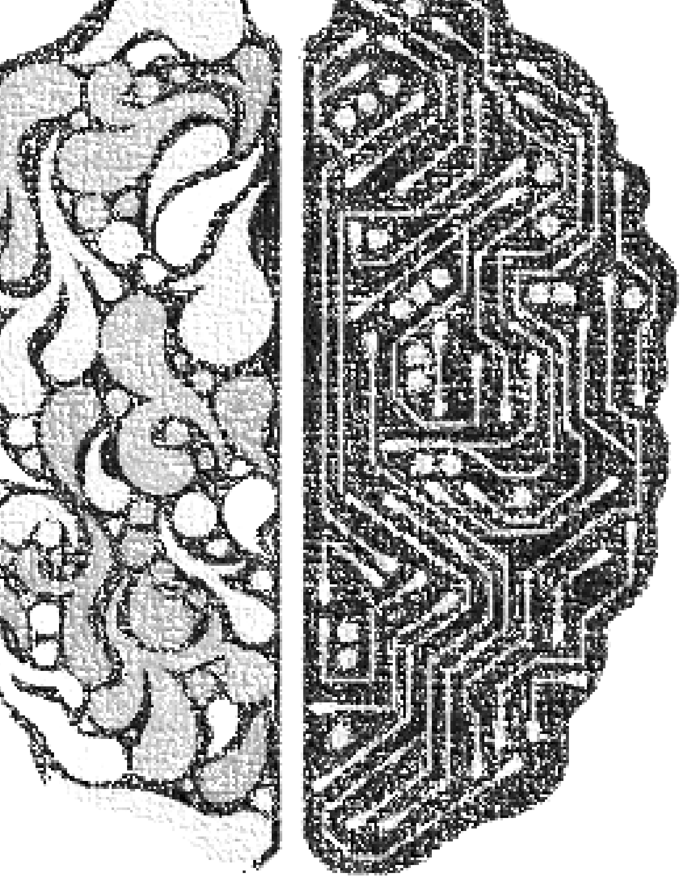
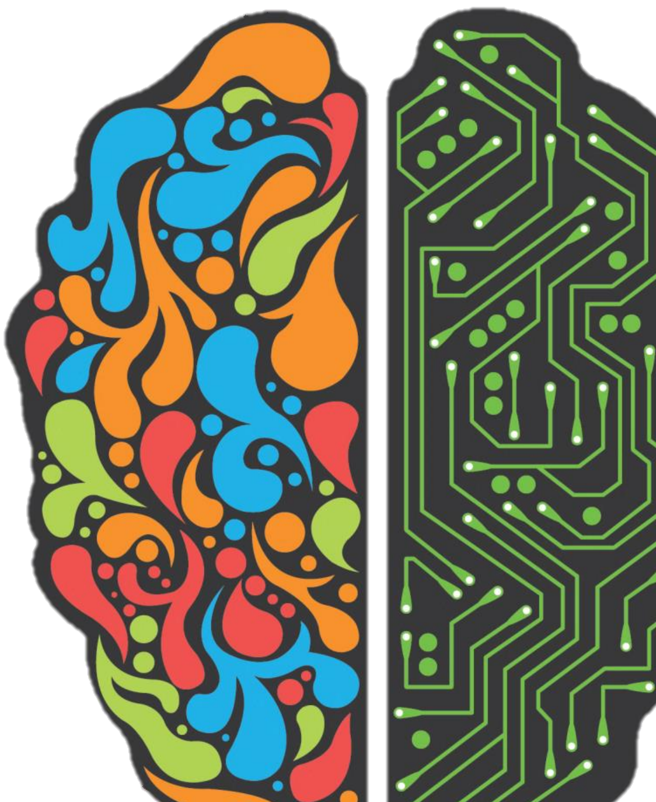


Master Thesis MA Philosophy

Sadaf Soloukey Tbalvandany

Embodied Neuro-Engineering:
Phenomenology and Neuroscience on the Same Team



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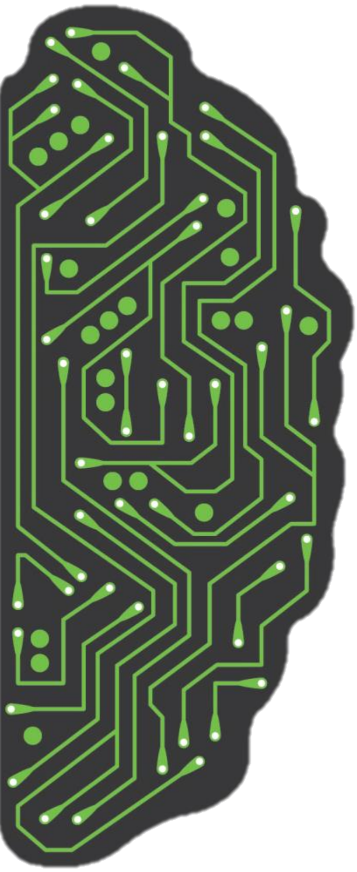
Abstract

The field of Neuroscience, and especially that of Neuro-Engineering, seems to be on the fast track towards its ultimate goal of enhancing or even replacing the nervous system. In the meantime, however, neuroscience on the one hand and philosophy on the other hand, have found themselves in a battle of giants leading to an unproductive two-sided reductionism and hostility, which has even made its way into the public debate. This thesis aims to reconcile the two fields by using the philosophical field of phenomenology, and especially the theoretical framework of 'embodied existence' of philosophers such as Merleau-Ponty. By discussing efforts already made by medical philosophers, comparing their use to the field of neuro-engineering in particular, and introducing the concept of 'Patient Transparency Diagnosis', we will formulate why and how phenomenology and neuroscience working on the same team will lead to better existential reorientation for the patient, a progression that the future of neuro-engineering needs.

Keywords: Phenomenology, Neuroscience, Neuro-Engineering, Embodied
Word Count: 21.879



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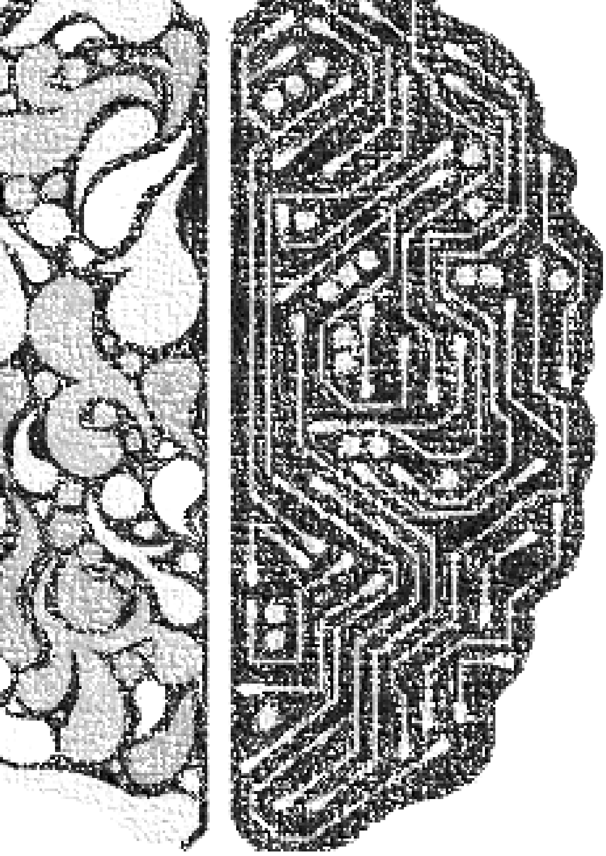


Foreword

As a student of Neuroscience, an aspiring Neurosurgeon and a passionate philosopher, I have often found myself in between two worlds.

On the one hand, Neuroscience tells me to focus on studying neurons and the networks they form, in order to understand the nervous system, and the behavior this system eventually ‘causes’. Cheered on by neuroscientists and writers such as Dick Swaab and Victor Lamme, I am often made to believe that Neuroscience will have some of the most ancient questions answered in the upcoming years, perhaps even in my lifetime. Dick Swaab in particular, already aims at answering one of the most fundamental questions we have been asking ourselves in his book titled *We Are Our Brain* (2014) (1). Because of the work of Swaab, Lamme and others, the discoveries of Neuroscience have also become a subject of discussion in the public debate. What are those Neuroscientists up there in their ivory towers really doing? And how will their work affect the common man, who (still) believes in Free Will and a Soul?

