further argumentation with regards to the self in this research. Chalmers considers identifying the problem of consciousness as one of the most fundamental problems in science of the mind. Even though it is still not quite clear whether or not consciousness is purely physical, thanks to large amounts of research, empirical investigations and scientific publications, it is evident that there is a link between chemical, biological processes and mental states and experiences.

Chalmers asserts that he confronts the problem of consciousness using a direct approach, providing what he calls a 'naturalistic' account of consciousness (Chalmers, 1995). First of all, he divides the problems regarding the concept of consciousness into 'easy' and 'hard' problems. Easy problems have to do with 'functions' and are susceptible to methods of cognitive science such as neural mechanisms. In this context, Chalmers suggests this part of consciousness should be called 'awareness'. The hard problem is experience. These include things like bodily sensations, mental images and the felt quality of emotion. This is similar to what other philosophers describe as qualia and introspection, explained above. The main question he addresses is the following; While it is widely agreed that experience rises from physical processing, why does it give rise to experience or a 'rich inner life' at all?

[9] As will become clear throughout this chapter, the explanation and conceptualization of consciousness and experience uses a more materialistic based starting point. However, it does not exclude that matter can give rise to immaterial states or experiences. Regardless, the plausibility of the conceptualization of consciousness proposed in this chapter does not depend on its materialistic approach. Both a materialistic and a property dualistic view are compatible with the theory of stream of consciousness and the theoretical framework that is built around it in the following chapters.

Functional Explanation

Chalmers argues that mental phenomena that belong to awareness are functionally definable, and only need the capacity for verbal report of internal information. Examples of such mental phenomena are the focus of attention, the deliberate control of behavior or the integration of information by a cognitive system. The hard problem of experience however, cannot be explained this way, because the argument above does not explain the link between the *physical* (such as the mechanisms in the case of the 'easy' problems) and *experience*. He argues that here, an 'extra ingredient' is missing. This can be many things, some of which have already been mentioned by other authors (such as functions involved in mathematical reasoning or new discoveries in neurophysiology). However, Chalmers claims these all fail to answer the question of why these processes that are described give rise to experience.

With the concept of this 'missing ingredient' in mind, Chalmers addresses his own theory, which takes experience as fundamental. This could mean the addition of something fundamental to our ontology by adding new (basic) principles to the basic laws of nature, in a sort of dualistic way that he calls naturalistic dualism. He then identifies the paucity of objective data as a problem for his theory, which he plans to solve through means of verbal reports and thought experiments.

In order to tackle the hard problem of consciousness, Chalmers suggests two non-basic principles and one basic principle. The two non-basic principles are the following:

- Principle of structural coherence
- Principle of organizational invariance

The basic principle:

- The double-aspect theory of information.

They will each be briefly explained below.

The Three Principles

1) Principle of structural coherence:

This principle entails that there is structural coherence between the structures of consciousness and awareness. Chalmers adds an extra definition to awareness that states that it is information that is directly available for global control. He argues that any information that is consciously experienced will be represented cognitively, and that awareness is the 'substrate' or 'neural correlate' of consciousness. He shows this with an example of the visual field. The example entails that the fine-grained structure of the visual field directly corresponds to the structure of visual processing. Even though this does not explain why experience exists in the first place, certain facts about structures found in processing, correspond to facts about the structure of experience.

2) Principle of organizational invariance

This principle claims that any two systems with the same functional organization will have qualitatively identical experiences. According to this principle, what matters for the emergence of experience is not the specific physical makeup of a system, but the abstract pattern of causal interaction between its components.

At this point, Chalmers uses a thought experiment to show that a system itself may undergo changes whilst not *noticing* these changes itself. He argues this is possible because physically, nothing *has* changed. The thought experiment proposes a physical system that gives rise to experience, consisting of neurons. Then, piece by piece, the neurons are replaced by silicon chips that function the same as the neurons, giving rise to the same experience. Chalmers claims that when this occurs, there is no room for a thought like 'something has changed.' If there *was* room for such a thought, it would be visible in the physical system, and it is not, because the system stays the same. Therefore, the specific physical make-up is not what matters, but the *abstract pattern of causal interaction between its components*.

3) Double-aspect theory of information

This basic principle involves the notion of information.[10] The double-aspect principle stems from the observation that there is a direct isomorphism between certain physically embodied information spaces and certain phenomenal (or experiential) information spaces. This means that we can find the same abstract information space embedded in physical processing and in conscious experience. In other words, a connection exists between information that exists

[10] For a definition of 'information', Chalmers uses the description by Shannon that can be found here: (Chalmers, 1995, p. 22).

in the mind, and information that exists in the world. This idea is used to support Global Workspace theory (4.1.2) and to explain environment-brain unity (4.2.2).

III.2 Theories of the Self: Unified Consciousness or a Bundle of Perceptions?

Now that the basics with regards to the discussion surrounding consciousness have been explained, we can turn to the concept of 'self', and the relation between consciousness and the self. This section discusses the self from the perspective of David Hume (1711 – 1776) and Immanuel Kant (1724 – 1804). Both have written influential literature on the subject of self, experience and consciousness. Hume differs from Kant in that he was an empiricist, which means he believed that all knowledge comes from experience. Kant was not an empiricist nor a rationalist, but rather aimed to combine the two. Even though Kant and Hume's perception of the self are partly contrasting, their ideas on the self and the unity of self will be helpful in conceiving how this self can be influenced by neurotechnology. In order to analyze via what ways it can be influenced, the concept of self must be broken down into the multiple aspects that it encompasses. By using views from both Kant and Hume to explain the relation between experiences and the self, it will also become clear how the two are related. This will aid in understanding the role of experiences in the theory of a stream of consciousness, which will be explained in section 3.3.

III.2.1 Hume and the Self

Hume took experiences as a starting point to approach the concept of self. The question he asked is by what impressions the concept of self is given to us. Hume argued that human beings have a natural habit of thinking of themselves as unities or stable entities. He acknowledged this natural tendency to ascribe a unified existence to all that is 'a collection of associated parts', but denied that there is any logical support for such an assumption. In Treatise of Human Nature, he called the self a bundle, "a bundle of different perceptions." (p.252) (Brook & Raymont, Winter 2014 Edition).

Hume argued that no matter how closely we look at our own experiences, nothing beyond feelings, sensations and impressions can be observed. According to him, that would make it impossible to ever see ourselves, or what it is that we in fact are, in a unified way. Instead, he suggested that the self is a bundle of perceptions. Whenever a person is 'insensible of him or herself', they can be said not to exist.

The Bundle Theory of Self

This would indicate that Hume assumed there is no 'self', and to a certain extent, he did. In his point of view, there is no fixed or unified self to tie all experiences and particular impressions together. We can be aware of what we are experiencing at a given time, but we can never be directly aware of ourselves. He wrote: "When I turn my reflection on myself, I never can perceive this self without some one or more perceptions; nor can I ever perceive any thing but the perceptions. It is the composition of these, therefore, which forms the self" (Hume, 1739, p. 322).

In order to understand Hume's point of view on perceptions and the self, it must first be explained that Hume divided all experiences, and therefore all ways of getting information, into two categories. Perceptions can either be an *impression* or an *idea*, and both are *derived* from experience (Hanna, 2001). According to Hume, impressions are anything that seems vivid, and could be described as though it was 'forced' upon the human mind. Examples of this are sensations, passions and feelings. In contrast, there are ideas, vague and feeble images that do not enter the mind through the senses. Instead, ideas are formed by our consciousness out of parts of impressions and ideas that were there before, i.e. memory. Furthermore, both impressions and ideas can be either simple or complex. A complex impression is a forceful, lively experience that consists of several different components. A complex idea is an idea about something that carries different properties, such as a furnished room. Complex ideas can be composed out of simple ideas, or under the influence of imagination.

Another way to describe these two ways in which information can be acquired, is to call them sensation and reflection. In this case, sensation is parallel to impressions and reflection to ideas. The first can be obtained through means of 'outward sentiment', the latter comes from 'inward sentiment'. According to Hume, both outward sentiment (sensation/impressions) and inward sentiment, coming from memory, together form all perceptions, and are therefore what Hume sees as the self (Hume, 1748).

The Principles of Association

Even though Hume denied real evidence of any unity or core that connects ideas, feelings and so on, he did seem to think there exist relations *between* them (Hume, 1748). He called these relations the principles of association. Hume explained this by pointing out how it can be observed in our own thinking that each thought is in some way connected with the one preceding it, a 'chain of ideas'. He claimed that there is a certain 'method' to the way in which they appear to memory or imagination. He showed this by pointing out that if the loosest of all conversations was to be transcribed, one could observe something that connected it through all transitions. So in each conversation, the simple ideas that are comprehended in the compound ones, are all bound together by a kind of universal principle. Hume found that among ideas, there are three kinds of principles of connection, or association. He did add that it cannot be proven that there are no other principles than these. The three principles he claims connect ideas, are: 'resemblance', 'contiguity' (in time or place) and 'cause or effect'. These are important concepts, because it shows how each thought or experience gives rise to the next thought, and so on, forming the stream of consciousness. Therefore these three principles of association are each briefly discussed below (Hume, 1748).

Resemblance: This occurs when something is much alike to something else, which can be a sound, an object or a person. For example when one sees a picture of something or someone, which leads one to think of the original object or person.

Contiguity: This concerns a different kind of connection, namely when two things lie close to each other, for example in time or place. The example Hume gives is that of an apartment in a building that leads one to think of the other apartments in that building.

Cause or Effect: When we cannot think of one thing without thinking of its likely consequence, such as a wound leading to thoughts of the pain that follows it.

As said above, these perceptions or ideas either enter the mind through outward sentiment (sensations/impressions) and inward sentiment (coming from memory). They are connected by the principles of association and so together make up the stream of consciousness. The role of memory in consciousness and the self will come back in chapter 4.1.

There is another aspect to the perceptions that form the self, which is shortly addressed by Hume. Because the self is formed only of multiple perceptions, and according to Hume death eliminates all of these perceptions, death would destroy the self in its entirety. To Hume, death was nothing but the extinction of particular perceptions (Hume, 1739). But this particularity that Hume described is what makes this collection of perception interesting. Even though he cannot not see them belonging to a unity that is called the self, these perceptions themselves do form the self. But the *way* in which these perceptions form the self, may be what makes the self a *unique* self.

III.2.2 Kant and the Self

A large part of what Kant argued carried out the idea that knowledge restrains itself to certain areas. Amongst these are mathematics, the science of the empirical, natural world, and knowledge about analytic statements (with regards to the relation between ideas). In his summation of what is knowledgeable, he excludes metaphysics. The reason for this, according to Kant, is that the mind itself participates in the constitution of features of experience. In this process, boundaries are created that limit the minds own access to the 'empirical realm of space and time'. The precise meaning of this will become clear in the following section.

Empirical Ego vs. Transcendental Ego

For Kant, both unity of experience and consciousness are integral to the self. This is different from Hume, who denied the existence of such a unity in his explanation of the self as a 'bundle'. Kant argued that apperception can cause all appearances to unite into one experience. He claimed that when a human being is conscious of him or herself as a subject, he or she is conscious of him or herself as the 'single common subject' of a number of representations (Brook, Fall 2013 Edition). Bennett has a similar view, in that he argues it is impossible for an undivided self not to exist, because then there would be nothing to think that 'it' is thinking. But if there is something wondering at its own possible plurality, then in fact there must be a unified something that is thinking this. He argues:

"To think of myself as a plurality of things is to think of *my* being conscious of this plurality, 'and that pre-requires an undivided *me*.' Unlike anything else, it is not optional that I think of myself as one subject across a variety of experiences" (Bennett, 1974, p. 83)

He agrees with Kant that there is something central, the 'me' or as Kant called it 'single common subject', that makes it impossible for a self to be utterly divided. Regardless of whether or not the self is unified, Kant furthermore argued that the concept 'consciousness of the self' comes in two kinds called the 'empirical ego' and the 'transcendental ego'. On one hand, there is consciousness of oneself and one's psychological states in inner sense. Kant considered this to be the active individual self, that is subject to introspection, which was introduced in chapter 3.1. With this self, there is an 'I' that is aware, and accompanies experience and consciousness.

It concerns the awareness of what one experiences, brought on when affected by thought (Brook, 2004). Kant called this the empirical ego, and argued that it is this self that makes the distinction between different persons. This occurs because the empirical ego provides each person with a definite character, through introspection and self-reflection.[11]

Besides the empirical ego, Kant claimed that there is consciousness of oneself and one's states through the performance of acts. This is called the transcendental unity of apperception, or the transcendental ego. Kant saw apperception as something that can present consciousness to one's self, so that it functions as a way to access this conscious state of mind. In other words, through acting, one becomes conscious of oneself as the single common subject. Nothing can be known of this self though, because it is considered a condition of knowledge, not of an object. It comes to consciousness when one acts, for example when one uses words to express oneself. The idea that consciousness can be presented to one's self through means of acts, will return in chapter 4 in my discussion on the ways in which self-understanding can be constituted and changed.

III.3 The Stream of Consciousness

To explain the role of consciousness in the constitution of the self and its various aspects in a more contemporary way of defining the self and unity of self, I will discuss the views of William James. His theory is spoken from a position that commits to the way I think the self will be influenced by neurotechnology. In addition, James' theory can be relatively easily related to aspects of contemporary neuroscience because it is based on an early idea of neuroplasticity.