On the other hand I am a true lover of philosophy, the mother of all sciences. Throughout my studies of philosophy I have been humbled and amazed by the thoughts of the great thinkers who have come before me and how bravely they have aimed to attack the questions that have been bothering mankind since ancient times. And often, we must remember, what limited means they had at their use in order to answer questions. What has always inspired me greatly, is the sense of the complexity of reality most philosophers seem to add to their own theories. ‘My perspective is just one perspective’ to my ears is one of the most beautiful things a philosopher could say[1]. Perhaps, therefore, my interest within the huge range of philosophy soon channeled towards phenomenology in particular, the study of phenomena, and especially the perspective-bound nature of these phenomena.

Not so surprisingly, phenomenology and Neuroscience throughout the years have come to discuss many of the same concepts. However, their relation has not always been a friendly one. While Neuroscientists sometimes arrogantly proclaim that philosophy is a field only

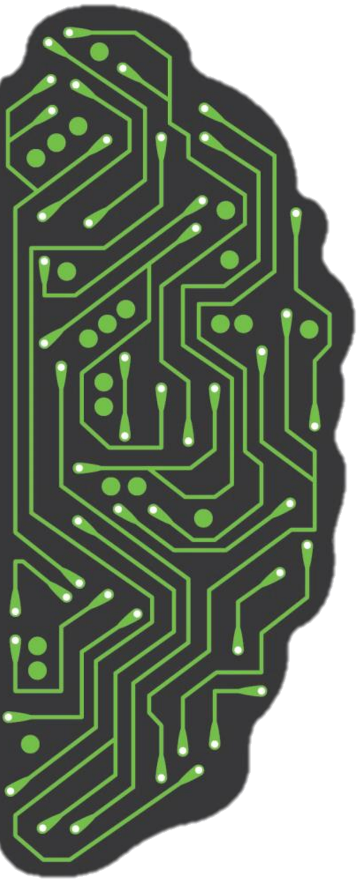
[1] Sadly, this does not happen all too often.

discussing the questions science has not yet been able to answers, Philosophers often refer to neuroscientists as narrow-minded reductionists, crippled by their own perspective (2).

In the meantime, I see advances of Neuroscience achieving the alleged impossible. Researchers have been able to implant chips into the brain, which link humans to machines and allow people with incredibly destructive diseases such as ALS to communicate with their surroundings. Primates with paraplegia have been made to walk again by implanting spinal cord stimulators, which bypass the damaged spinal cord. All of these amazing developments have rightfully earned their own realm within Neuroscience, named Neuro-Engineering.

Watching this leaves me with contradicting feelings. On the one hand, these advances make me extremely excited for my possible future in the studies of the brain and nervous system. On the other hand, these advances are as much marvelous as they are challenging. And these challenges do not only lie in the theoretical scientific side of the development, but especially affect the ones most involved in the practical side of the actual implementation of neuro-engineering techniques: the patients.

Therefore, I have made it my aim in this master thesis to reconcile phenomenology with neuroscience and especially the field of neuro-engineering. And not just reconcile, but actually intertwine the two for the benefit of the field as a whole and the patient in particular. Maybe then we will one day actually realize that phenomenology and neuro-engineering were on the same team after all.



"We have created a man with not one brain but two. This new brain is intended to control the biological brain. And therefore the patient's biological brain, indeed his whole body, has become a terminal for the new computer. We have created a man who is one single, large, complex computer terminal. The patient is a read-out device for the new computer, and is helpless to control the readout as a TV screen is helpless to control the information presented on it."

— Michael Crichton, *The Terminal Man*, (1974).

"We may well argue that today most of us have become prosthetic through and through already."

— Jenny Slatman, *Our Strange Body* (2014).

"The insertion of the implant under the skin amounts neither to its disappearance nor its transparency but rather entails new body-technology configurations and ways of being in the world."

— Lucie Dalibert, *Living with Spinal Cord Stimulation: Doing Embodiment and Incorporation* (2016).

Introduction

The 1974 movie *The Terminal Man* paints the picture of a scientist who implants himself with a brain-implant hooked up to a computer in order to counter the seizures he experiences. Back then this was marked '*Sci-Fi*'. A little over 40 years later, *Nature*, one of the leading scientific journals, publishes one of the first successful case reports involving a brain-computer interface (BCI), restoring the communicative abilities of a patient with severe ALS, a muscle and nervous system disorder, which ultimately leads to complete isolation due to loss of muscle function (3). In the same year, a group in Switzerland (4) succeeded in restoring the walking pattern in two primates with paraplegia by implanting a spinal cord stimulator, which translated walking pattern signals in the brain to actual motor response. As such, the damaged area in the spinal cord was bypassed.

With these latest accomplishment, the field of Neuroscience, and especially that of Neuro-Engineering, seems to be on the fast track towards accomplishing its ultimate goal of enhancing or even replacing the nervous system. For many hardcore neuroscientist, these success stories are the proof of the fact that, given time, Neuroscience will unravel even the most difficult questions mankind has been asking itself since the beginning of time. Almost all of these 'fundamental' questions, including the ones involving the brain, were once the domain of philosophy only. Philosophy has often been named 'the mother of all sciences' and has been debating many of the questions of today, such as the ones regarding the nature of the human brain and the concept of consciousness, for centuries.

Today, these once so overlapping fields, seem to have drifted away from each other in a power struggle. On the one hand, Neuroscientists are claiming that philosophy consists just of the questions that Neuroscience has not been able to answer yet. As neuroscientist and neurophilosopher Patricia Churchland (5) states:

"The history of science can be seen as a gradual process whereby speculative philosophy cedes intellectual space to increasingly well-grounded experimental disciplines- The mind's turn has now come."

On the other hand, philosophy is continuously pointing towards the reductionist point of view that neuroscience is preaching and especially how Neuroscience is still 'lacking' in many respects: the inventions such as brain implants and robotic arms are nowhere near finished or working probably. Interestingly enough, these issues have made their way into the public debate as well, with philosophers and neuroscientists alike publishing polarizing books with titles such as *We Are Our Brain* (2014) by Dick Swaab (1) and *Out of our Heads: Why you are not your Brain* (2009) by Alva Noë (2).

Intuitively, one might already feel the sibling-type of rivalry underlying these debates. As intuitively as a mother would during these cases of sibling rivalry, one might want to point the common goal both neuroscience and philosophy seem to have in the cases of neuro-engineering especially.

Neuro-engineering involves the process of repairing, restoring, enhancing, replacing, or bypassing the nervous system with the aim of enhancing human performance in the face of disease. For the patient in question, these enhancements often mean a step towards life as we healthy people take for granted. As such, neuro-engineering as a subfield within neuroscience and medicine as whole, is continuously dealing with human experience, both of the patients involved, as well as the family and friends surrounding the patients, and to a certain extent, even the doctors and technicians supporting the patients through the process.

Within the philosophical field of phenomenology, and especially within the theoretical framework of 'embodied phenomenology' of philosophers such as Merleau-Ponty, the focus lies on this human experience. Therefore, there seems to be plenty of fruitful ground for reflection upon and collaboration with the field of neuro-engineering.

Carel et al. (6) discuss the role of Merleau-Ponty's theory within the field of medicine in their 2011 article 'Phenomenology and its application in Medicine':

"The kind of creatures we are is circumscribed by the types of experiences we have and the kinds of actions we perform, both of which are shaped by our bodies and brains. Any attempt to understand human nature would have to begin with the body and perception as the foundations of personhood." (p.36) (6)

This leaves us with a perhaps unnecessary battle of giants. While neuroscience and philosophy continue to push away each other's expertise, the field of neuro-engineering is left with a 'two-sided reductionism', where Neuroscience on the one side reduces philosophy to the field only relevant for ‘questions still unanswered’, and Philosophy on the other side reduces Neuroscience to a narrow, reductionist field with still a whole lot of work ahead before it can even come close to delivering the claims it is making.