James called the self the 'I', or 'the pure ego'. For him, this was similar to the mind or what others think of as the soul. This does not automatically mean that James believed there was one single unified conscious self. On the contrary, he merely believed this self provided the thread of continuity between the past, present and future of an individual. He argued that

[11] In this research, self-reflection will be regarded as the conscious thinking of one's own (past) experiences and behavior. Where introspection concerns the investigation into one's own thoughts or mental state, self-reflection includes reflection on the performance of acts and the conclusions that are drawn from these observations, and their meaning. Self-reflection plays are large role in the forming of the self-understanding, which will be presented and explained in chapter 4.

consciousness is not regarded as a set entity within our mind or a certain pre-given state that human beings can be 'in' or 'out'. Instead, consciousness should be seen as an ever changing process that is constantly transforming itself. This line of thought pictures consciousness as a flowing from moment-to-moment sequence of experience, under the influence of either internal or external stimuli. This concept will now be explained in more detail.

James claimed that the concept that he called consciousness contains 5 characteristics. They are as follows:

1. Every thought tends to be part of a personal consciousness
2. Within each personal consciousness thought is always changing
3. Within each personal consciousness thought is sensibly continuous
4. It always appears to deal with objects independent of itself
5. It is interested in some parts of these objects to the exclusion of others, and welcomes or rejects all the while, *choosing* from among them so to say

James, like Kant, made the assumption that every thought had to be had by something or someone. Only in contrast with Kant, James did not think there exists a 'unified conscious self'. He did believe that a consciousness had to belong to one person over time, but did not think it would have to be continuous. Time-gaps can occur, only after this happens the consciousness of one person still belongs to that same person after the time-gap, which is why he referred to consciousness as a *personal consciousness*. Within this personal consciousness, thought was, according to James, in constant change and *sensibly* continuous (James, 1890). He claimed that "no state once gone can recur and be identical with what it was before" (James, 1890, p. 230). With 'sensibly continuous' he meant to say that within each personal consciousness, thought *feels* continuous. Even when a time-gap in consciousness occurs, the personal consciousness after the time-gap will feel as if it belongs to the same self as the consciousness from before the time-gap.
The gaps that can be felt are gaps such as sleep, and can usually be connected to a duration through means of practice, produce an interruption in the time-sense of the word. But in the common whole sense that stands for the parts that are inwardly connected, consciousness is still *sensibly* continuous. The natural name he gave to the common whole sense of consciousness is 'me', 'myself', or 'I'.
When waking from a sleep, memories of previous conscious experiences come back, whether

these are recent experiences or not. With these memories, James argued, come qualities that he calls warmth and intimacy which are exclusive to one's own memories, and they do not come with when one has mere knowledge of for example what happened to somebody else before the state of sleep was commenced. This is an explanation of why a time-gap cannot interrupt what he calls personal consciousness, nor should it then be described as a sort of chain, for its parts are still interconnected in a continuum. Therefore he deemed that it flows, compared it to a river and called it a 'stream', the stream of consciousness. This theory shows consistency with contemporary neuroscientific discoveries on several occasions, which will become clear in the next chapter.

What is interesting as well is that James thought the introspective view to be superficial, since thoughts seem to be more interconnected than it would be assumed when evaluated objectively. To clarify this idea he uses the example of thunder. When the clap of thunder sounds we think that it is this mere clap that we hear, and that it is this that disturbs us, or suddenly breaks into our consciousness. But, as he argued, what we in fact hear is the thunder breaking upon existing silence, which is quite different from a thunder clap that was closely preceded by another. The difference is in the *feeling* of the thunder and the *feeling* of the silence as just gone, which means that the thoughts and perceptions preceding the sound of the thunderclap shape how the thunderclap is perceived in turn, weaving them together in a continuous flow of experiences.

In addition to this he emphasized that many (around that time) believed the brain to be an organ that is always in a state of change, and is never still at an equilibrium. It is constantly rearranging, and corresponding to this rearrangement is consciousness. Consciousness in turn is constantly changing and responding to itself in accordance, flowing from one thought or experience to the next. This early idea of neuroplasticity, along with its neuroscientific explanation from chapter 2, will be used to support the self that I will be investigating. In the following chapters it will be elaborated on and build upon by additional philosopical- and neuroscientist theories.

III.4 Conclusion

The aim of this chapter was to present the general definition of the concept that I wish to investigate, the version of the self that I deem in danger of being unnaturally influenced with several types of neurotechnologies. I have explained the self as an aspect of consciousness through the views of both Hume and Kant. Hume defined the self as a bundle of perceptions, making clear that consciousness does not necessarily consist of one unified entity. Kant did seem to believe there is a unified self, but more importantly, his view shows in which ways the self can be understood through his explanations of the empirical and transcendental ego.

Because consciousness plays a crucial role in the constitution of the self, it was important to understand its organization. I explained the concept of stream of consciousness of James, because this view will be helpful in understanding the role of consciousness in the self.

In the following chapter I will go deeper into the specific aspects of the self and consciousness and the way that they function, along with various other aspects of the organization of consciousness. I will also continue the discussion with regard to the unity of self in chapter 4.2.1 (self-perspectival organization), where I discuss the idea that there is one central point to a collection of perceptions, both from a philosophical and neurophysiological perspective. I will then support these views with neurophysiological explanations, in order to carry out the analysis of neurotechnological influences. James' theory of stream of consciousness will be used to explain the concept of dynamic flow. I will also return to Kant's explanation of the empirical and the transcendental ego, in the conceptualization of self-understanding.

CHAPTER IV

A NEUROPHYSIOLOGICAL EXPLANATION OF CONSCIOUSNESS, THE SELF, AND SELF-PERSPECTIVAL ORGANIZATION

In chapter 3 I have shown that the self is constituted by consciousness. In this chapter, I will elaborate on this by arguing that the self is not merely a bundle of experiences, it is the organization consciousness that determines how experiences are perceived through means of apperception. This organization exists out of several components. I will discuss these components separately; in particular those aspects that are important for understanding how neurotechnologies can affect specific aspects the self. These are the underlying prior organization, self-perspectival organization and self-perspectival point of organization. I will then review these aspects from the contemporary and empirically informed discussion regarding neurophysiological processes that are associated with the self in literature. I will also discuss resting-state activity, activity that is found when the brain appears ‘to do nothing’, and that is thought to be related to a sense of self. Self-specific organization concerns an increase in brain activity upon the subject being exposed to self-specific stimuli. This will be discussed in 4.2.2.

In chapter 4.3 I will address the question of whether or not BST’s and neurofeedback can also change the way subjects see themselves, by explaining the concept of self-understanding. Self-understanding is shaped by beliefs one has about oneself, based on self-knowledge. There are two ways of obtaining this self-knowledge. These are self-specifying processing and self-related processing. Self-specifying processing describes the process of reflection on ones acting as an agent, whereas self-related processing describes the process of evaluation of one's own thoughts or mental states.

IV.1 The Dynamic Organization of Consciousness

In the discussion of Hume's bundle of perceptions and principles of association, and Kant's unity of experience as the self, I have explained the idea that experiences do not simply find themselves unconnected and unstructured in consciousness. This also finds support in the more contemporary neurology-based discussion regarding the self. What is important in the constitution of the self are not the separate experiences that a subject has, but the dynamic organization of consciousness that underlies these experiences; the organization that determines how experiences are perceived by the subject, that I call underlying prior organization. I will also explain that consciousness can be viewed as a self-creating and organizationally closed system, a more recent theory by Varela and Maturana, supported by Baars' Global Workspace theory.

IV.1.1 Should Consciousness be Regarded as an Autopoietic System?

Information that enters the body via sensory perception, is perceived within a larger structure made up of 'what is already there'. This pre-existing structure of interconnected objects partly determines in what way external stimuli (information from the senses) are *received* and therefore perceived in this structure, which is also what determines the shape of the experience. This underlying pre-existing structure is what I will define as the underlying prior organization. Experiences entering via sensory perception, and the underlying prior organization, together form the dynamic structure of consciousness.

The view that experiences are not isolated entities and that consciousness can be described as a dynamic structure with a constantly changing organization is supported by Varela and Maturana. In this section I will discuss one of Varela and Maturana's earlier theories that the dynamic flow of consciousness is a *self-creating* and *self-organizing system* or an *autopoietic* system (Maturana & Varela, 1980) (Van Gulick, Spring 2014 Edition). This is important in investigating the constitution of the self, because it shows that the stream of consciousness is not merely a structured entity or flow that can only transform under the influence of external stimuli, but also reshapes itself continuously. This is partly determining for how neurotechnologies influence this dynamic structure, as will be shown in chapter 5.

The term autopoietic system was first used by two Chilean biologists; Humberto Maturana and Francisco Varela, to describe the self-providing and self-maintaining chemistry and structure of living cells. The idea behind this term describes how cellular autopoietic systems are bound by dynamic material that the system itself makes out of its own components. It emphasizes life's maintenance of its own identity and its ability to 'make more' of itself, and describes how living beings can maintain their own form by a continuous interchange and flow of chemical components (Margulis, 2016). In the same respect, consciousness can be viewed as an autopoietic system.

Varela and Maturana's idea of consciousness as a closed system does not mean that the system itself is closed, since exchange of matter and energy with its surroundings does take place. It merely maintains that the system is *organizationally* closed; the whole of it is not the sum of its parts but instead, as Varela argues, it is the organizational closure thereof (Varela & Goguen, 1977). The system cannot be separated from the interaction with outer domains, it functions as a whole, a dynamical system in which continuous *structural* changes occur but that has a stable and unchanging organization. This underlying unchanging organization is, according to Varela, what determines its identity.

IV.1.2 The Distribution of Information in the Brain: Global Workspace Theory

To be able to substantiate the concept of consciousness with another scientific explanation, one that perhaps shows the process on a more tangible level, I will turn to the Global Workspace Theory (Baars, 2003). Global Workspace Theory (GW theory) contains the same fundamental ideas as and is compatible with the concepts stream of consciousness and dynamic flow, but approaches them from a more biochemical angle. It suggests to view the brain as an immense parallel distributed system with a central information exchange that can enable specific parts of the brain such as sensory systems, to distribute information to the whole system (Baars, 2003).

This was also argued by Kanwisher (2001): "[…] it seems reasonable to hypothesize that awareness of a particular element of perceptual information must entail not just a strong enough neural representation of information, but also access to that information by most of the rest of the mind/brain" (Kanwisher, 2001). It is suggested that this system exists of specialized 'processors' that regulate information flow.

The concept of GW theory may be better understood if we return to the third principle of Chalmers, the double-aspect theory of information described in chapter 3.1. This principle stated that information is a natural candidate to play a role (beside other factors) in a fundamental theory that explains consciousness. Even though in this theory, the focus lies on the fact that the same information space can have physical and phenomenal properties, it supports the idea that the laws of physics can be cast in terms of information the same way Baars does. As explained, according to the double-aspect theory of information, there is a direct isomorphism between physically embodied information and phenomenal information spaces. In terms of Global Workspace theory, this would mean that information spaces in the brain that have physical properties, give rise to the corresponding mental conscious experiences to which, according to Baars, is a global access function. Scientific evidence suggests that such a global access function exists in human beings (and some other mammals), and it would seem that its primary agent is consciousness, which functions within the system as a gateway to the many capacities of the brain (Baars, 2003). This is not a surprising fact in itself, however, it does support that because consciousness functions as such a globally accessible network neurotechnological influence could have many diverse (and many unknown) downstream neuronal consequences. This will be elaborated in chapter 5.

The main claim of GW theory is that the brain can enable access between different brain areas and functions through a process called 'fleeting memory capacity', increasing the ability to exchange brain activity between these different functions. Conscious perception seems to enable these working memory functions, as opposed to unconscious sensory processing, which is probably much more limited. Baars argues that consciousness thus provides a gateway to many capacities of the brain. He states that "conscious perception, inner speech, and visual imagery enable working memory functions" (Baars, 2003, p. 1), and emphasizes that there is no evidence for unconscious access to working memory. GW theory includes the idea that the conscious state is a subjective state, emerging from the globally available information system that is the workspace, which can again be understood in terms of Chalmers' third principle of the double-aspect of information. Such a system is possible through cortical areas in the brain that work together to form a link between emotions and goals on one hand and actions on the other. These emotions and actions arise from stimuli from the visual cortex or midbrain amygdalae (needed to recognize facial expressions of fear and anger) to specific parts of the motor cortex, thus resulting in actions (Le Doux, 1996). This connection is essential in self-understanding, which will be discussed in the following section.

In support of Baars, Dehaene & Naccache (2001) also proposed a theoretical framework that contains the hypothesis of a global neuronal workspace. They postulated that this global availability of information throughout the workspace gives rise to the conscious state as subjectively experienced by individuals (Dehaene & Naccache, 2001).

Dehaene and Naccache also scientifically support the theory that conscious contents are distributed throughout the brain, by showing interesting results in brain research that was performed over the past years. Dehaene and colleagues showed that when words were presented of which the second half was covered, activity was found in the brain that was similar to that of the word recognition areas of the cortex (Dehaene S. , et al., 2001). This experiment has been performed over a dozen times with varying factors, all results compatible with a wider and higher level of brain activity during conscious input as opposed to unconscious input. These results point towards the mobility of a network that supports unconscious functions. At the same time, it describes a system that is dynamic in its form and in which the physical elements that bring forth the mental aspects of consciousness are widely distributed.

IV.2 The Dynamic Organization of Consciousness: A Neurophysiological Approach

In this section I will go deeper into self-perspectival organization. I will first explain the concept of self-perspectival organization itself from a philosophical perspective and its role as an aspect of the self. In chapter 4.2.2 I will go deeper into the underlying neurophysiological mechanisms that are associated with the self-perspectival organization and the self, based on empirical findings.