The effort to reconcile phenomenology with the medical field as a whole has already been made very bravely by medical philosophers such as professor Jenny Slatman, professor at Tilburg University in the Netherlands. In her book ‘*Our Strange Body: Philosophical Reflections on Identity and Medical Interventions* (7), Slatman sets out to use the work of phenomenological philosophers such as Merleau-Ponty, Wittgenstein and Nancy, to claim that our ‘own’ body always entails a strange dimension. And that it is exactly this strangeness which allows us to incorporate other ‘strange’ things such as medical aids.

Interestingly enough, Slatman uses many examples in her book to illustrate the broad diversity of medical interventions currently applied, and their phenomenological consequences. However, neuro-engineering specific interventions, such as brain implants and spinal cord stimulators, have not been discussed as thoroughly as we might want to. The current focus seems to lie on perfecting the technical aspects of these devices, while clinical experience has shown that the ‘human experience’ and his or her ability to use the device and incorporate it in a daily routine, is as important for success.

This leaves us with an interesting lacuna. On the hand we have medical philosophers already aiming to reconcile phenomenology with medicine with the aim of being of benefit to the medical field and its patients, on the other, neuro-engineering specific scenarios have not been taken up in this effort. Neuro-engineering, as well as Neuroscience as a whole, are indeed a particular subfield within medicine. Neuro-engineers, brain doctors and neuroscientists work on a part of the body many philosophers have been mesmerized by for centuries. In addition, the brain and nervous system immediately spark associations with consciousness, Descartes’ dualism, religious believes in the soul and so on. Therefore, we should examine whether the brave accomplishments of reconciliators such as Slatman can successfully be applied to the field of neuro-engineering as well.

In this thesis we will tackle this almost iconic battle of giants, by zooming in on a potential field of reconciliation: embodiment in neuro-engineering. By discussing the current state of the field of neuro-engineering and its accomplishments, we will touch upon the issues it faces now and will face in the future from the perspective of both the researcher and patient. By discussing the phenomenological efforts of Jenny Slatman in her book *Our Strange Body* (7) and comparing their applicability to the field of neuro-engineering with regard to issues concerning 'transparency', incorporation and tolerance, we will firstly discuss to what extent the more general points made by Slatman would be equally applicable to the field of neuro-engineering in particular, and secondly, we will try to define the phenomenological conditions that actually enable incorporation and facilitate a positive patient experience during the neuro-engineering endeavor . Using the above, we will try to break down the apparent rivalry between the two fields and argue *why* and *how* the two should actually be 'on the same team'. Given the answer to the last question, we will finish off by giving pragmatic recommendations aimed at experts[2] in the field of neuro-engineering, which will hopefully allow a continuity in the collaboration between neuro-engineering and phenomenology in clinical practice.

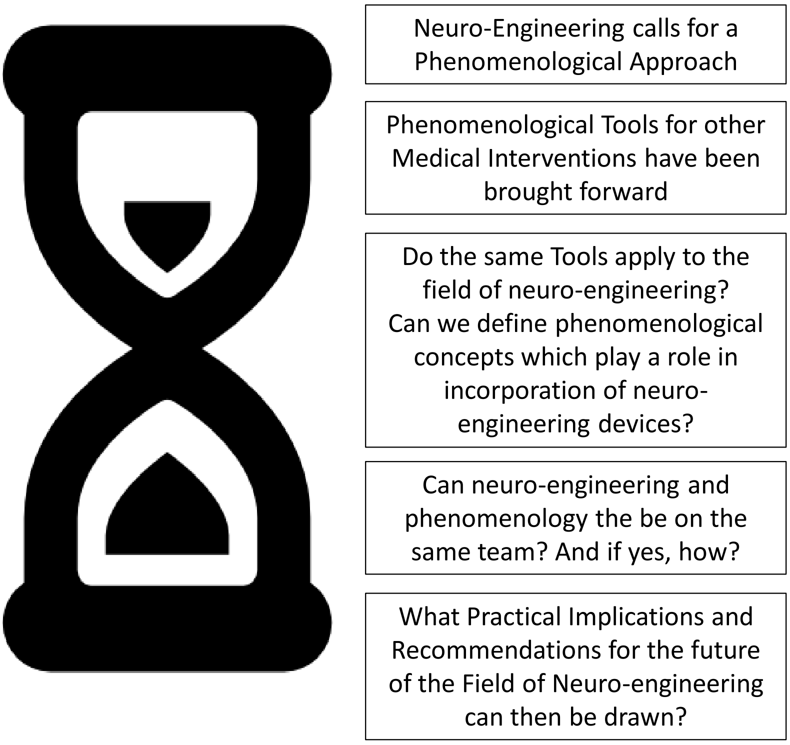


Figure 1 *Build-up of this thesis*

[2] Physicians, nurses, engineers, psychologists and many others that form the support centre around a patient undergoing this process.

Neuro-Engineering: The Current Status Quo

"Any man could, if he were so inclined, be the sculptor of his own brain." – Santiago Ramón y Cajal

In 1906, Cajal and his colleague and rival Golgi, received the Nobel Prize in Physiology for their work on the structure of the nervous systems. Together, these men who first in detail described the morphology and function of brain neurons, are now considered the founders of modern-day Neuroscience.

Much has happened since their discoveries. Many of the previous 'mysteries' of the brain are now almost completely demystified and understood: the visual system, the walking pattern and also emotions such as fear seem to have a clear, and understandable neuronal basis. From this gain in knowledge of the fundamental structure of the brain, emerged a new development: efforts to manipulate, enhance or replace parts of the brain and nervous system. A special subtype of these efforts are now categorized within the field of 'Neural Engineering' or 'Neuro-Engineering': the use of engineering techniques to understand, repair, replace or enhance structures in the nervous system (8,9).

With the rise of neuro-engineering, Cajal's prediction of mankind becoming 'sculptors' of the brain, may become a reality. Especially within the field of medicine, we find extraordinary applications of these neuro-engineering techniques. In 2016, a group in Utrecht developed one of the most successful neuro-engineering techniques as of yet (3). Using a brain-computer interface (BCI) the group of prof. Ramsey succeeded in restoring the communicative abilities of a patient with severe ALS, a muscle and nervous system disorder, which ultimately leads to a loss of the ability to communicate due to loss of muscle function (3). By recording the brain activity, and transferring and decoding these signals, the researchers were able to 'understand' what the patient was thinking (3). By translating these signals into words and sentences to a typing program, a new interface of communication was established (3).

In addition to these BCI's, many other forms of neuro-engineering are currently being developed. We will briefly discuss several types of neuro-engineering devices as an outline of the current landscape of the field. Then, we will bring in two more elaborate case examples, which we will use as concrete examples for the rest of the discussion.

Cochlear Implants (CI)

One of the first examples of an interface between man and machine used in clinical practice are the Cochlear Implants (CI), used for people with hearing problems. Using an external microphone, acoustic signals are recorded and sent to a device which turns the acoustic signals into electrical impulses.

Through wireless transmission, these now electrical signals are sent to a receiver implanted inside the skull and hooked up to the auditory nerve through an internal neural interface. The still intact auditory nerve is then able to send the electrical signals through the brain, where they will be decoded and processed as sounds (10).

Figure 2 *Cochlear Implants.*

Deep Brain Stimulation (DBS)

With deep brain stimulation (DBS), researchers have been able to implant a Central Computing Unit (CCU) in relevant regions of the brain. Electrical pulses generated by this CCU are guided towards particular areas of the brain which need to be stimulated. DBS is currently in use for the treatment of Alzheimer disease, by counter-stimulating the subthalamic nucleus, which is known to be overexcited in Parkinson's, leading to uncontrollable motor movement. In addition to Parkinson's, researchers are now also exploring the potential use of DBS for the treatment of epileptic seizures through stimulation of for example the deep cerebral nuclei (11,12). In addition, DBS is also considered as a treatment for diseases such as myotonia, Gilles de la Tourette and psychiatric conditions such as Obsessive Compulsive Disorder (OCD) and depression (13).