IV.2.1 Self-Perspectival Organization

An important aspect of consciousness as described in this research, is the idea that the organizational structure of consciousness contains a *perspectival* structure. I will include Northoff in explaining this idea, because his empirically informed theory with regards to the dynamic organization of consciousness will provide insight into the subject of self from a neurophysiological perspective. This perspective will then be elaborated on in section 4.1.5.

Northoff's description of consciousness shows many similarities to that of William James, except that Northoff's theory is up-to-date and more empirically informed. First of all he claims that consciousness has a certain dynamic structure by claiming its contents have to be put together, ordered, structured and ultimately, organized in a certain way (Northoff, 2014). This organization, he claims, is manifested on the phenomenal level, in this case the level of subjective experience, but has a neurophysiological foundation.

Northoff mentions how William James described the contents of consciousness as 'specious present' or 'dynamic flow', and takes this further by presupposing a flow of time that is continuous and extends from the past over the present, to the future. This flow of time is at the same time condensed in the present moment, the here and now. Consciousness contains the organization of time as a continuum rather than a discontinuum (Northoff, 2014). This corresponds with James' idea of the flow of consciousness as the flow of water in a river, a continuous temporal flow with gaps between different discrete points in time (and space).

As described in the previous section, the way in which objects in the world are experienced, shapes the self. But this 'way' of shaping which is so determining for the shape of the self, is not just one particular form or type that can be categorized. It exists out of several aspects. First of all, it offers a perspective of space and time to the self. This is because experiences of the world that are perceived are never completely unattached from all other things in the world, experience will always enter the mind in a framework that gives meaning to the perceiver related to time and space. This happens partly in the underlying prior organization, which is as explained before, built up out of several aspects such as memory and past experiences. The underlying organization takes part in determining how an experience is perceived, its particular perception. In addition to this, Kant argued that the underlying prior organization has a center that determines the way experiences will be perceived, and their place and time context. This center is called the *self-perspectival organization* of consciousness, and its structure determines the way the experience is perceived (Van Gulick, Spring 2014 Edition). This can be understood in the sense that some memories are 'closer' to the present mental state than others, which also emphasizes the role of Hume's principles of association for the shaping of the self. In the underlying prior organization, some memories are more recent than others, some past experiences have made a more intense (emotional) impression than others, and some memories show large resemblance to the present state of mind. One could imagine those memories and past experiences will be more prone to come forth and be connected to present thought and experiences than others. They are thus more likely to be associated in consciousness and have the role of forming a sort of 'frame of reference' for the perspective with which a present experience in perceived, hence a perspectival organization unique to each self.

Kant furthermore argue that the self-perspectival organization has an aspect that can be called meaning itself, since this aspect aids in shaping the way the world is experienced (thereby shaping the self). This can be understood as follows: Aside the frame of time and space that will tell the perceiver something about an object in the world, there is the information of content and intelligibility of the object that an experience will bring forth. An experience is always a part of a bigger whole, a unified system of an object in the world, the way it is perceived and the conscious subject that experiences it. Since the content and intelligibility of an object enter the stream of consciousness, the stream or dynamic structure *itself* is changed. The 'new' experience molds the existing dynamic organization that is made up out of memory and previous experiences, forming a new whole. This is the process defined as 'apperception'. Herbart (1776 – 1841), a post-Kantian philosopher and psychologist, described this as "the process by which new experience is assimilated to and transformed by the residuum of past experience of an individual to form a new whole" (Michel Hersen, 2004). In other words, the effect the perception itself has on the self-perspectival point of organization changes its organizational structure. Taking the effects of both these comprehensive and substantive aspects of an experience into account, it becomes clear that the self-perspectival organization of consciousness describes an interdependence between the self and the world. The self functions as a perspectival point from which objects are perceived in a specific way, which in turn defines the *nature* of the self.

Northoff claims this self-perspectival structure also has a core or center, a sort of gravitational point which he calls a *prephenomenal stance* (Northoff, 2014). He argues that this center of self-perspectival organization provides the point from which 'contents', or 'objects in the world' are experienced. From this supposed prephenomenal stance, the contents and ultimately the world are experienced in consciousness. Northoff goes as far as claiming that on a phenomenal level (in this case the level of subjective experience), this stance is not part of the self but *is equal to* the self. The next section will provide insight in those aspects of self that seem susceptible for influence with BST's and NF from a neuroscientific perspective. Northoff's empirically based reasons to explain these aspects will be addressed in the following section.

IV.2.2 Self-Specific Organization and Environment-Brain Unity

In this section I will go deeper into the neurophysiological processes that appear to have properties that can be related to the self based on empirical research, and discuss in what ways they are related to previously described aspects of consciousness. Georg Northoff proposes a hypothesis about the self-perspectival organization that he calls the "unity based hypothesis of self-perspectival organization" (Northoff, 2014). Northoff points out how scientists have found that when the brain is 'doing nothing at all', the network of neural activity seems to be most active in the cortical midline structure. He calls this the brain's resting state. The location in the brain is in this case not of importance in this research, what matters however is that Northoff claims this is the structure responsible for creating our own unique self. Since the functions of these particular areas were first described, they have been associated with and related to the self and consciousness. The set of these areas is called the 'default-mode network' in neuroscientific literature (Northoff, 2012).

In order to understand the resting-state activity in more detail, it must first be explained how Northoff sees what Chalmers called the explanatory gap (see chapter 3.1). Northoff describes the explanatory gap as the relationship between phenomenal features of the stream of consciousness and the specific neural mechanisms in the brain. He claims there is a step in between these two, that consists out of "transitive parts" (Northoff, 2015). According to Northoff these transitive parts are the temporal linkage or 'glue' between the various contents of stream of consciousness. There is a difference between these transitive parts and the "substantive" parts, which were also already described by James. These substantive parts account for the neural mechanisms that can be related to sensory, motor and cognitive functions. Instead of focusing on this so-called stimulus-induced and task-evoked activity of the brain, Northoff wants to emphasize the brain's intrinsic activity, which may account for the transitive parts, the linkage between the contents of consciousness. This intrinsic activity of the brain is what Northoff calls the resting-state's activity.

Northoff postulates that the self-perspectival organization partly comes forth from the way in which the resting-state's activity of the brain is organized, which is specific for the self of each individual. He argues that this is because the degree of statistically based correspondence between the resting-state and external stimuli, can predict the stimulus' degree of self-specificity. The higher the degree of temporal and spatial correspondence between an extrinsic stimulus and the intrinsic resting-state activity, the higher the degree of self-specificity. Therefore, the organization of the resting-state activity is called the resting-state's *self-specific organization*. Self-specific organization is based on the relatively strong correlation between self-specific stimuli (stimuli that are personally relevant) and high resting-state activity (in comparison with non-self-specific stimuli).

In other words, when a person has high affinity with a specific activity, hobby or job and they are shown pictures or objects that relate to these specific interests, a relative high amount of brain activity is shown in the area where resting-state activity is found as well. An example of this is when a concert pianist is shown a picture of a piano, or when someone is shown a picture of a family member.

This is why Northoff argues that "In short, resting state activity may be organised and structured in a self-specific way" (Northoff, 2012). Research has shown that the more highly the self-specific stimuli are according to subjects, the stronger the match with activity in those areas of the brain that researchers associate with resting-state activity. According to Northoff, this rise in activity also means association with consciousness, the self and spatiotemporal continuity. With this observation it is important to keep in mind that the degree of self-specificity that is observed does not only depend upon the stimulus, but also again on the structure and organization of the resting-state.

The other part that is involved in the formation of the self-perspectival point of organization, is the environment-brain unity. With this unity Northoff describes a rather complicated process that would explain an increased or decreased probability of consciousness. Environment-brain unity describes the unity between the natural and social circumstances of environmental stimuli on one hand, and the brain's intrinsic activity on the other (Northoff, 2014). Northoff describes this process as follows.

He proposes that the resting state's activity takes form in low-frequency oscillations. Oscillations are electronic signals that move in a 'pulse' or 'swing' movement. Northoff bases this assumption upon research that was performed by Nagai et al. (2004), He and Raichle (2009) and Khader et al. (2008), who discovered a direct relation between fMRI-based low-frequency fluctuations and the contingent negative variations (CNV) defined by He and Raichle as a function observed during orientation and attention. In other words, a direct relation was found between motions of particles in the brain, and attention and orientation of subjects. Northoff argues that the more low-frequency oscillations align themselves to the environmental (and bodily) occurrences of stimuli that are take place at (physical) time and space, the stronger is the environment-brain unity. This explanation is based on the statistically based matching between the temporal and spatial features of the stimuli themselves and the spatial and temporal neuronal measures (like low-frequency oscillation's phases, functional connectivity) of the resting-state activity. (Varela, Lachaux, Rodriguez, & Martinerie, 2001). According to Northoff, a high environment-brain unity then predisposes increased probability of consciousness. This can be clarified with the following example: Imagine a person in a room sitting in front of a door. In the first scenario, the person lets his mind wander and does not think about what he or she sees in front of him/her. In the second scenario the person focuses on the door and what it looks like. In this latter scenario, the extrinsic stimuli of the environment (light particles from the door) match what the person is think about (what the door looks like). The extrinsic stimuli match the intrinsic activity of the brain. In this case, the person is more conscious. In the first scenario, the stimuli from the environment do not correlate to the brain's intrinsic activity, because he/she is thinking about something other than the door. In this case, there is a low environment-brain unity, which then also means a decrease in the probability of consciousness (the person is not consciously thinking about what is in front of him/her, his/her mind is 'somewhere else'). It can now be concluded that together, the environment-brain unity and the self-specific organization play an important role in shaping the self-perspectival organization, by aiding in determining how experiences are perceived in consciousness through the processes explained above. The direct associations between external stimuli and self-specific neuronal processes support that the self can be influenced through the above mentioned aspects of consciousness, on a neurophysiological level. However, although Northoff is helpful in showing the parallel between extrinsic stimuli and intrinsic activity, it remains difficult to describe exactly what happens in the brain, because much of the underlying processes are still unknown.

IV.3 A Post-Reflective Self: Self-Understanding

Now that the specifics of the various relevant aspects of self, the underlying prior organization and self-perspectival organization have been discussed on both a philosophical and neurophysiological level, it will be possible to analyze how BST's and neurofeedback might influence them. Before I will do so in chapter 5, there is one more concept that needs explaining, in order to also be able to investigate in what ways subjects may believe themselves to be different selves after undergoing a neurotechnological application. Up until now I have been talking about the self in terms of a pre-reflective state. In this section I will discuss the understanding that is formed with regards to the self based on self-reflecting processes. Self-understanding is an important aspect of consciousness, because its post-reflective properties allow it to take part in the constitution of the self as well, besides the aspects of self that were described before in this research.

Self-understanding is in this research regarded as *the self that I believe myself to be*. The term "believe" is a very important term in this definition, as will become clear in chapter 4.3.2. Self-understanding can be shaped through self-related processing and self-specifying processing, as they are both processes through which features are attributed to the self.

Two important aspects in this attribution are 'beliefs' and 'expectations'. They will be explained using an article by Carol S. Dweck, because in this article the relation between beliefs and expectations on one hand, and actions and behavior on the other gives more insight in the concept of self-understanding and how it could possibly be influenced by neurotechnology (Dweck, 1999). In order to investigate how information with regards to the self can lead to beliefs about the self, it must be explained in what ways subjects obtain this information or *self-knowledge*. Therefore, in the following section the concept of self-knowledge will be briefly explained. This concerns the knowledge one thinks one has about oneself and one's own particular mental states. The factors that make up the *contents* of self-understanding and a biochemical explanation for the processes through which this occurs, will be discussed in section 4.2.3 and 4.2.4.

IV.3.1 How Do We Attribute Features to Our Selves? Self-Knowledge

Self-knowledge in philosophy is commonly referred to as the knowledge of one's own particular mental states. That includes their own beliefs, desires and sensations, but also things like capabilities and motivations. It is a necessary concept to self-understanding, because knowledge about one's own states is necessary for, and part of, the forming of thoughts and opinions about themselves. More concretely, it concerns the image individuals have of themselves when it comes to their idea of their self and the qualities they think they possess. This will be explained in more detail in chapter 4.3.2 and 4.3.3. The image that a person has of him or herself does not necessarily have to be exactly similar to their self, due to self-deception (explained in this section) and particular mental states that are not consciously reflected on, or remembered.

There are two strong claims concerning the epistemic status of self-knowledge, that will be explained to create a better understanding of what self-knowledge is and how it can be acquired. These two claims are infallibility and omniscience.[12]

The infallibility claim assumes that one cannot have a false belief concerning one's own mental states. The omniscience claim encompasses that being in a certain state is enough for a person to know that one is in that state. Both claims have been thoroughly criticized. An argument against infallibility is the possibility to trust more in the insight of another person than in one's own insight into one's psychology. Trusting another person with regards to this insight, one can believe another when they are told something about their own beliefs or desires. For example; If a person 'A' desires to go to college, they could be convinced by a person 'B' that they would actually rather want to start working right away. Person 'A' might believe person 'B' due to a lack of reflection on their own mental states and fail to know their own desire regarding this matter. This same example provides an argument against omniscience. If it is possible for person 'A' not to know their own desire, it is not true that having a certain mental state automatically means that one has knowledge of having this mental state. A more nuanced

[12] There are several contrasting views concerning self-knowledge, with regards to its epistemological status and ways and methods of acquiring it. There are different views on the distinctive features of self-knowledge, and different opinions concerning the validity of the methods used to acquire self-knowledge and form beliefs. It is not possible to discuss each of these views separately, because that would not fit the scope of this paper. There is also another definition of self-knowledge, which lies more in the area of a description of a 'persisting self'. This has more to do with its ontological nature and identity concerns. This type of self-knowledge will not be discussed in this research, because it would not contribute to the relation between self-knowledge and self-understanding.

and plausible definition of self-knowledge claims that one is generally aware of one's own mental states and has a natural tendency to avoid self-attributions that are false. This means that individuals have a built-in system that aids in attributing the 'right' knowledge to themselves. This would mean that self-attribution is also connected to an underlying part of the neurological mechanism in the brain, that 'tells' an individual what they desire, and other forms of self-knowledge.