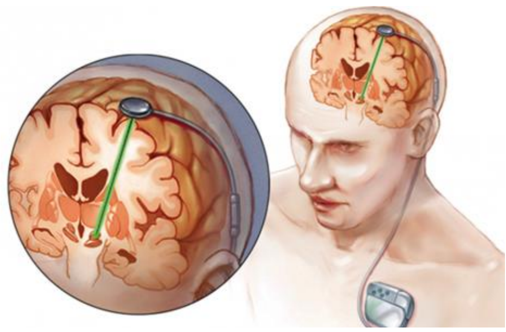


Figure 3 *A stimulating electrode in the brain.*

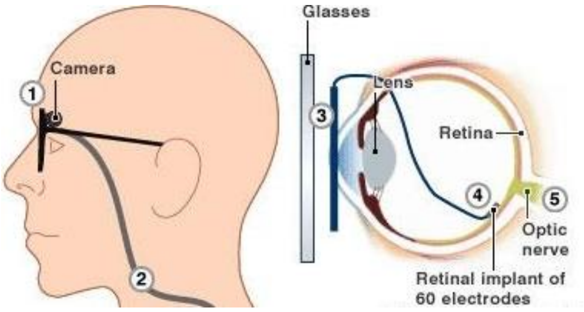


Figure 4 *The Retinal Implant.*

Retinal Implants (RI)

For people with loss of vision, several different ways of recording visuals signals and translating them to neuronal signals, are now being tested. Some implants use diodes that stimulate the remaining cells of the retina. Other implants make use of signals recorded by an external camera, which are then almost directly fed into the optic nerve, quite similar to the previously discussed CI's. In addition, researchers are now exploring the direct stimulation of the cerebral visual cortex itself, the station where the optic nerve eventually ends up (14).

Brain-Machine Interfaces for Motor Response

Using CCU's, scientists have also been able to link cortical recordings of the brain to external computer-driven machines, such as robotic arms. Through strenuous training protocols, the cortical signals of the patients during particular thoughts (such as thinking about lifting your arm) are fed into an algorithm. This algorithm uses multiple trials of cortical recording to fine-tune the signal. Once the signal is optimized (which can take up to a year of training), the cortical signals are connected to the movement of a robotic arm. In this way, the patient is able to control a machine with his thoughts, as such enabling motor response. In cases of ALS or other motor diseases, these developments allow for interaction with the world, something that is often lost in these patients (4).

Brain-Machine Interfaces for Language

In a similar way as the machine interfaces described for motor response, scientists have also been able to link cortical signals to the movement of an arrow on a keyboard, presented in a computer program. In this way, the patient is able to create words and sentences by using thoughts to control the key pad. Again, for patient groups losing their ability to communicate due to loss of motor function, this new thought-controlled keyboard still allows them to communicate their thoughts. In extreme cases such as Locked-In Syndrome, where patients are completely paralyzed, but have almost completely intact brain functions, such an interface has made it possible to communicate minimally. Currently, these devices are useful is discussing pressing matters such as euthanasia by asking basic 'yes' or 'no' questions. In the future, the aim is to further optimize these functions so that more complex communication is made possible (3). One example of more complex communication is the case of Ms. A, who is able to control spelling software using a digital keyboard. More on her case in the next chapter.

Figure 5 *A patient moving a robotic hand using a brain implant.*

Brain-Spinal Interfaces for Motor Response/Pain management

In addition to the brain-machine interfaces, scientists are also developing brain-spinal

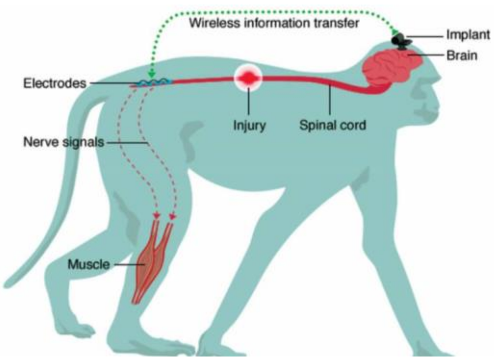


Figure 6 A primate with a Brain-Spinal Interface.

interfaces aimed at restoring motor response in paraplegia in particular through spinal cord stimulation (SCS). By implanting an electrode in the brain which records the brain signals in a similar way as the previously described brain-machine interfaces, the researchers have been able to decode the locomotion signal in two primates with a paraplegia. The motor signal from the cortex is then fed into an array of electrodes placed on top of the spinal cord. These electrodes translate the brain signal very specifically into muscle activation signals, which eventually mimic a walking pattern. With this technique, researchers in Switzerland have been able to restore motor function in two primates with complete paraplegia.

In addition to SCS for motor response, the same electrodes are placed in the spinal cord with the aim of electrically stimulating in the case of chronic pain. By stimulating the electrodes, the pain in counteracted, making previously unbearable pain almost completely disappear. Instead of an electrode implanted in the brain connected to the stimulator, the SCS in case for pain management is controlled by an external stimulator device with a touch screen. The patient themselves can control the intensity with which they stimulate, depending on their posture, level of pain and daily activities (15–17).

Two Case Examples

Having discussed the general areas of neuro-engineering developments, we will now move onto describing two different case examples of patients undergoing the process of implantation of a neuro-engineering device.

Ms. A

Figure 7 *Ms. A after the implantation.*

Ms. A is a real patient, who became world-famous when she received, as the first ALS patient ever, a brain-computer interface by the hands of the neuroscientific research team in Utrecht, led by professor Nick F. Ramsey. At the time of the informed consent, Ms. A was 58 years old and in a locked-in state due to her disease.

ALS, or Amyotrophic Lateral Sclerosis, is a disease which affects the neurons that control voluntary muscles. Slowly but steadily, the disease affects these neurons to such an extent that they eventually degenerate. As such, the muscles receive less stimulation, the muscles become weaker and smaller, eventually leading to all sorts of muscle-related problems, such as an inability to walk, speak and eventually breath. One of the last stages the patients ends up in, is the so called 'locked-in' stage. Apart from some vertical eye-movements, a patient is then no longer able to move his or her muscles. Breathing is taken over by a machine, and the only movement remaining is the ability to move the eyes vertically (18,19).

As one can imagine, this inability to move any muscle whatsoever is extremely devastating for these patients that otherwise function perfectly cognitively. Daniel Wolpert, neuroscientist and movement expert, very interestingly stated the following about the importance of movement in his TED-talk titled '*The Real Reason for Brains'* (20):

"Now you may reason that we have one [brain] to perceive the world or to think, and that's completely wrong. If you think about this question for any length of time, it's blindingly obvious why we have a brain. We have a brain for one reason and one reason only, and that's to produce adaptable and complex movements. There is no other reason to have a brain. Think about it. Movement is the only way you have of affecting the world around you. Now that's not quite true. There's one other way, and that's through sweating. But apart from that, everything else goes through contractions of muscles.

So think about communication — speech, gestures, writing, sign language — they're all mediated through contractions of your muscles. So it's really important to remember that sensory, memory and cognitive processes are all important, but they're only important to either drive or suppress future movements. There can be no evolutionary advantage to laying down memories of childhood or perceiving the color of a rose if it doesn't affect the way you're going to move later in life."

Our patient Ms. A used her last remaining eye movements, the vertical eye movements, to answer 'yes' or 'no' questions by having her eyes tracked with a camera-device. However, the researchers of the team in Utrecht wanted to develop a more extensive communication tool for Ms. A and set up the brain-computer interface.