Introspection and the Performance of Acts as ways of Self-Attribution

I will discuss two main ways in philosophy of acquiring knowledge of the self, related to Kant's empirical and transcendental ego, as discussed in chapter 3.2.2. These two ways are introspection (and in the same category but discussed separately; self-reflection) and the performance of acts. Acts are in this sense ways of expressing oneself, such as through speech. In this section, I will use Kant's description of the empirical and transcendental ego to interpret Christoff's explanations of self-related and self-specifying processing as ways of self-attribution in a similar fashion. Kant's perspective can shed a light on the processes of acquiring self-knowledge according to contemporary literature, in the sense that it will aid in explaining these processes on a phenomenal level.

As explained in section 3.2.2, Kant's notion of the empirical ego concerns consciousness of oneself and one's psychological states as the subject of introspection. With it comes an awareness of what one experiences. This notion shares similarities with the notion of self-related processing, in which features of oneself are attributed to the self, by inspecting them through introspection and then evaluating or judging these features. What Kant seemed to mean with acquiring knowledge concerning the intrinsic features of the mind (via introspection) can be explained through self-related processing, which, like in Kant's theory, encompasses the specification of oneself as an agent. However, the concept of self-related processing is empirically supported by research that has shown that a specific part (or parts) in the brain are responsible for the evaluation and/or judgment of character-related features in relation to one's existing perceptual image of oneself (Christoff, Cosmelli, Legrand, & Thompson, 2011).

In addition to the acquiring of self-knowledge through the process of introspection, there is the acquiring of knowledge of the self through means of acting or aspects of *agency*. This second aspect is based on *self-specifying processes*, concerning the specification of oneself as an agent, by implementing a distinction between 'functional self', and all that does not belong to this functional self ('non-self'). It means that an individual specifies the self by attributing actions, perception, cognition and emotions to either the self or the non-self (Christoff, Cosmelli, Legrand, & Thompson, 2011). In line with this, the agentialist view claims that one distinctive kind of self-knowledge, is the knowledge that a subject has of these 'active states of normative commitment'. Kant made a similar point in claiming that the transcendental ego is presented in consciousness of oneself and one's states through the performance of acts such as speech. Again, it seems there are parallel arguments between Kant's theory of the empirical and transcendental ego (in this case the latter) and recently discovered neuroscientific processes. However, Kant renunciates from the claim that something can be known about this self, as explained in chapter 3.2.2.

Christoff et al. furthermore argue that cognitive control and regulation of one's own emotions are also a self-specifying processes. They, like Northoff, emphasize that there is much evidence that the way in which a stimulus is processed by the brain depends crucially on how it is taken up into the brain's ongoing, intrinsic or 'spontaneous' activity. They furthermore claim that directed tasks that require attention give rise to the experience of being a cognitive-affective agent. The processes of emotion regulation and social cognition are assigned self-specifity by the individual. In other words, Christoff et al. regard emotion regulation and social cognition as qualities belonging to an individual. They argue that individuals therefore regard the actions that they perform within these qualities are therefore experienced as part of one's self (Northoff, 2012). Hence, self-understanding will be constituted in a specific way.[13] This is interesting because both cognitive control and regulation of one's own emotions are factors that can be purposefully influenced with neurotechnology. This will be elaborated on in chapter 5.

Beliefs: Revealed or Created?

Moran claims that the first-person privilege that introspection offers, is an opportunity to constitute oneself (Moran, 2001). This is because that privilege provides one with the ability to regulate one's own states. However, Moran claims that the idea that mental states are stable, unchanging entities that await discovery, is a naïve thought. Moran views mental states as being dynamically related to introspection. He argues that as soon as one becomes aware of a mental state, the state itself is exposed to scrutiny. Within the framework of dynamic flow that is

[13] For a more detailed explanation of the underlying neuronal mechanisms of self-specifying processes and self-related processes, read (Northoff, Unlocking the Brain: Volume 2: Consciousness, 2014).

consciousness, this means that awareness of a mental state influences the mental state, as both are part of the flow itself. Moran framed this thought as "self-consciousness has specific consequences for the object of consciousness" (Moran, 2001, p. 28). This means that a belief regarding a mental state is shaped by the awareness of the contents of this particular mental state. One is aware of the fact that one is aware of a certain belief, which makes one wonder whether or not the belief represents the truth, shaping the belief. So instead of the idea that self-knowledge consists of simple observation of one's thoughts, it recognizes human beings as agents that constitute themselves. The agents that they are pictures as, are relative to their own reflexive states, which means states that are open to change within the method of knowing one's own states.

Can We Always Believe What We Think We Know? Self-Deception

The theory of self-deception should also be briefly mentioned to emphasize that not all self-knowledge is simply true. It can also be the case that false beliefs are formed due to misinterpretations, lack of accurate self-reflection, or failure to recognize what guides one's reasoning, leading to *self-deception*. These false beliefs build themselves upon hopes and fears that can manifest themselves against reason or tangible proof that the opposite is true.

It must be kept in mind that this form of deception does not involve an attempt to deliberately make someone believe something that they themselves believe not to be true. It can be understood in the sense that there can be a deceiving part of the self that deceives another part, or that the self can have two contradictory beliefs. This can occur due to the fact that not all beliefs have to be in the conscious part of the self at the same time, which is also why one can convince oneself of something that goes against reason. Another line in philosophy denies the possibility of two beliefs in one self, and explains self-deception by claiming that the obvious conclusion with regards to a belief is simply avoided. Instead, the wanting to believe in the contrary makes one more prone to believe it, by giving the information that supports this contrary and false belief more weight or a higher value (Gertler, Summer 2015 Edition).

In any case, it should be clear that a belief is not always formed out of successful introspection and self-constitution. It can also be formed out of doubt and being deceived. In addition to knowledge and beliefs with regards to mental states, beliefs about one's own character traits can also be of influence on the self. These types of beliefs are called self-theories, and will be discussed as an important aspect of self-understanding in the following section.

IV.3.2 Self-Understanding: Beliefs and Expectations

In this section I will elaborate on self-knowledge and the way in which in gives rise to a self-understanding. In order to do so, I will go deeper into the role of the beliefs, expectations, hope, etc. that self-knowledge can contain. Dweck discusses how beliefs and expectations that a conscious subject holds about him- or herself are of influence on their selves, which can express in and bring about a change in functioning (Dweck, 1999). Dweck focuses on core beliefs or belief systems that can create certain *patterns of experience*. These beliefs are based upon self-knowledge as they are resulting from the knowledge obtained through self-related and self-specifying processing. According to Dweck, actions are affected as well, leading to the assumption that beliefs have the power to mold both experiences and actions. In this section I will explain how beliefs and expectations are connected to experience and how self-understanding is connected to dynamic flow. It must be taken into account that people's beliefs also include the beliefs they have regarding their own mental representations of the nature and workings of the self. This already partly explains in what ways self-understanding is of influence on the self. In addition to this it concerns beliefs about their world, including their relationships and environment. Dweck argues that therefore, these beliefs can shape people's goals and strivings and via this way also organize the reactions to their world. Through these reactions, patterns of experiences are created, and in turn patterns of actions.

Self-Theories: Malleable vs. Fixed

The type of beliefs described above that are about people's character traits and their environment, and that have the power to shape their goals, strivings and the reactions to their world, are called self-theories. According to Dweck, these self-theories can be divided in either a *fixed* or in a *malleable* self-theory. The importance of this division will be explained below. When an individual has a fixed self-theory, this means that they have the belief that most of their qualities are fixed character traits. They believe that these features are set and not susceptible to change through personal efforts. A malleable self-theory on the other hand, is the belief that most features in a person are changeable and can be developed through personal effort and education. People who believe they have malleable self-theories, believe that learning and facing challenges can lead to a change in features and character traits. Research has shown that people with a malleable self-theory and thus the belief that their character traits are changeable, are also more open to bringing about these changes (Dweck, 1999). This becomes evident in the fact they are more prone to confront their personal challenges, more open to learning and more capable of recovering after failures. They are also better at sticking with and finishing difficult tasks.

A self-theory and the beliefs it encompasses are part of self-understanding. As said, self-understanding can be understood as ‘the self that I believe myself to be’. This includes the character traits one believes one has, but as was shown in the paragraph above, it also includes aspects such as the malleability of these traits. If one believes one has malleable character traits, one believes one is capable of different things that someone who has a fixed self-theory.

In addition to this, the division between malleable and fixed self-theory shows how much of influence beliefs can be on ones capabilities. Dweck points out that for this reason, self-theories also play an important, causal role in self-regulation and resilience. As research also showed how the nature of one’s self-theory and thus their beliefs can be of influence on people’s real-world functioning, it becomes clear that beliefs can also change experience.

Another part of self-understanding that can be of influence on experience and the self is the concept of expectance. Dweck shows this through means of an experiment concerning expectations of rejection in first-year minority college students. An experimental intervention was designed by Walton and Cohen (2007) to increase the expectations of acceptance in African-American first-year students. Participants were informed of the fact that doubts about belonging in college occurred commonly at first but were never permanent and would subdue soon after the start of a new college year. They were informed through means of survey statics, an explanation of how perception of acceptance could change over time and through personal testimonies from upperclassmen. The control group went to similar activities but their contents were only about political beliefs. There were several results indicating and emphasizing the impact of expectations and the expected malleability of perceptions. Participants took more courses that were considered challenging. They also appeared to be more resilient with regards to motivation, and reached out to professors more often (sending three times as many emails as the control group). They also studied more hours and their grades increased after the intervention, in contrast with the control group, in which occurred a decrease in grading (Walton & Cohen, 2007).

The experiment above is just a small example of how expectations can influence and predict functioning of human beings with regards to education and interpersonal settings. Therefore, expectations and beliefs that lie at the core of motivational and self-regulatory processes are of influence on the functioning within these processes. But also the belief in the measure of malleability plays an important role. How one understands this in oneself can shape functioning in these processes and situations, at the same time shaping experience.

What must be pointed out in addition to this, is that experience, in turn, plays a key role in the shaping of self-theories and expectations. It may be clear that many of our past experiences can come back in the form of certain beliefs or mental representations. These past experiences are part of the self, for which reason the self is of influence on beliefs about oneself. Therefore, it is not only the case that self-understanding can influence the self, but also that parts of (the past experiences of) the self shape self-understanding. This is a two-way dynamic structure that forms the centre of the stream of consciousness. In the next section, I will use Glannon to show how beliefs can be of influence on the self by explaining some of the workings of the underlying biochemical processes.

IV.3.3 Self-Understanding: A Biochemical Explanation

In this section I will, as said, address the biochemical processes that amongst other things are believed to underlie beliefs and anticipation. It will show the influence that mental states such as beliefs can have, in this case on experience. In an article by Glannon, this is shown with experiments concerning pain, pain anticipation and pain relief. It will be explained so that it can be better understood how such a mental state like belief can influence processes in the body and therefore be of influence on experience and the self. The influence beliefs and anticipation can have is due to the biochemical changes in the brain as a consequence of a changes with regards to the content of these beliefs and anticipations. Part of how this works exactly shall be elaborated on in this section.

In Bioethics and the Brain (2007) Glannon addresses bioethical issues with regards to advances in psychiatry, neurology and neurosurgery. These questions concern for example electrical and magnetic stimulation of the brain to relieve symptoms of obsessive-compulsive disorder, but also things like drugs that help regenerate neuronal connections. Glannon also addresses the biochemical changes as a consequence of changes in belief and/or anticipation. He considers beliefs to be a function of expectation that stems from trust, and is linked to previous experiences. Research has shown that ‘positive’ beliefs and emotions emerge from the left prefrontal cortex, which is also where they are processed and regulated. (Glannon, 2007) In several cases it has been shown, that a patient’s belief was an agent in the occurrence of biochemical changes in the brain or body. This can be explained through means of the results of an experiment which concerned the relation between anticipation of pain and the experience of pain. The results showed that the intensity of pain in volunteers correlated with the information they had received about the experiment, and not with the intensity of the pain stimulus. When volunteers were expecting pain, an fMRI showed increased brain activity in the anterior cingulated region of the brain.

These results confirmed that a mental representation of the anticipation of a sensory event, could influence the neuronal processes that underlie the sensory experience that goes with this event. In addition to this it was shown that the expectation of a biochemical effect can result in an actual biochemical effect (Glannon, 2007). These results support the causal influence that mental states can have on biochemical processes in the brain. It explains how self-understanding can be of influence on the conceptual apparatus of self in this research, because it shows how beliefs one has about oneself can influence processes that lead to actions in the what Glannon calls the ‘actual world’, in turn leading to a change in how the world is experienced.

In chapter 1.4.1 I already mentioned the ‘danger’ of the placebo effect. This is also an example of how beliefs can inspire biochemical changes in the brain. What type of changes these beliefs and expectations bring about will be partly dependent on their contents. It then follows that minor variations in information that subjects receive about a neurotechnological procedure and the way this information is perceived in the subject will be of influence on what they believe on several levels, influencing biochemical processes in their brains. (Glannon, 2007)

IV.4 Conclusion

In this chapter I have explained that consciousness can be seen as an organizationally closed, self-creating dynamic system, and that this organization is responsible for the way in which experiences are perceived. I have also shown that the role of an important aspect of the self, self-perspectival organization, has one central point that takes up a large part in the organization of consciousness and plays an important role in determining how experiences are perceived. Furthermore, I discussed self-specific organization to point out that some areas in the brain can be associated with the self, because there is a relative high brain activity in these areas when subjects are shown objects or images that are relatively close to their personality (such as a piano to a concert pianist).