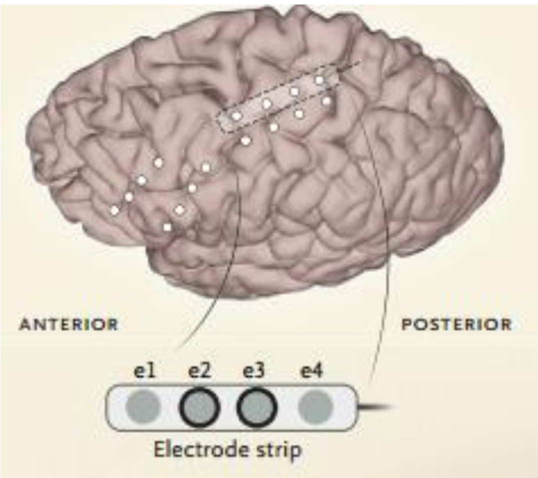


Figure 8 *Location of Electrode Placement.*

During brain surgery, the researchers placed electrodes of the motor cortex of Ms. A, the part of the brain which in healthy subjects activates hand movements (**Figure 8**)

What then followed was an intense training period of 28 weeks. The electrodes placed over the cortile motor movement area of the brain, were hooked up to a decoding software (**Figure 9**). The aim of this software was to decode electronic brain signals picked up by the electrodes to actual intended movements. This meant that the software had to be 'in tune' with Ms. A's pattern of brain signals. By continuously performing training tasks, which entailed withholding or activating 'brain clicks' on a computer screen, the software would get used to interpreting the meaning of particular signals in the brain activation of Ms. A. The authors (3) describe the following task as an example:

"First, the patient practiced activating the motor cortex with a task in which she attempted to hit a target on a video screen by trying to move her right hand to move a cursor upward and then relaxing her hand to move the cursor downward" (p.260) (3)

On day 197, she started using the entire system , the software was accurate enough at decoding Ms. A's brain signals and could actually be used without assistance from the investigators. Ms. A could use the system as an autonomic form of communication:

"Spelling was accomplished by the selection, with brain clicks, of individual or grouped letters that were highlighted automatically and sequentially. Similar to the click task, spelling involved brain clicks being consciously withheld by the patient until the desired letter (or group of letters) was highlighted." (p.2060) (3) (**Figure 10**)

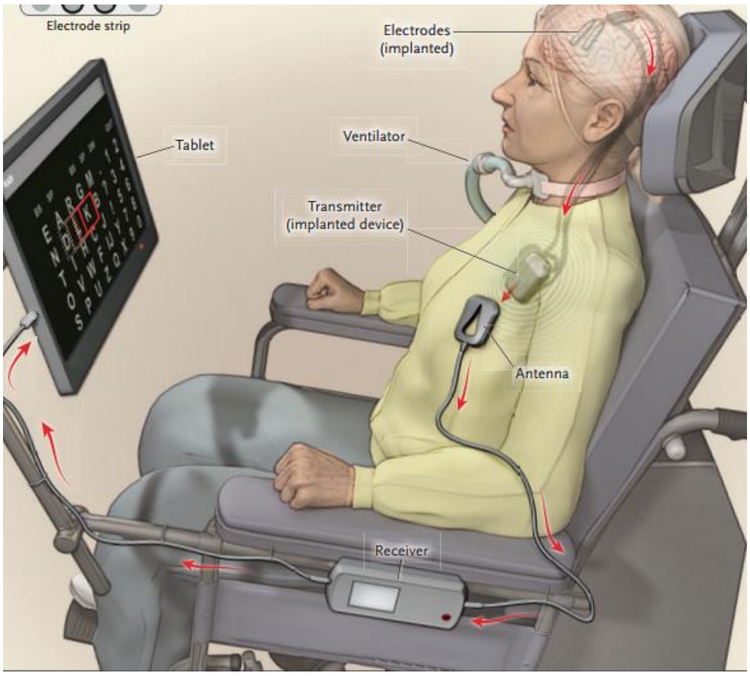


Figure 9 *A schematic overview of the implanted electrode and the connection to the spelling software.*

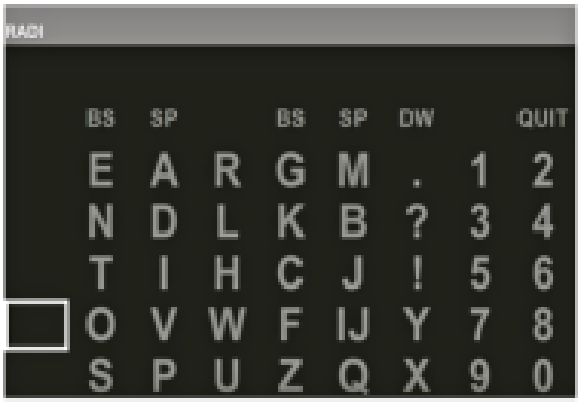


Figure 10 *Screenshot of the spelling software displayed on the screen.*

Mr. B

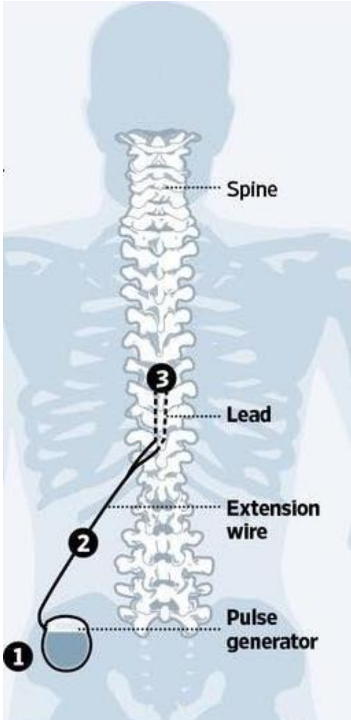


Figure 11 Location of the leads for the spinal cord stimulator.

Mr. B is also a real-life patient who participated in one of the experiments performed by professor Harkema in the United States using the technique of epidural stimulation.

Mr. B injured his spinal cord after a severe vertebral fracture due to a car accident. This left him with a motor complete paraplegia (meaning paralyzed below the level of injury) of the legs. As a consequence, Mr. B is bound to a wheelchair and intensive physical therapy to prevent atrophy of his leg muscles, as well as thrombosis or decubitus due to lack of muscle movement. In addition to the motor paralysis, Mr. B also experiences problems with bowel movement, urine continence, pain at the level of the injury and muscle spasms. Especially the pain and bladder control, he reports, are terrible. They make an autonomous life extremely difficult. His loss of motor function, somehow, he experiences as less of a burden due to his wheelchair. Nevertheless, Mr. B enters the experiment of Harkema to see whether her technique of epidural stimulation could produce motor response.

Harkema explains the technique of epidural stimulation as follows in an interview (21):

"Epidural stimulation is where we place an electrode over the lower spinal cord, below where the injury is, where we're exploring the complexity of the nervous system in that area and what its capacity is to generate complex patterns. We use different stimulation configurations to generate different behaviors."

The electrode with 16 contacts goes over the lower spinal cord, and an implanted stimulator and battery is wired to the spinal cord. (**Figure 11**) A continuous electrical current, at different frequencies and intensities, is applied via a patient programmer (remote), the size of a smartphone, to specific locations on the lower part of the spinal cord, activating nerve circuits. The system is actually an off-shelf device that was originally built for pain management, but Harkema stumbled across unexpected results when conducting research and used it to complete her experiment. So far, study participants, who are all motor complete, regained voluntary movement with the stimulation, and reported improvements in cardiovascular health, temperature regulation and bowel control, even after the stimulator is turned off.

Harkema's original experiment was only meant to find patterns in people with chronically motor-complete injuries, to demonstrate that there were complex interneurons for locomotion. Then her team started seeing unanticipated results. To reach the full potential of that capacity, though, the technology behind epidural stimulation needs to be further advanced.

Figure 12 *Prof. Harkema (left) and her patient Mr. B (middle).*

For Mr. B this technique meant a regain in some voluntary movement. After months of intense training in combination with the epidural stimulation, he was able to retract and extend his legs, bend his knees, and stand with assistance of a cane (**Figure 12**).