In chapter 4.3 I have explained the concept of self-understanding, a post-reflective aspect of consciousness. In order to investigate the influence of NF and BST's on self-understanding, have explained how self-related processing and self-specifying are processes allow individuals to gain self-knowledge, which leads to specific beliefs that in turn create and shape an image of the self they think they are.

In the following chapter I will analyze the results of the investigation in the previous chapters. I will draw conclusions with regards to the effects of neurofeedback and brain stimulation technologies on the self and self-understanding via influence on the different aspects of the consciousness that were discussed in this research. The conclusions will be drawn both from a philosophical/phenomenal level and from a neurophysiological perspective.

CHAPTER V

IN WHAT WAY MAY CHANGES IN ASPECTS OF DYNAMIC FLOW CONTRIBUTE TO A CHANGE IN SELF AND SELF-UNDERSTANDING UNDER THE INFLUENCE OF NEUROTECHNOLOGY?

In this chapter, the aim is to analyze the implications of neurotechnology on the different aspects of self that were covered in chapters 3 and 4, and to draw conclusion based on the literature that was studied. I will emphasize there is still much unknown about brain processes and thus it remains difficult to predict what the exact consequences for the self and in the brain on a neurophysiological level will be. I will argue that these uncertainties and gaps in knowledge are substantial, and use the precautionary principle to support that further research into the involved exact mechanisms of the brain prior to application of neurotechnological devices is necessary. Furthermore, in sections 5.2 and 5.3 I will present brief concluding overviews of possible effects of BST's and neurofeedback respectively, based on the conceptual apparatus of the self that was described in chapter 3.

V.1 To What Extent Can the Effects of Brain Stimulation Technologies and Neurofeedback be Predicted and Analyzed?

Up until now this research has mainly focused on the aspects of the self, consciousness and the way the function together as a self-organizing system. However, it has become clear that there are still some important questions in the area of neuroscientific research with regards to the details of dynamic organization on the neurophysiological level that remain unanswered. The other side to the progress that is seen in the areas of neuroscience, is what is *not* known about what happens precisely on a neurophysiological level, and what this means if experimenting with application of brain stimulation technologies is already taking place.

In the following section I will elaborate on this gap in scientific knowledge and emphasize that to prevent all possible unintended consequences of neurotechnology that were discussed in this chapter, thorough research of the each neurotechnological application is important.

V.1.1 A Gap in Scientific Knowledge: Underlying Neurophysiological Mechanisms

In the previous chapters, I have explained the concept of dynamic flow and the complex dynamics that it contains, which also shows precisely why it is so difficult to predict the particular consequences on a detailed level. In addition to this, even if particular consequences would arise and expressed for example via a change in behavior, they would be difficult to recognize as such because behavior is difficult to quantify or measure. Especially for specific neural pathways and neuroplasticity with its precise functioning, not all is known yet. Researchers speak of "considerable gaps in our knowledge" with regards to how modulation of the excitability of cortical areas near a TMS coil is achieved and maintained (Davis, 2014). Others make the more general claim that "given the newness of these methodologies, one caveat is that not much is known about the chronic effects of either magnetic or electrical brain stimulation" (Hamilton, Messing, & Chatterjee, 2011, p. 190). These articles emphasize that future studies may bring to light other (side) effects and risks than those known yet, and warn that these might be more serious than conventional methods of behavioral and cognitive manipulation.

In chapter 4 I have discussed Northoff's explanation of the self and self-perspectival organization of consciousness. Even though there seem to be plausible neurophysiological explanations for the phenomenal aspects of consciousness that correlate to these explanations, the details of the underlying processes and precise pathways remain unclear. It is the same for the philosophical descriptions of self and their relation to contemporary results in research that support the idea of resting state activity and self-specific organization. In chapter 4 we saw that Northoff proposes that the basic forms of consciousness and the self may be closely related to the intrinsic features of the resting state. However, he also emphasizes that the exact neuronal mechanisms of the interaction between such a resting-state and extrinsic stimuli remain unclear (Northoff, 2012). He explains how findings in his research suggest “some kind of, yet unclear, matching process” between neural activity associated with extrinsic stimuli and the resting state (Northoff, 2012, p. 358). This shows that there is perhaps enough scientific evidence to suggest the existence of neuronal activity in relation to phenomenal aspects of consciousness and the self, but it is at the same time clearly not detailed enough information to predict the exact outcome of neuronal stimulation for those neuronal processes and phenomenal aspects.

In addition to this, an article by Medeiros et al. reviewing the neurobiological effects of tDCS from 2012 states that “Although tDCS is a promising treatment approach for chronic pain as well as for neuropsychiatric diseases and other neurological disorders, several complex neurobiological mechanisms that are not well understood are involved in its effect” (Medeiros, et al., 2012, p. 1).

The same article presents findings showing that tDCS involves a cascade of events, at cellular as well as molecular levels, whilst the exact pathways that are involved in the *effects* of tDCS are not fully understood (Wagner, Valero-Cabre, & Pascual-Leone, 2007) (Utz, Dimova, Oppenländer, & Kerkhoff, 2010) (Stagg & Nitsche, 2011). Medeiros et al. emphasize that in order to support the clinical application of tDCS, more studies are necessary. Furthermore, they claim that application of an electric field with the right strength and duration can cause an increase in the electrical conductance of biological membranes, which is associated with increased permeability for ions and small and large molecules. This means that naturally occurring processes such as those described in chapter 1.1.1 (The brain’s own communication system) and 2.1 (Neuroplasticity) are influenced by tDCS. While this is not a new idea, these articles emphasize that while this occurs and technologies such as tDCS is deliberately used for particular brain stimulation purposes, full knowledge about the precise mechanisms of the processes is still lacking.

For the case of DBS as well, the same types of warnings can be found. Kringelbach, Green & Aziz point out that even though large numbers of patients with treatment-resistant disorders have been helped by DBS, “a full scientific understanding of the underlying mechanisms is still missing” (Kringelbach, Green, & Aziz, 2011, p. 25). Furthermore, there are several indications that BST’s that stimulate and enhance some cognitive functions and abilities, may be deleterious to others. Direct manipulation of one part of the brain could result in indirect inhibition or excitation of other parts. This is because different parts of the brain are connected and influence each other, as I have also shown by emphasizing the dynamic structure of its organization. As was discussed in chapter 2.2, and supported by GW theory, changes in some neural pathways can influence downstream neural elements (Hamilton, Messing, & Chatterjee, 2011). Here it is suggested as well that brain stimulation that increases the performance of a particular cognitive task, is often accompanied by a decrease of other cognitive tasks that are enabled by similar brain areas as the cognitive task that was increased. The impact of neurofeedback on brain function is still controversial and not well understood either, even while clinical applications are emerging (Ros, et al., 2015). This supports the necessity for more research in the area of neurofeedback as well as in the field of brain stimulation technologies.

V.1.2 The precautionary principle

Up to this point, this chapter has shown that there is still much uncertainty where the underlying mechanisms of neural processes are concerned, and therefore automatically the concepts that are related to such processes, such as the various aspects of dynamic flow described in this research. These concepts and their exact relation to the self and self-understanding as described in this research, should be understood in detail as well, preferably before neurotechnological techniques with the ability to change such concepts are applied to and used by the public.

Giordano also addressed this problem, which he called the mechanistic dilemma, by saying that “although science and technology provide important tools to understand and control the mechanisms of nature, any such knowledge is incomplete” (Giordano, 2012, p. 6). Giordano argues that despite this, there is a strong pull to act upon this partial knowledge and employ new techniques. He applies this notion to the field of neuroscience in particular. He describes how developments in neuroscience contribute to the evolution of neurotechnology, technologies and capabilities that in turn affect the nature of humanity. Giordano addresses the problem of acting upon incomplete knowledge especially in relation to authenticity, by emphasizing that the unnaturalness of neuroenhancement can affect authenticity in an individual and violate the ideal of being true to oneself.

This argument can be supported by the precautionary principle. The precautionary principle encompasses the idea that protective measures should be taken in case there is no absolute certainty or scientific consensus that something cannot cause any harm in any way. The World Health Organization (WHO) defines the precautionary principle as "the intuitively simple idea that decision-makers should act in advance of scientific certainty to protect the environment (and with it the well-being interests of future generations) from incurring harm" (Martuzzi & Tickner, 2004).

In de Sadeleer's book on implementing the precautionary principle, it is stated as a shift towards a preventive approach: "Precaution means that the absence of scientific certainty as to the existence or the extent of a risk should henceforth no longer delay the adoption of preventive measures to protect the environment" (de Sadeleer, 2007, p. 3), emphasizing that uncertainty is the keyword around which the precautionary principle is organized. The precautionary principle is often used in environmental issues and policies, but can also be applied to other areas and forms of technology that possibly pose a threat to the well-being of the public. In the case of neurotechnology, this would mean that more research in the area of brain stimulation, neurofeedback and neural mechanisms is necessary, and along with this all downstream neural consequences of stimulation or reduction of brain activity of any kind. Using brain stimulation techniques or neurofeedback to stimulate neural pathways and circuits while there are still such holes in neurophysiological knowledge poses a risk, especially when such fundamental issues as the self and self-understanding are at stake.

V.2 Possible Consequences of BST's That May Be Expected

Even though it is clear that not all of the consequences of neurotechnologies can be predicted in exact detail, that still leaves the question: With the knowledge that we do seem to have, what *can* we know about possible consequences, and what may we expect in this area? This is what I aim to answer in the following two sections of chapter 5. The first section discusses some possible consequences of BST's, and the second section aims to discuss some possible consequences of neurofeedback on the self and self-understanding.

As has become clear in the previous chapters, there are several factors that can induce or accelerate neuroplasticity and influence the dynamics of the stream of consciousness in various ways. In this chapter, my aim is to relate the changes in the processes of neuroplasticity and dynamic flow to possible changes in self and self-understanding, using the previous chapters as a framework for this analysis. The difference between the effects of brain stimulation technologies as compared to neurofeedback will become clear by discussing them separately. They will be approached from an individual as well as a societal angle. As mentioned, this section focuses on the effects of BST's.

V.2.1 What Possible Effects of BST's on the Self Can be Expected?

In this section I will discuss what possible effects of brain stimulation technologies on those aspects of the self that were distinguished in previous chapters we may expect. This in order to determine what happens on a neurophysiological as well as the phenomenal level when the self is indeed changed, according to the framework of dynamic flow. In this section, I will anticipate possible changes in the self as a consequence of changes in these aspects of the self.[14]

Throughout chapter 3 and 4, the self was shown to be build up out of several aspects. According to Northoff, the prephenomenal stance of self-perspectival organization gives rise to the self, the point from which 'content' or 'objects in the world' are experienced, and the point from which ultimately the world is experienced in consciousness. In addition to this, self-perspectival organization is brought forth by the relation between experiences in the world and activity in our brain (environment-brain unity) and how our resting-state activity is organized, as explained in chapter 4.2.2. The spatio-temporal trajectories in the brain that lead to and from the gravitational center of the self-perspectival organization, are responsible for how experiences are placed within space and time. When things are experienced, as explained before, these experiences are associated with previous experiences and memories from the underlying prior organization, and placed in space and time through the spatio-temporal trajectories. Via this mechanism, spatio-temporal trajectories take part in determining how the experience is perceived alongside the brain's resting state activity.

As explained in chapter 1, the usage of TMS, tDCS or DBS can interfere with basic neural functions, which can lead to modified aspects of behavior. Natural occurrence of nervous system changes due to neuroplasticity (as explained in chapter 2.1, Neuroplasticity) can happen at any moment in daily life, under the influence of various factors such as experience, stress or genetic factors. However, when induced via BST's, the occurring nervous system changes are no longer of natural origin. This does not only mean that neural processes are now steered by

[14] It should be noted that when I talk about "changes", I mean unnatural changes (explained in chapter 2) that occur in the organization of self-perspectival organization as a consequence of the application of neurotechnologies, and not the changes that occur due to extrinsic stimuli that change the neurophysiological structure of the brain due to neuroplasticity.

unnatural as opposed to natural stimuli, but also that other types of neural processes or pathways may be possible. This concerns processes that would not occur naturally, or perhaps they would but at a slower pace. It may even be the case that the process of neuroplasticity *itself* is changed. Medeiros et al. already speak of "tDCS-induced neuroplasticity" (Medeiros, et al., 2012). For this reason as well, it is important that the neurobiological mechanisms involved are known first, to be able to predict effects more accurately. In chapter 5.1 it became clear as well that it is still difficult to determine which basic neural functions are affected precisely. However, if it is the case that modified aspects of behavior are the consequence of technologically induced changes in basic neural functions, it will also be difficult to determine the level at which these technologically induced changes take place. Still, Varela and Maturana argued that consciousness is an autopoietic and organizationally closed system that determines an individual's identity. From this viewpoint it can be argued that if the process of neuroplasticity could be influenced with neurotechnological applications, we are indeed in danger of changing or losing our identity.