Interestingly enough, ever since this discovery by Harkema in 2014, researchers of the group of Cagrusso et al. in Switzerland have been able to take a step further in the development of spinal cord stimulation by combining this with the use of a brain implant, as we already briefly discussed in **Figure 6**. The same technique of electrical stimulation of the spinal cord is then combined with an implant inserted in a motor region in the brain, similar to the location of the implant we described in Ms. A's case. The implant then records the cortex signals, decodes them to signals that describe a certain motor movement, and translates these movements to a stimulation pattern sent to the spinal cord stimulator, allowing mimicry of a walking pattern. With the addition of this brain implant, two further advantages of spinal cord stimulation can be produced. First of all, the implant allows for better voluntary initiation of movement than a stimulator alone could do. Second, by including the implant and combining it with the stimulator, researcher are able to

Figure 13 *Primate in the Cagrusso Experiment.*

introduce sensory feedback into the system as well. By recording from sensory regions in the spinal cord (such as the dorsal root ganglion), the body's natural sensory feedback is fed back into the system, to adjust the algorithm and eventually allow for a dynamic walking pattern which is able to adjust itself to the surrounding environment, much like is already the case in healthy subjects. So far, this brain implant in combination with a spinal cord stimulator has only been successfully tested in two primates. (**Figure 13**) The researchers conducting these experiments expect to need another 10-15 years before this technique can be applied in humans.

Phenomenology: The ‘Embodied’ Experience

Having discussed current examples of neuro-engineering devices which reflect the status quo of the field, we will now move into the phenomenological aspect of this thesis. In this and the following chapter we will lay down the phenomenological groundwork for reflection, on the basis of which we will discuss to what extent and how phenomenology and neuro-engineering could join forces.

In this chapter we will elaborate on the field of phenomenology within the context of medical interventions and especially neuro-engineering. We will pay special attention to concepts such and body boundaries, ‘ownness’ and ‘embodied’ experience. After having introduced these phenomenological concepts within the context of this thesis, we will move on to a more in-depth reading of Jenny Slatman’s phenomenological reflection upon the field of medicine as a whole, and whether these reflections could be applied to neuro-engineering as well.

‘Experience’

As discussed in the introduction, neuro-engineering touches upon the human *experience* of body-ownership and 'owness' in general. By introducing technical devices which aim to recover some of the ‘natural’ abilities healthy subjects have, neuro-engineering asks of the patients to somehow ‘recalibrate’.

This emphasis on experience fits well into the philosophical tradition of phenomenology. Phenomenology has sought to unravel what in the literature is called *Erlebnis*, our lived experience of the world, our body, and others (7). Phenomenology focuses on how things *appear* to us instead of how things ‘really are’ (7). We might see a simple screen with spelling software, but the same screen could to Ms. A *appear* as his/her voice, the only way to interact with the world. And similarly, a broken screen to Ms. A might mean something completely different than to the technician called in to fix it.

German philosopher Edmund Husserl (1859-1938) is known as the founder of phenomenology. At his time, psychology was becoming an autonomous science, advocating the idea that the ‘psyche’ could be considered a ‘thing’ to investigate. Husserl disagreed with this notion and advocated the idea of consciousness as ‘being directed’ instead. According to Husserl, consciousness makes it possible for humans to be more than just a passive receiver of stimuli. If we take the example of a table, we will realize that consciousness of this table is more than the sum of total of sensations. When standing in front of a table, for example, I will not see the underside or the backside of it, but nevertheless I perceive the whole table. Sensations (*Empfindungen*) are only the raw matter, consciousness allow us to 'grasp (*auffassen)* the whole table. As such, consciousness makes co-present (*mitgegenwärtig machen*) that which is not necessarily present. This 'grasping' is also called the 'intentionality', the fact that consciousness is always being conscious of 'something' (the 'intentional object') (7).

Interestingly enough, phenomenology is not bothered at all with the question whether this 'intentional object' my intentional act is pointed towards 'really' exists. Rather, it exists in so far as it appears to me, and through that, has particular meaning to me. If the intentional act changes, the meaning of the intentional object changes along.

This phenomenological thinking is often put in contrast to the Cartesian way of thinking which advocates an unbridgeable gap between the body (*res extensa*) and the mind (*res cogitans*). Descartes' idea of the body as a res extensa, did not only make the body a 'thing', but also something separate and independent from consciousness. Instead, phenomenology emphasizes the idea of the body as a subject, as lived, and as zero-point of orientation and action (22). Nevertheless, the notion of intentionality makes two different dimensions of the body visible as well: the body as intentional object or as holding an intentional orientation. Or in other words, 'having a body' versus 'being a body'. A movement which makes both dimensions visible is when one touches one's own hand (7).

Leib* and *Körper

This distinction of the body as a thing and the body as a non-thing, is also described by Husserl using the terms *Leib* and *Körper*. On the one hand Husserl distinguishes an animate reality, which is constituted by what he calls *Leib.* This animate body co-exists with the inanimate matter, which he call *Körper* and which could be compared to the previously mentioned *res extensa* as defined by Descartes. The co-existing nature is also important to emphasize: the two terms refer to different aspects of one and the same living body. According to Husserl it is the *Leib* which is the *medium* or *organ of all perceptions* (*Wahrnemungsorgan* (7)). This distinction between *Leib* and *Körpe*r is sometimes also described as a distinction between the 'pre-reflective body-awareness' on the one hand and ‘reflective consciousness’ on the other hand (23). As we will see later on in this chapter, the idea of the body as a *Leib* and *Körper* reflects back into the concepts of ´Body Schema´ and `Body Image´.

Body Boundaries

What is it that actually separates ‘me’ from you and the rest of the world? Many speculations about what exactly entails the boundary of a human being and the body in particular have been made throughout the years. Some claim the body consist of everything that is useful or functional to the human being ,others consider the skin to be the only relevant physical boundary, as Slatman comments with slight irony ‘*We might as well say that our body is all which is held together by our skin’* (p.54) (7). In this chapter, we will zoom into this question of body boundaries and what they might consist of.

Mr. A, after having lost his ability to walk, is left with two legs still similar to the ones which used to help him around, but now ‘not functional’. I have always wondered what kind of ‘phenomenological’ experience that would have to be. Not long ago I was operated on my foot and when asked if I would prefer general anesthesia or epidural anesthesia, I chose the latter to come a little bit closer to experiencing what it would feel like if I were unfortunate enough to suffer from paraplegia. The experience which then followed, I will never forget.

After initiation of the anesthesia, I was brought to the operating ward by an orthopedic surgeon in training, who having heard I was a medical student, proceeded to explain the procedure that would follow in great detail. Then he looked my way as I was laying on the operating table and said, ‘this might look funny’. All of the suddenly I saw a leg laying on top of his shoulder, pink from the disinfectant liquid which was poured all over it by the nurse. As the surgeon in training was prepping the leg for surgery, I suddenly realized, that must be my leg! Desperately looking for clues, I saw the little birth mark, the shape of my nails and I realized yes, indeed, it is mine.

Without the sensory feedback of the legs, without the ability to move them, the legs had become some form of dead weight to me, hanging from my trunk uselessly. It was extremely fascinating how it took me actual conscious gathering of clues to realize that it was indeed my own leg. And although I have had years of familiarity with these two legs- I knew the story behind the scars, how long I have had each of the birth marks on my thighs and why I was being operated in the first place- I still felt estranged from them. Ownership of these legs was no longer ‘automatic’ or preconscious, but rather a strenuous process.

I can only speculate how this must be for a paraplegic patient such as Mr. B. Patients like Mr. B lose the functionality in their legs even sooner as I had lost the functionality in mine for the operation. Often they wake up after tragic and traumatizing accidents to a world they did not know before. A world in which they will be no longer able to stand and walk as they used to before. A study on emotional aspects of SCI (24) describes the problem as follows:

“In the present series, a depersonalization syndrome was observed in almost one third of the patients with spinal cord injury; the body image changed, and perception of the self as 'half, 'shrinking', 'degenerating' and phantom-limbs hanging around were common.”(p.52) (24)

As one can imagine, it is the loss of functionality which leaves them with a pair of dull legs, they, as the study suggests, often fail to identify with. What is more, over time, due to lack of use, the legs will lose their original shape due to muscle atrophy and decubitus wounds, making recognition and identification even more difficult.