Now let's take a look at the changes that might occur on a phenomenal level. As Dweck argued, self-theories also contribute to shaping and organizing the reactions to the world of their owner. Through these reactions, patterns of experience are created. An example of this is the self-theory that someone believes they have good memory for learning texts. This belief creates a perspective in the owner of the self-theory. When this individual learns a text, and they believe to be good at it, this can for example reduce their level of stress, or take away the doubt they may have felt otherwise. Because the individual in this case has the self-theory of being good at learning texts they are more likely to be so, as was also argued by Dweck (Dweck, 1999). The experience of learning the text, in this example representing the 'reaction to the world', is shaped under influence of the self-theory. Such patterns of experiences are taken up in the dynamic flow by becoming a part of the underlying prior organization as a 'past experience'. This example shows how reactions shaped by self-theories can indirectly aid in shaping the underlying prior organization. If we now return to the fact that self-theories might be changed with BST's, it becomes clear how the underlying prior organization will change from such an intervention as a consequence. The underlying prior organization is also one of the aspects of self that play a role in its constitution, as I have shown in chapter 4. I described that Northoff sees self-perspectival organization as the organization of experiences that are structured around a 'core' or center. The way in which future experiences will be apperceived is dependent on the self-changing structure of the underlying prior organization, the spatio-temporal trajectories and the resting state's self-specific organization. As I argued in chapter 4.3.2, Northoff as well as Christoff et al. stress that there is much evidence that the way in which a stimulus is processed by the neural pathways depends largely on how it is taken up into the resting-state activity. Even if it is not clear how exactly memories and past experiences shape present experiences and reactions, this analyses gives an idea of a way in which this aspect of the self could be affected. If this is the case, future experiences in an individual will also be affected, because the underlying prior organization has been changed. The perspective with which new experiences will enter the organization is no longer 'neutral'. New experiences may not be taken up into the dynamic flow as they would have if stimulation of the brain had never taken place. In turn, these experiences will still affect the underlying prior organization as they become a memory to the individual. The effects of brain stimulation may therefore interfuse deeply into the dynamic flow over time.

One case of such an occurrence has been described in an article by Maslen, Pugh and Savulescu, which studies the ethics of DBS for the treatment of Anorexia Nervosa (Maslen, Pugh, & Savulescu, 2015). A central issue in this article is the issue of authenticity. In the article, it is suggested that the changes that are brought about through means of deep brain stimulation, can alienate the subject from him or herself, as they call it in this case their true or 'authentic' self. The article refers to two 'mindsets', and questions whether one of these should considered as the 'authentic' self, or if both mindsets contain elements of this authentic self, showing the difficulty of determining the self on a phenomenal level after brain stimulation. Maslen, Pugh and Savulescu explain how it may be questioned whether a subject can make authentic decisions with regards to their own treatment, after the evaluated judgments of this subject have been affected by the treatment. This case shows what I aimed to explain by claiming that the perspective with which experiences are taken up into the dynamic flow is no longer 'neutral'. The entire perspective of an individual, or in this case 'mindset', may have become undermined.

V.2.2 What Possible Effects of BST's on Self-Understanding Can be Expected?

In this section I will analyze the effects that brain stimulation technologies might have on self-understanding, by first focussing on BST's possibly affecting self-related and self-specifying processing. Self-specifying processing encompasses the forming of a self by acting as an agent, and self-related processing concerns the attribution of features to the self through introspection and self-reflection.

As explained, self-understanding concerns the self that I believe myself to be. So, it concerns beliefs that one holds that apply to oneself, self-theories. These self-theories are held with regards to what an individual thinks he or she is. These beliefs include those that refer to their relationship with other people and beliefs towards their environment, and are based upon introspection, self-reflection and the awareness of (changed) behavior. These reflective processes were described by Christoff as self-related processing (introspection and self-reflection) and self-specifying processing (specifying oneself as an agent by reflecting on behavior) (Christoff, Cosmelli, Legrand, & Thompson, 2011).

Now let’s take a look at the concept of self-related processing. Self-related processing occurs through the processing in the brain that is necessary for evaluation and judgment of features of the self. This occurs in relation to the perceptual image that one has of oneself at that moment. Through this process of evaluation and judgment of the self, mental attribution of features to this self occurs. There are indications in research that cognitive control during emotion regulation can be enhanced or suppressed with tDCS (Feeser, Prehn, Kazzer, Mungee, & Bajbouj, 2014). The ability to control one’s own emotions is an example of a self-theory that influences the understanding an individual has of him or herself. It is a quality that is vital for mental health, and when reflected upon, can change one’s opinion of oneself. Another example of this is that evidence suggests that TMS and tDCS can alter an individual’s understanding of and relationship to others (Hamilton, Messing, & Chatterjee, 2011). The ways in which this happens can be traced back to the neural basis of ethical and moral thought and behavior, also influencing their abilities of judgment.

Furthermore, in chapter 4.3.2 it was argued that an individual specifies him- or herself by the attribution of actions, perceptions, cognition and emotions to the self (self-specifying processing). This would mean that the acts that are performed arise as a consequence of modified behavior under the influence of unnaturally changed basic neural functions, are also attributed to the self. One specifies oneself as an agent based on these particular actions as well, and becomes conscious of the self through the performance of these acts, that may otherwise not have been attributed to the self. So, self-specifying processes occurs based on unnaturally modified behavior and actions, due to basic neural functions that were changed under the influence of brain stimulation. Via this process, self-understanding may ultimately be shaped by the influence of BST's because unnaturally modified actions and behaviors are also attributed to the self. This is how they can start to see themselves as a different person. The other side of this is that subjects possibly consciously renounce this behavior, as they recognize it as uncharacteristic behavior and ascribe it to the influence of brain stimulation entirely. In this case, the issue of accountability and responsibility may arise, because what actions do and do not 'belong' to a person, becomes questionable. In their article, Maslen, Pugh and Savulescu already pointed out that the various ways in which DBS is likely to affect AN patients' experience of themselves, and their ability to be self-governing (Maslen, Pugh, & Savulescu, 2015). They recommend to keep these effects in mind in research and clinical developments with regards to treatment with DBS.

In addition to this, there is the issue of the difference between malleable and fixed self-theories. As explained in chapter 4.3.3, a fixed self-theory is the thought that a quality is a fixed character trait and can hardly change. Malleable self-theories are beliefs about character qualities in a person that can be adjusted and changed through means of hard work and personal effort. Brain stimulation technologies might also lead a subject to think they would not have been able to alter the particular character trait they mean to change *only* through personal effort, or that personal effort would at least not have been so effective by far in a short amount of time. Brain stimulation could in this sense, even if it functions as it should, pose a threat to the subject. When viewed like this, brain stimulation improved abilities could inspire the belief that the quality was a more fixed quality, because it has proven difficult to improve through training, but was effortlessly changed with brain stimulation.

This could concern for example an individual with the quality of aggression. Let's say an individual has dealt with being aggressive his whole life. He may have tried anger management training and several other therapies, which may have helped in some ways, but did not eliminate the quality of aggression to this individual's satisfaction. There are still many moments in this person feels he would want to have responded less aggressive. Now let's imagine after trying to reduce aggression via all kinds of other ways, he has received brain stimulation. After a relatively short period of time, anger responses are lessened and aggressive outbursts are significantly reduced. He does no longer have the feeling they need to change this quality about themselves. After years of struggling and personal effort with little success, the technology has relieved him of this pressing matter in an instant. This change may lead to the question what this can mean for other qualities that this individual has, and whether aggression would have been an issue for the rest of his life if brain stimulation had not been an option. This may then lead to the question of whether other qualities are also *only* adjustable through technological intervention. This is an example of how BST could raise the belief that *without* brain stimulation, qualities and character traits cannot be changed, or perhaps at least very difficultly.

As the research by Dweck showed, people that were told to be less capable of changing character traits or abilities through effort, were less resilient with regards to motivation, studied less hours and showed a decrease in grading as compared to the participants that were told the opposite. So in the case of brain stimulation, fixed self-theories might suppress the belief that the subject is capable of changing decision-making him or herself, thereby possibly demotivating the idea to change other abilities through means of personal effort as well. At the same time this can also happen the other way around. Subjects may believe that they are *more* capable of changing, due to the fact that the quality that they considered fixed, was changed with brain stimulation. This could lead a subject to believe that their qualities are more malleable than was initially thought. Either way, both cases emphasize the need for qualitative research in this area, and show to what level BST's might influence the understanding one has of oneself.

V.2.3 What Possible Effects of BST's Can We Expect on a Societal Level?

In this section I will briefly outline some of the possible consequences of brain stimulation technologies on a societal level, as compared to the scenario in which the public is not aware of its existence. Included in this analysis is the way brain stimulation technologies influences the public without it actually being used by this public. Answering these kinds of questions are useful in order to gain insight in the effect on people who did not make the choice to employ a neurotechnology, in order to find out what its mere presence means.

As it was shown in chapter 4.3.3, beliefs and expectations can have an effect on the self and self-understanding. In case of societal effects of BST's it concerns changes in beliefs about the procedure, and expectations with regards to what the effects will be. An important factor in changes in beliefs and expectations, is the way in which the public first receives information with regards to the existence and/or presence of brain stimulation technologies. This depends on the medium and the interests, intentions and goals of the party providing the information. For example, it can be promoted commercially by independent clinics, or on a professionally advisory basis by a psychologist. The information includes a variety of promises that in turn shape expectations. Even between these two sources there is already a big difference in how it would be perceived in a non-user. Additional examples of sources are the media or social media. In section 1.3.2 ‘media hype’ it already became clear that such a way of providing information can have various effects on what people believe. People form assumptions and based on this ideas and expectations with regards to the technology and what they think it could and will do. This also concerns information with regards to the procedure and the results, which can be of influence on how they experience the procedure and whether or not they are content and positive towards the outcome. These experiences could then shape changes in expectations with regards to one’s own behavior.

Another aspect of BST’s is that by offering the technology for example as a treatment of a psychiatric disease, already exerts pressure. By not accepting the offer, patients may become more critical towards their own behavior and mental states, because they ‘could have’ let themselves be treated and so there was a chance not to have these particular behavioristics and mental states anymore. At the same time, pressure of treatment with brain stimulation can push patients to make a decision to employ it, while had there been no choice at all, they would not have wished for such a treatment to be possible.

Finally, there is the issue of equality discussed in chapter 1.2., which becomes relevant when a technology such as a tDCS becomes available for particular target groups, or the public as a whole. In cases of medical treatment, if equally distributed amongst those in need of a particular treatment, it could be that it does not pose a threat to equality. On the other hand, with so many applications and the possibility of enhancement, BST’s may breach gaps between rich and poor or other layers in society, or deepen already existing gaps.

V.3 Possible Consequences of NF That May Be Expected

Just as I have done above for BST’s, I will now discuss what *can* be known with regards to the effects of neurofeedback in light of all of the above. Again, the difference between the effects of brain stimulation technologies as compared to neurofeedback will become clear by discussing the effects of neurofeedback below. In the concluding summary, all possible effects that could be extracted will be recited briefly once more.

V.3.1 What Possible Effects of NF on the Self Can be Expected?

In chapter 2.3, I have illustrated the differences between brain stimulation technologies and neurofeedback that are most relevant for this research. Now we will continue on to look at possible influences of neurofeedback on the described aspects of the self and self-understanding, as opposed to BST's.

There are some differences between BST's and neurofeedback when it comes to an unnaturally changed self. This is because as opposed to brain stimulation technologies, NF is a self-regulation method. This means that it 'teaches' or trains the brain to modulate the excitatory and inhibitory patterns of specific neural pathways at a neuronal level, as discussed in chapter 2.1 on neuroplasticity. The self-regulatory system is based upon the sensor placement and feedback, which make that NF increases both flexibility and self-regulation of the patterns that give rise to an 'activated' or 'relaxed' state of mind (ISNR International Society for Neurofeedback & Research, 2015). This means that NF 'teaches' or trains the brain to modulate the excitatory and inhibitory patterns of specific neural pathways at a neuronal level. By stimulating the processes that actually determine the way in which stimuli are processed, the brain's perspectival point itself may be changed, because neurofeedback influences the process of neuroplasticity itself. However, as pointed out in chapter 5.1, how these underlying processes are functioning is unknown most of the time, which is why it is difficult to say in *what way* training such brain processes results in a change in the process of neuroplasticity.

In the same way, modulation of the excitatory and inhibitory patterns of certain specific neural pathways could possibly influence the underlying neurological mechanisms that place experiences in space and time, the spatio-temporal trajectories. Ultimately, these changed would influence how external stimuli are taken upon into the underlying prior organization. As was shown in chapter 1, the resting-state's activity's prephenomenal stance is part of this underlying organization. Therefore, changes in spatio-temporal trajectories could influence what Northoff calls 'the self' of a subject. It should be kept in mind at this point that this still concerns unnatural changes, that would not be possible without neurofeedback. (The EEG that is used in this method to measure brain activity in particular, because this is what allows the practitioner to 'steer' the training of the brain).

One of the consequences on a more phenomenal level may be discovered by returning to Moran's claim that the awareness of a mental state influences this same mental state, thereby corrupting the original one; as was explained in chapter 4.3.1. An example of this is when somebody is feeling rather down. Their intuition tells them to stay home, sit on the couch and perhaps be distracted by a movie. Upon doing so, they observe their own behavior, contrast it to their behavior on other days (going out, enjoying the sun) and become aware of a slightly depressed mental state. The awareness creates a shift in perspective. It makes them ask themselves *why* they are feeling the way they are feeling. The mental state is placed in contrast to other mental states, on other days, perhaps under different circumstances. It is observed from a reflective point of view, leading to different conclusions with regards to it. The individual sitting on the couch for example remembers how he slept pretty awfully for the past two nights, and realizes that this may cause the blue feeling. It does not necessarily mean that the origin of the feeling disappears, but a change in perspective can change the mental state in general.

As awareness of a mental state is a prominent factor in neurofeedback, the influence on mental states and particular thoughts may go beyond the adjustment of brain wave patterns. Moran also pointed out that the first-person privilege that introspection offers – during which mental states are exposed to scrutiny- aids in constitution of the self (Moran, 2001). So according to Moran's theory, neurofeedback training might in this sense influence mental states directly, thereby influencing the self.

In a final remark on the subject of neurofeedback and the self, I would like to point out a comparison with BST's. Up until today, results after stimulation via TMS, tDCS or DBS are reversible or temporary, and decrease after a while, depending on the duration and intensity of the stimulation. In the case of neurofeedback, the brain is trained to train itself, so to say. So after a varying amount of sessions, the brain will 'take over' the procedure and continue the adjusted patterns. On a Dutch website that offers neurofeedback training, it reads: "After an intensive period of treatment with neurofeedback, the subject will be able to produce the right brain waves, and these changes can become permanent (compare this to learning how to ride your bike, once you are able to do this you never forget)"[15] (Neurofeedback Instituut Nederland, 2014). This means that in the case that the self is indeed changed in any way, these changes can become permanent as opposed to brain stimulation technologies. However, it may be possible to make the effects of brain stimulation technologies permanent as well in the future.

[15] Freely translated.

V.3.2 What Possible Effects of NF on the Self Can be Expected?

Self-understanding was defined as the self that I believe myself to be, but also concerns the thoughts one has with regards to what one is and the nature of their self. I will start with self-related processing and discuss self-specifying processing, the acting as an agent, after that. Since self-related processing concerns the attribution of mental features to oneself, it may already be taking place during the neurofeedback training. In addition to this, due to the immediate feedback of the subject’s particular brain wave pattern, an immediate response can arise in the shape of a change in thought regarding one’s own abilities. This would mean a direct change in a self-related process.

It is different for self-specifying processing, because this occurs through the performance of actions. It is not required for a subject to act during the procedure, unless to execute the orders from the practitioner. There are no reactions to social situations tested during the neurofeedback training, all noticed behavioral changes in environmental situations occur after training when a subject has returned to his or her regular daily life settings. Therefore, it is not likely that self-specifying processing is influenced and changed by the neurofeedback training, during the time of the training. However, when a subject returns to their regular environment, the changes in acting as an agent may give rise to a change in self-understanding. This can occur for example in a subject’s reactions during social interaction. For example, in children with ADHD, there might be a change in behavior in groups or a different way of handling feelings of anger. Changes in such behavioristics can be classified as a change in self-specifying processing, meaning that these subjects will express themselves as an agent based on trained neural capacities (see chapter 2.2).

Self-related processing could take place after the procedure as well, in addition to its occurrence during the procedure. Subjects use introspection and self-reflection to evaluate their own thoughts and mental states. If a neurofeedback session has been successful, a change in mental states will necessarily have occurred, because the brain was trained to produce a certain type of brain waves. Even if this type of brain waves is only related to a general feeling such as ‘calm’, this general mental state will still affect other feelings that a subject is having at that moment, because everything at that moment will be experienced ‘from a calmer state of mind’. For example, if a subject was supposed to respond less direct to a social situation and has therefore been trained to remain more calm at those moments, they might also feel more patient, or feel more relaxed and positive towards receiving certain comments. Self-related processing will bring a subject to reflect on these feelings, upon which the subject will conclude a change in feelings has occurred, experiencing themselves differently. Again, the point here is that these changes in mental states occur naturally on a daily basis, as consciousness is a self-changing process. When this happens, self-related processing occurs with regards to these naturally occurring mental states and shifts in mental states, to produce natural reflections on the self. However, since the evaluated changes in mental states brought about with neurofeedback training are possible at an unnatural speed as opposed to naturally induced neurophysiological changes, self-related processing that focusses on these changes might be leading a subject to draw different conclusions. At the same time, a subject may still ascribe the noticed changes to the neurofeedback training, as they are aware that they were exposed to this. Although in that case it may then lead to a relatively small change in self-understanding (because they do not believe it was their 'self' that changed), it may still lead to the problem of fixed versus malleable self-theories, described in chapter 5.2.2.

V.3.3 What Possible Effects of NF Can We Expect on a Societal Level?

Societal issues that arise in relation to neurofeedback differs from those in relation to BST's, because of the different methods via which the brain is influenced. In this section I aim to discuss two possible complications with NF on a societal level, the first of which is the idea that subjects feel more and more as if their brain is an autonomous system. In chapter 4.1.1, I already described how over thirty years ago, Varela already suggested that consciousness could be seen an autonomous system. This idea now seems to be applied to the brain, reinforced and intensified by the fact that it is not only regarded as autonomous but also treated and addressed as such, and in addition to this, externally influenced and controlled. General conceptions of what the brain is *and* does, and what it originates, could be pressured or changed by the idea of the brain as an autonomous system. The second issue that arises is that NF uses operant conditioning mechanisms that are comparable to those in forms of addiction.

The Brain; an Autonomous System?

Besides and because of a change in self-theories, there is another way in which neurofeedback can change self-understanding. I have touched upon this in the beginning of this chapter, namely what the mere knowledge of existence of such a technology brings about. This concerns the effects on each individual in a society where neurofeedback exists and is applied, even if these individuals are not treated with neurofeedback themselves.

In chapter 2.4 where I compared neurotechnologies to drug use, I already briefly mentioned the consequence that subjects may change their perspective with regards to their own brain. With this, I mean that they believe their consciousness to have its origin in the brain, while at the same time viewing their brain more and more as an autonomous system that can be externally altered and controlled. This was introduced by saying that subjects that undergo a neurofeedback training are told that their brain is functioning a certain way, while at the same time they are attempting to use their brain to come to a certain mental state, and thus influence this functioning. In this section I will provide some additional examples of how the existence of neurofeedback in society itself can cause individuals to understand themselves more as something ‘mechanical’ due to their belief that the brain is something autonomous. It should be mentioned that this effect could also occur after brain stimulation, but it is more relevant in the case of NF because of the aspect of effort that is missing with brain stimulation (see chapter 2.3). The importance of this difference will become clear in the following section.

It starts with the noticing of changed behavior and a possibly changed self, as described in the sections above. What makes this consequence different is that it includes the subject having conscious knowledge of the fact that he or she, and character traits that the subject regards as authentic, are changed by a technology. This realization can in turn change how a subject sees him or herself and what they consider as their nature. There is also the fact that subjects become more conscious of the direct relation between their thoughts, their brain and technology. This does not happen the same way it does with BST’s, because in that case there is not a real-time relation for the subject that requires effort.

However, with BST’s there is a clearer causal relationship between technology and a change in mental state/behavior, because the results are more direct and quantifiable. For example, subjects stimulated with tDCS to enhance a cognitive function that took a test measuring that function showed improved scores immediately after stimulation (Fregni, et al., 2005). With neurofeedback the results do not become so directly apparent, because they are often not clear until the subject finds him or herself in situations to which the adjusted type brain waves apply. However, in both cases subjects reflect on changes made by technology to their own brain and their self.

To clarify this argument are some examples of the texts on websites that provide information on EEG and neurofeedback. On these websites, it reads things like “unlock your brain’s potential” (EEG Info, 2016) and “neurofeedback is essentially a form of exercise for the brain” (Center for the Advancement of Human Potential & Institute for Applied Neuroscience, 2014). A website related to a foundation for research and exploration in the area of neurofeedback states the following:

“Neurofeedback is direct training of brain function, by which the brain learns to function more efficiently. We observe the brain in action from moment to moment. We show that information back to the person. And we reward the brain for changing its own activity to more appropriate patterns” (EEG Info, 2016). Written like this, it sounds almost as if the brain itself was a separate object or even a person. On how it works it reads: “We show the ebb and flow of this activity back to the person, who attempts to change the activity level. Some frequencies we wish to promote. Others we wish to diminish.” An additional website offering information on neurofeedback reads:

“Even for people who are not aware or not engaged, you can’t turn off your hearing. The brain hears the beeps, and responds. We’ve seen many examples where there was rapid response despite apparent lack of interest or attention. But that’s because of the sounds. When you hear more beeps, that means the brain is “getting it” (About Neurofeedback, 2014).

The way in which the text on this website approaches the brain, seems to place the brain further away from the self, mental states and the individual, by making it sound like a sort of external machine that operates completely separated from a subject’s consciousness thoughts. Approaches like “Rewarding the brain” instead of the person, and to “diminish frequencies” might create these feelings of detachment. From a third person perspective, the subject is asked to ‘step outside’ of their own mind to look at their own brain and the activity that it produces. They are asked to form thoughts about the brain activity that they are told produces these thoughts itself, to form thoughts that are based on the mechanisms underlying those thoughts.

A final additional factor is the fact that if the desired brain waves have been rewarded to such an extent that it will produce them each time a similar trigger presents itself, the effects can become permanent after a while (see chapter 2.4). The realization that this is in fact the case might make subject even more prone to view their brain as detached from their self and their consciousness.

Neurofeedback as a Mechanism of Addiction

During neurofeedback, the brain employs one or more reward mechanisms of the brain. As explained, what basically happens is that the 'desired brain wave' triggers a response (see chapter 1.1.4 on neurofeedback and operant conditioning), resulting in that the brain is 'trained' to reproduce this certain type of brain waves. A website offering the procedure reads:

"For example when somebody desires to become more alert, they will receive a reward during the procedure, for example through means of a sound or short movie clip, each time when the brain waves find themselves in an 'alert' state"[16] (Neurofeedback Instituut Nederland, 2014).

This was already briefly addressed in chapter 2.4, where it was explained how the idea that the brain uses a same mechanism as those during addiction, a specific kind of behavior can make a subject feel differently towards this behavior. It can be strange for subjects to request an improvement in a desired type of behavior, or to be able to maintain a desired mental state in certain situations, by using a reward for the brain. The idea of an 'addicted' brain provides a different perspective towards the using of reward mechanisms and raises several ethical questions, perhaps especially in the case of applying neurofeedback training to children (for example to treat ADHD) (Arns & Kenemans, 2012). So, in addition to showing how neurofeedback can increase the feeling of 'being steered' by an autonomous and externally influenced system, the idea of making the brain addicted to certain types of behavior raises questions with regards to ethics and authenticity as well.

V.4 Normative Claims

In some cases, a technology or scientific discovery can disrupt an existing view on a societal level. An example of this is how discoveries about the brain have changed the way society looks upon drug addiction. Where it was first believed that people with an addiction were morally flawed and lacking in willpower, scientific research has shown that it is a disease that affects both the brain and behavior (Volkow, 2014). The subject of neurotechnology also concerns

[16] Freely translated.

research in the area of the brain and behavior, therefore it should be taken into account that research with regards to NF and BST's can also lead to a change in existing conceptions the self and the brain. In my research I have discussed how the *effects* of the application of neurotechnology can reach such a result, but in this passage I would like to emphasize that the research alone that is done in this area may cause such a shift in view and attitude on a scientific and societal level. The visualization techniques mentioned in chapter 1 also play a role in the societal understanding of the brain, especially when they are employed in combination with stimulation technologies or other external input, such as light stimulation. It should not be a reason to diminish research in this area, but it should be kept in mind in order to take precautions around a new conception, where this be deemed necessary.

In the comparison that was made between neurotechnology and drug use, the five differences that were outlined showed that the two may have some aspects that are similarly expressed on a general level, such as the fact that in both cases neurological changes can give rise to a change in behavior. However, it also showed that with regards to the effects on a more detailed level there are significant differences, especially with regards to means.

Another difference between neurotechnology and drug use concerned the duration of the effects. Especially in the case of neurofeedback, but also for example with tDCS, depending on the intensity and duration of the stimulation effects may last up to months. This cannot be said for drugs, in which case the effects stop occurring after degradation of the drug (apart from long-term damage). For this reason, it is necessary to be convinced of the positive outcome of neurofeedback training or stimulation before it is used, and the lack of negative (side) effects. For this reason, effects and mechanisms involved in neurotechnology cannot be compared to the known effects and mechanisms involved in drug use. If the two are placed in the same category too lightly, wrong conclusions may be drawn. This can have consequences for example in the sense of underestimating the different and more extensive phenomenal effects of neurotechnologies in comparison to drugs. Another consequence is that wrong advisory guidelines are given, for example in policy and lawful regulations towards the public. I have shown that neurotechnologies, both when used improper and correctly, can cause negative responses in individuals on a different level than the use of drugs or pharmaceuticals. Therefore, differences between neurotechnology and drugs or pharmaceuticals are important to recognize and acknowledge; and awareness of these differences is vital in neurotechnological research.

The area of neurotechnology should be treated as a new area that is in need of its own research, without relying entirely on (previous) findings that show a similarity in effects, but concern a crucially disparate field.

In the case of neurofeedback, it has been shown that effectiveness is still controversial. Differences in effect appear per individual and per training method that is practiced. This could be problematic when for example feedback training procedures are being standardized. What is effective and works a certain way in one subject, is not necessarily as effective or beneficial in the next. Especially when it is taken into consideration that environmental differences and genetics also play a role in the way in which the brain responds to specific stimuli or distinct thinking patterns. While the origins of these uncertainties cannot be explained, neurofeedback training should be approached with caution. In research, attention should be paid especially to such differences, because they might tell us more about the underlying mechanisms of the effects as well.