This makes one wonder what it is that makes us able to claim body ownership at all. What is considered a boundary and what is my ‘own’? The many different theories in literature on this subject show us that answering this question, often also implies answering questions on identity. Some, such as the psychologist Baumeister (25), claim that ‘your own’ is all that is held together by your skin, as such arguing for a view of the self as a ‘bodily self’. Although patients such as mr. B undergo changes, which leave them with non-functional, different-looking legs, the integrity of the body is still intact. The skin the patient ‘lives in’ is still intact, as the same ‘skin-encapsulated ego’.

Other philosophers, such as John Locke (26), would call for a more ‘mentally’ driven concept of identity, and as such would reserve a much smaller, if not non-existent role, for our consideration of the body. Locke himself focuses on the role of continuity of consciousness in our ability to claim our ‘ownness’, leaving a paraplegic patient completely untouched in his or her integrity as a Self when it comes the loss of functional abilities in particular.

Some, mostly scientific researchers, claim that all which ‘contributes’ to your body is yours. In contrast to the previous theory, functionality does come to play an important role. As

Aymerich-Franch, for example claims in a review article titled *The role of functionality in the body model for self-attribution*:

"Previous studies have suggested that, in addition to a necessary multi-sensory stimulation, the sense of body ownership is determined by the body model, a representation of our body in the brain." (p.31) (27)

In the case of paraplegia, this theory would leave the patient with a great lack of ownership, given the fact that paraplegia per definition leads to an enormous lack of functionality. Slatman takes a less rigorous stance on this last point and states the following on the issue:

"Although the parts that belong to a body or some organism must perform a specific function to sustain it, this does not yet indicate where, exactly, the boundaries of a body or organism are to be located."(p.55) (7)

This leaves us with a difficult task to define the body boundaries for our patient Mr. B, but Ms. A as well, who has a fully non-functioning body, but an external screen and software taking over her ability for autonomous communication. Body boundaries are nevertheless relevant for these patients, as they form the delineation from the outside world, defining 'I' versus 'Others' and allowing the fundament necessary to protect and demarcate itself from all that is not. On the other hand, this boundary demands a form of flexibility or dynamics, as it steadily changes throughout a lifetime, or very rapidly due to diseases as ALS and paraplegia. While the body undergoes tremendous changes throughout a lifetime, both due to natural process of aging, as well as more externally mediated changes such as trauma leading to SCI, most of us manage to continuously identify ourselves with the changing body. We cut our hair, we observe new wrinkles on our face, and we might need time to get used to them, but eventually we continue to identify them as 'ours'. And parallel to this process, others continue to see us as 'ourselves', regardless of the changes.
When we come to think about it, this flexibility in drawing the body's boundaries is not alien to us at all. Some women have been wearing heels or hats almost every day for years and years. They get perfectly used to their hat or heels, take this into account when walking through doors or narrow hallways without even consciously taking their accessory choices into account. Slatman adds a another element which she calls being 'porous', '*both from the inside out and the outside in, if at least we are to have an external frame that we can live with'* (p.56) (7).

This idea of the flexibility of our boundaries, leaves us with two important questions still unanswered. First of all, what is the role of me vs. others in the acceptation of something as part of my 'own'? And secondly, if it is personal whether or not something counts as part of the body, could we then count anything as being part or no part of the body, depending on our perspective?

To further illustrate this very intuitive objection, let us take the example of body dysmorphic disorder (BDD). In this devastating disorder, patients have a very clear experience of a part of their body 'not being theirs'. It is sometimes also referred to as 'alien limb syndrome'. The inability to identify with that certain body part is so extreme, that some patients even resort to self-inflicted amputations of these body parts. Many of us would say that this is indeed a 'disorder' and that in fact these patients have no *reason* to want to distance themselves from their body and as such *ought* to accept their 'alien' limb. And it is exactly in this example where the difficulty of our previous two questions comes to light. Even though, from a phenomenological point of view, we would consider body image and acceptance to be a very personal thing, we do have an idea of which cases are just 'too extreme'. Imagine someone claiming the table and chair in front of them is also 'part of their body'. Would we not also frown upon that claim? Later on in this thesis we will discuss more in-depth what are actually the factors that enable the incorporation of external devices. However, this discussion between *is* and *ought* will remain. In the chapter in which we will discuss Slatman's application to the field of neuro-engineering, we will return to this issue.

Embodied tools, Body Schema's and Body Image

"Having gained great skill in using some tool, we may altogether forget we are in fact relying on an extension of our body"(p.53) (7)

Apart from things such as clothing or accessories, human beings have been using other forms of body extensions as well. We have come a long way from using sticks and stones, to the first primitive knifes, steam-powered vehicles and now hand-held supercomputers we call smartphones. Some of these extensions we refer to as 'tools'. It is especially this category of extensions that the field of neuro-engineering seems to be focused on developing.

In his essay *Embodied Tools, Cognitive Tools and Brain-Computer Interfaces* Richard Heersmink (8) discusses the phenomenological consequences of some of the earliest forms of BCI's and especially to what extent these neuro-engineering tools are incorporated into the 'body schema' of the patients and as such could be considered embodied tools.

'Body schema' is a term often used by French philosopher Merleau-Ponty (1908-1961), who is known for his 'embodied' consciousness. For Merleau-Ponty, the previously discussed notion of intentionality, '*giving meaning to that which appears and manifests itself*' (p.66) (7), is a bodily affair. This system of sensorimotor capacity that functions without one really being aware is called this 'body schema'. The basis of this schema follows from a coherence or unity at two different levels:

> 1- The parts of the body form a unity that does not just result from their sum total: the living body is experienced as one, rather than as a torso with a head, two arms and two legs attached to it.
>
> 2- In its pre-reflective perception and acting, the relationship between our body and the world is not oppositional, but marked by interaction and harmony.

Don Ihde defines a body schema as *'a non-conscious neural representation of the body's position and its capabilities for action'* (p.6) (8). As such, we could say that the incorporation of something into our body schema is a phenomenon falling under the concept of our body ´as lived´.

Whether or not tools have the possibility to be incorporated into the body schema depends on the so called 'transparency' of the tools. Martin Heidegger's distinction between *Zuhanden* (ready-to-hand) and *Vorhanden* (present-at-hand) illustrates this idea of transparency. Let's take for example a hammer. To someone who has never used a hammer before, the tool might feel clumsy, and that person is focused on learning how to work with the tool. As such the tool demands attention, remains in the forefront and is 'present-at-hand'. To someone having used a hammer before and being able to use it properly, it becomes a true tool, a means with which he can accomplish his aims. As such, using the tool of a hammer is no longer a point-of-focus. The hammer becomes a true tool, 'ready-at-hand', without requiring conscious thought about how to use it, where to hold it, and so on. Don Ihde builds further on this by stating that when using embodied tools to interact with the environment, one does not first intend an action on the tool and then on the environment. Rather, *'one merely intends an action on the environment through the tool and does not consciously experience the tool* *when doing so. The perceptual focal point is this on the tool-environment interface, rather than on the agent-tool interface'* (p.6) (8). This incorporation takes time, sometimes years as it will in the case of Ms. A for example, before a patient is truly able to use the tool properly.

In addition to transparency, Heersmink (8) mentions two more properties of tools which are beneficial to embodiment. First of all, he describes how trust in a tool is necessary for embodiment. If we use the example of a hammer, one that is stable, in which the handle does not have the tendency to fall off and which as a good grip, will be incorporated more quickly and easy than one which shows a variable performance.

Lastly, and quite interestingly, Heersmink discusses the role of proprioceptive feedback. As we briefly discussed in the case of Mr. B, proprioceptive feedback is the sensory information one receives as a result of a certain movement. This proprioceptive feedback we healthy subjects mostly take for granted. If we walk, we feel the earth under our feet, if we slam a hammer on a nail, we feel the backlash of the force and so on. According to Heersmink, this feedback is necessary while using tools in order to be able to assess the effect the tool has had on the environment and the agent.

Heersmink (8) discusses how opinions on the actual level of transparency of current BCI tools as experienced by the users, differ. Clark (28) points to a concrete example of a macaque monkey implanted with an electrode array in the motor cortex, which in turn controls an external robotic arm. The researchers working on this project saw how, after an intense training procedure, the monkeys learned to use the robotic arm independent of its real arms and could move its biological arms and the robotic arm at the same time. As such, Clark argues, that the robotic arm is a transparent bodily extension, making the BCI incorporated into the body schema.