There are also some normative claims that can be made with regards to practitioners, and the utilization of a technology as Thync in private environments. In chapter 1 I described Thync, a device that stimulates the brain and can be controlled via an application on a smartphone. This technology is an example of the application of brain stimulation in private environments, where use is unregulated by the government. In the scenario where such devices become available for these types of use, the government should be made aware of all the possible effects, so that employment of these devices may be registered and regulated by law. At the same time, consumers should be provided with the right kind of information to limit accidents and misuse, and to create awareness of the implications of use. This may be done by obligating companies to provide extensive information and way of use on their websites, but also for example by delivering this information in a manual along with the product. In any case, it should be specified that these technologies concern a different category than (pharmaceutical) drugs or other stimulants.

There should also be discussion with regards to the facilitation amongst different societal groups, for example children. Brain stimulation and neurofeedback in children may raise additional ethical questions as to application in adults. Guidelines should be determined in which cases brain stimulation should be allowed. In addition, independent advice should be given with regards to how these guidelines should be determined, and which factors play a role in doing so (for example age, level of intelligence, working field).

Finally, general normative claims should be extended towards the field of information that subjects are provided with when they are to receive brain stimulation or neurofeedback training. As has been shown in this chapter, beliefs are of influence on self-understanding. Because these beliefs include those that are based on the information subjects are provided with about the procedure of a neurofeedback training, it is important to carefully determine the kind of information that subjects should receive. This information can create doubt, uncertainties, lessen the effects, raise expectations, etcetera. It is important for the practitioners to be aware of the effects of the information that they provide, and what is at stake.

V.5 Further Research

In the following section I will point out in which fields and concerning what topics further research is wanted and could be beneficial. In chapter 5.1, it became clear that there is still much uncertainty with regards to the effects of neurotechnology, underlying neurophysiological mechanisms and the exact functioning of neural pathways involved. Therefore additional research in these areas is recommended and necessary to be able to predict the effects as precise as possible, in order to minimize potentially negative and damageable effects. This need for research is stressed by the fact that the neurotechnologies covered are already being used in clinical settings, and in some cases private spheres.

As mentioned in the discussion, the conceptual apparatus of self that was analyzed in this research is not a universally accepted conception. Research should be performed to investigate if the conclusions that were drawn about the consequences for the self and self-understanding also hold for other conceptions of the self. The conclusion that was discussed in chapter 5.1 is not included in this recommendation, because it was based on results that stand apart from the conceptual apparatus of self and my explanation of self-understanding. However, there may be more need for philosophical research in general, especially for conceptual clarity with regards to the aspects of consciousness that constitute the self, and also the precise relation between them, perhaps on a more detailed level than was done in this research.

There is also the question of what the consequences of neurotechnology on non-users may be on both a societal and an individual level, as I have explained in chapters 5.2.3 and

5.3.3. In order to answer this question, the public should be interviewed, so that an analyses is possible with regards to the public view and public opinion with regards to neurotechnology. From this research, it should become clear how different groups of people feel about the existence and application of neurotechnology. In such an investigation it would be important to take into account subjects that undergo brain stimulation or neurofeedback, people that are close to subjects that are treated with one of these technologies, and people that have nothing to do with the technologies directly, but are aware (or unaware) of the existence and possibilities of application of neurotechnology.

In the discussion I mentioned that it was difficult to analyze a change in self-related processing, because it would be too speculative to assume how a subject would reflect on their own thoughts during a neurofeedback training. Therefore I recommend to perform empirical research that focuses on this question, in order to achieve an understanding of the influence of neurofeedback training on self-related processing. Because self-related processing has proven an important factor in the constitution of self-understanding, this will aid in the investigation of what the consequences for self-understanding could possibly be.

Another issue that needs further research is the issue of individual and cultural differences, as explained in the discussion. Even though the conceptual apparatus of self can be considered to be organizationally equal in general in each person, the areas that are associated with the self and the self-specific organization can still vary for each individual on a more detailed level of the organization of neurons in the brain. Even though this was not covered in my research, this issue needs to be recognized and researched in order to prevent that wrong or generalized conclusions are drawn based on research that concerns itself with brain stimulation and neurofeedback.

Finally, in chapter 4.3.3 I discussed that that research showed that people with malleable self-theories are more prone to confront personal challenges, more open to learning and in case of failure, are more capable of recovery, and that they are better at finishing difficult tasks. (Dweck, 1999). These conclusions are based upon grades and social behavior in a learning environment. As I explained, brain stimulation improved abilities might inspire the belief that the quality was a more fixed quality, because it has proven difficult to improve through training, but was effortlessly changed with brain stimulation. This raises the question if these effects will also arise in other social circumstances and situations. The belief that something like this is easily learned, can aid in actually learning it. I have explained that this can also occur the other way around, in the sense that BST's can change a fixed self-theory, allowing the subject to believe other capabilities are susceptible to change as well. I suggest that (predictive) empirical research is performed to be able to determine which of these scenarios is more likely to be the case, or that both scenarios will occur. This would be beneficial to know before application of BST's and NF, due to the relatively large effects of fixed as opposed to malleable self-theories as explained by Dweck (Dweck, 1999).

V.6 Conclusion

The main conclusion that could be drawn from the analysis in this chapter, was that there is still much unknown and unclear with regards to the precise neurological mechanisms that are included in brain stimulation, but also neurofeedback, which showed the difficulty of discovering and predicting the influences of these technologies on the self and self-understanding as described in this research. I used the precautionary principle to argue that further research is necessary before application.

Despite this difficulty I have attempted to use the phenomenally analyzed aspects of self to deduce what possible consequences neurotechnologies *might* have on self-understanding and various aspects of the self, as well as on an individual as on a societal level. On the individual level, I have shown that BST's can induce nervous system changes and through this, aspects of behavior. This leads to unnaturally modified behavior, in this case with an unnatural speed as opposed to non-users and more specifically targeted aspects of behavior. Another way in which the self might change due to BST's is through unnaturally changed self-theories, that shape experiences in such a way that the underlying prior organization is changed, an important aspect of consciousness. BST's may influence self-understanding through self-related and self-specifying processing that are both based on unnaturally modified thoughts and behavior. It may also influence whether a subject sees him or herself as having mostly malleable or fixed self-theories. On the societal level, I argued that there should be paid attention to informing of (potential) subjects with regards to the technology, because this influence how the technology and the aspects of the treatment are experienced. I also discussed how BST's as an option alone can cause pressure in (psychiatric) patients, and in addition raise the issue of inequality.

With neurofeedback, there are indications that the training can cause changes in the self-perspectival organization via adjusted patterns in the process of neuroplasticity. However, because the patterns that result from neuroplasticity are often unknown, it has proven difficult to determine what these changes in self-perspectival organization might be. Another aspect of neurofeedback training is that it forces the subject to reflect on their own mental states with aid of the technology (direct feedback). According to Moran, these mental states are corrupted upon reflection, which, upon occurring unnaturally, can cause unnatural changes in the subject's current mental state(s). Neurofeedback may also change self-related processing, during and after the procedure. During the procedure, subject may reflect on their thoughts differently based on the feedback they have received. After the procedure, changes may occur based on adjusted neural patterns that give rise to specific thinking patterns or a specific mental state. Self-specifying might be different due to the fact that subjects reflect on aspects of modified behavior. Both these processing can give rise to a different self-understanding, which can mean a subject forms different thoughts about him or herself, or what he or she is. The analysis of the effects of neurofeedback on a societal level brought to light two major possible effects. The first is that subjects and the general public increasingly feel like their brain is an autonomous system, due to the means of the forced direct reflective method and the general nature of the procedure, in addition to the estranging approach that the offering parties employ in relation to the brain. This can lead to a shift in perspective on human nature as well, which would raise questions in the areas of authenticity, responsibility, control and free will. The second is based on the fact that in neurofeedback, a mechanism is used that is comparable to the neural mechanisms involved in addiction. This raises several questions, amongst other things with regards to the ethical justification of the procedure and the possible consequences for authenticity of the subject.

I have also made normative claims with regards to the application of neurotechnology. I have explained that we should be careful with general research that is performed in the area of neurotechnology, because even research (and the found results) in itself can play a role in the societal understanding of the brain. Furthermore, the role of the government should be considered in the development of neurotechnological applications that are developed for private use. Employment of such technologies should be registered and regulated by law, and the public should be given extensive information before utilizing these technologies. The facilitation amongst different societal groups, for example children should be considered, because brain stimulation and neurofeedback in children may raise additional ethical questions as to application in adults. A final important point is that it should be carefully considered what information subjects are provided with when they are to receive brain stimulation or neurofeedback training.

I have proposed that further research should be performed with regards to the ‘gap of knowledge’ that involves the lack of knowledge in underlying neurophysiological mechanisms and the exact functioning of neural pathways involved in neurotechnologies. Another area in which additional research is desired is the conceptualization of the self, and whether the found results would also hold in general terms. In addition to this, I explained that it should become clear how different groups of people feel about the existence and application of neurotechnology, taking into account social groups that vary in their relation to the neurotechnology at stake. Finally, empirical research may be performed with regards to the influence of neurotechnology on self-theories, and whether they change the malleable- or fixedness of these beliefs.

SUMMARY

The research that was done consisted out of four main steps that have expressed themselves throughout the chapters that make up the body of this research project. First of all I have conceptualized consciousness as a constantly changing, self-organizing and dynamic structure that functions as an autopoietic system. I have used Hume and Kant to create an understanding of the self and its relation to the various aspects of consciousness. Interestingly, a number of the philosophical claims made by both Kant and Hume were related to contemporary findings and hypothesis regarding neurotechnology, so that a parallel conceptualization was made. Hume's explanation of the principles of association shows that these relations are fundamental in consciousness and the forming of the self as a bundle of experiences. By evaluation of changes in behavior through Kant's theory of the transcendental ego, it becomes clear that the self can be changed due to neurotechnological influences if it changes behavior.

Furthermore, it became clear that beliefs and belief systems play a role in action patterns. In turn this means that actions and behavior are influenced when beliefs are changed. Beliefs can be changed by neurotechnology, because application thereof can make a subject believe something different about him or herself. In addition to this, a change in self-related processing and self-specifying processing means a change in self-experience, which ultimately results in a change in the so-called 'center' of the underlying prior organization. In neurophysiological terms this center was defined as the resting-state's activity's gravitational point of self-specific organization. Since this center, alongside of spatio-temporal trajectories in the brain, determines how all experiences are perceived, Northoff and others regard it to be the same thing as the self. In other words, a change in self-experience would mean a change in self.

The main finding was that there is still much unknown about the exact functioning of the neural mechanisms and pathways that are involved in the effects of neurotechnologies. This in itself can have unprecedented and possible undesirable consequences, on an individual as well as on a societal level. Taking the precautionary principle into account, the subject needs to

be more extensively researched on a qualitative and neuroanatomical level before it is used in clinical settings or private spheres.

After discussing in what ways neurotechnologies influence self-specifying processing and self-related processing, I have opted several possible scenarios for changes that could affect the self as it was defined in this research, the resting state and self-understanding. It was concluded that self-understanding mainly changes because of a change in beliefs. In this case it does not concern a change in beliefs about oneself based on changed mental states/behavior as is the case with self-experience. It concerns a change in beliefs with regards to what a subject thinks he or she is, based on the fact that mental states and behavior can be changed at all via neurotechnologies. There are two main factors, the fact that a process that shows similarities to an addiction mechanism is used to achieve desired behavior or a desired mental state and the fact that subjects are forced to take a position towards their brain that is more autonomous than it would be assumed through natural everyday learning processes. Both these factors can cause a change in the relationship between a subject and their brain. This was the case mostly for neurofeedback as opposed to brain stimulation technologies, because with neurofeedback the subject is aware of the changes in brain activity in this procedure, and is asked to take a reflective position towards the changes in this activity in their brain.

Evaluation of the Research Process

During this research, some concerns arose with regards to content-related circumstances of the research process. Most of these concerns have been discussed and processed throughout the entire investigation. However, some of the issues that arose were difficult to solve upon encountering, due to the limited time that was available for this research. The following concerns additional to the ones discussed throughout this investigation, should be mentioned:

While continuing through the research process, it became clear that it is difficult to determine the exact neurophysiological consequences on the level at which neurotechnologies influence brain activity, for which reason it was difficult to claim in what ways the self is changed on this level. The reason for this was that the precise underlying mechanisms of neurological processes are still unknown, including those that are likely to be involved in brain stimulation processes.

It should also be noted that caution should be taken in applying the results of this research to a broader definition of the philosophical 'self' than the conceptual apparatus that was formed in chapter 3, because this conception of self and the discussed aspects may not be in line with other conceptualizations and aspects of the self and self-understanding. Even though I have attempted to analyze what constitutes the self from a general and perspective and through several different influential philosophers, others can presume conceptions and aspects that may not be compatible with the ideas I analyzed.

Another issue was the issue of uniqueness per individual. This problem was defined in the beginning of this research and it was explained that due to the scope of this research it could not be included. However, it is still something that should be considered when possible influences of neurotechnologies are discussed in detail. Each individual is unique and has a unique resting-state and self-specific activity, but it is unclear whether individual differences are significant in case of differences in consequences of brain stimulation and neurofeedback. The same goes for cultural differences that may have a fundamental influence on the way in which the various aspects of the self are organized, that can also lead to differences in the effects of NF and BST's.

It also became clear that it would be difficult to say something about a change in self-related processing, because it can hardly be determined how a subject would reflect on his or her own thoughts without performing empirical research. Therefore, this aspect of self-understanding and the way it is constituted through self-related processing in this context, proved very difficult to analyze. It was easier to analyze in what way a change in self-specifying processing would arise, because it is more likely that an individual will actively reflect on a change in behavior, since this is based on actions in the actual world that can be evaluated by others than the person that experiences them.

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