On the other hand, Heersmink (8) himself argues that the current BCI systems are not enough transparent for users to be able to talk about embodied tools. He mentions examples of long training protocols for patients using the tools, the variability of the performance of the tools and the slow information transfer rated. Nevertheless, Heersmink argues that the potential for BCI's to become transparent bodily extensions is clearly present.

In addition to the body schema, Merleau-Ponty and philosophers after him have used the concept of ´Body Image´. In his article *Body image and body schema: A conceptual clarification*, Gallagher (29) describes the concept of Body Image as follows:

"[...] an intentional content of consciousness that consists of a system of perceptions, attitudes, and beliefs pertaining to one's own body". (29) (p.149)

Although the distinction between 'Body Schema' and 'Body Image' has lead to confusion in the literature over the years (29), it does help with identifying stages of 'tool-embodiment' or in the case of this thesis, neuro-engineering tool incorporation. More on this in the final chapters.

Language and Speaking

So far we have focused on the concepts of embodied experience, and how this relates back to the issue of body boundaries in disease. One last aspect worth mentioning and elaborating on, before moving onto Slatman's achievements, is the concept of language and speaking within this context of neuro-engineering endeavors. The phenomenon of language is a broad subject which we could write several separate thesis on, but nevertheless one worth briefly mentioning within this context.

As we have already briefly seen in the description of the case example of Ms. A, technology within the field of neuro-engineering is also focused on finding a way to reinstate a patient's ability to communicate with the world around him. In the extreme case of ALS, in which all muscle function is lost, this means that the brain-computer interface is actually the *only* way to communicate. Another famous example of a patients suffering from ALS and having to use technology to communicate, is the physicist Stephan Hawking.

As we briefly explained, in order to make communication possible, the newest versions of brain-computer interfaces translate brain waves picked up in motor areas in the brain to commands which on a computer screen translate (with a point-and-click system) into letters, words and sentences, which are then read out loud by an automated voice. The motor areas are actually targeted as these are areas where rather 'uncomplicated', well-translatable thoughts are formed. The patient is instructed and then trained to think of a certain movement, such as a hand movement which would mimic the movement of the cursor on the screen. By translating these brain waves into cursor movements through dedicated software, the patient is able to use the screen as if he was moving a mouse on a computer screen.

This functional process brings about an interesting situation. Suddenly, thinking about a certain command (for example hand to the right), is more important than the command itself (namely for the hand to go to the right). The command itself, namely, is no longer relevant or even the actual aim, but rather, a means of translation towards the screen and its cursor. If we connect this to some of the most basic concepts used in theory of language and language in relation to phenomenology, we will see that the use of such communicative technologies actually has very practical issues that need to be considered.

One of the main issues is the distinction between on the one hand 'thinking' and on the other hand 'speaking' or the use of language. For centuries, philosophers have asked themselves, does the one come before the other and put more broadly, what is the relation between the two? Some have argued that thought precedes language and that speaking is just the communication of thoughts. Merleau-Ponty himself has also added to the discussion (7). According to him, language could be compared to music. If we talk about music, we could focus on its components, namely the tones in the music. However, the meaning in these tones in themselves cannot be considered separately or as preceding the music. The tones are heard *through* hearing the music. In a parallel way, he argues that the meaning of thought can only be realized through language. Harré and Gilliet (30) have added to this by stating that consciousness is not something that comes before language but is in fact shaped by it. With the rise of the new BCI's aimed at communication, the role of thought in relation to language seems to be reinvented, or at least, changed significantly. To what extent can we still say that the meaning of thought is realized through language?

In addition, philosophers such as Wittgenstein have discussed the issue of 'private language', which could also be relevant in cases dealing with communicative technologies for patients. These theories on private language argue whether communication of subjective, private feelings such as 'pain' could ever be understood by others, or whether these spoken words would also have to be considered 'private' language. Wittgenstein argues that the latter is not the case, especially given facts such as our ability to teach children what the meaning of 'pain' is and how to use it. Slatman explains Wittgenstein's point of view as follows:

'*The meaning of words such as 'pain' cannot be explained as a reference to an assumed* *private object, but their meaning is achieved by using the words in a specific language game.*'. (p.150) (7)

How do these general points of discussion tie in with the developments in communication technologies for neuro-engineering? Interestingly enough, these more theoretical points of discussion tie in with quite practical decisions in the development process of these technologies. Take for example the screen the patients are presented with. This screen can be designed in multiple ways: technicians could choose to display the whole alphabet and have the patient type every word letter for letter. Other options would be to for example add a side bar with words often used, or even pictures instead of words, whole sentences or phrases ranging from 'I need to use the bathroom', to 'I love you, mom'. As such, one of the very first steps in designing the technology could have far-reaching consequences for the use of the system for the patient, and as such his ability to express himself through the device. One can imagine that the most ideal situation in this case would be to make these decisions on the design of the software based on the patient's preferences and his or her position in the world, as part of the already rising interest in personalized medicine within the medical field. Depending on the current situation of the patient, but also the patient's previous events, his or her personality, ambitions, preferences, family-members and so on, different issues would be more interesting to communicate than others. The design of the software could cater to that. Here we find an overlap with what we discussed earlier: language may convey private matters, but they are communicated into a public language as understandable for all. The software designed needs to perform this translations as optimally as possible, based on the particular patient's position in the world. Something the brain was used to doing on its own before the disease stuck these patients. For our case example of Ms. A, this means that her use of language through the BCI is not an objective matter. The communication software in the BCI is not just a 'neutral' instrument, which could be used by everybody and anybody with the same level of success and ease. Language as such is also an 'embodied tool', tied in with the patient's position in the world, as Slatman also tries to explain when discussing the role of the mouth in language*: 'the mouth ensures the connection of thought to the body's extension or put more precisely: the speaking mouth is the embodiment of thought'* (p.152) (7).

Although this language-aspect is not our main focus in our line of argumentation, we will see towards the ends of this thesis how these practical insights will tie in with the rest of the advices emerging from this collaboration between philosophy and neuro-engineering.

Jenny Slatman on Our Strange Body

In the previous chapter we have introduced phenomenological concepts surrounding the idea of the body and especially the embodied experience. In this chapter we will build further on this by discussing how Jenny Slatman uses similar concepts to discuss the phenomenology in today's medical interventions. Her central claim is that, due to the inherent strangeness in all of our body's, other 'strange' things such as prosthesis can be incorporated. While introducing her central thesis in this chapter, we will use the following chapters to compare and contrast the general medical interventions Slatman mentions with those particular for the field of neuro-engineering.

The Idea of Fremdkörper

Slatman starts out her reflections positioning herself within the interesting debate surrounding the question of identity: what is it that makes me remain the *same* person? After briefly discussing the thoughts of philosophers such as Aristotle and Locke on this matter, Slatman drives the discussion towards the physical component of this discussion: what is the role of the body in identity? And especially what can we consider to be our 'own'?

In order to illustrate her point, Slatman quite interestingly brings forward the example of organ transplantations. Currently, researchers and doctors have been able to perform transplantations previously only mentioned in sci-fi movies. Multiple successful face transplantations have been performed in the last decade, and even the first complete head transplantation is scheduled to be performed in the coming year on a patient with a muscular disease. Slatman discusses how in these transplantation settings there is always the discussion between what is 'own' and what is 'strange'. And although we have come a very long way and transplantations are no longer considered to be as shocking as perhaps some time ago, they do illustrate the idea of '*Fremdkörper*'. Slatman describes how this originally German term indicates that '*something or someone does not quite fit in some particular place; as if there is a stranger or alien in our mids.t*' (p.18) (7)

Slatman then sets out to explain the realm of the rest of her book, in which she aims to examine identity as a *phenomenon,* from the angle of the difference between the body's ownness and strangeness or otherness, while still considering the possible interdependency between the two.

Tolerating the Strange

'Tolerance is the Holy Grail for Transplant Physicians' (p.128) (31)

First, Slatman zooms in on the question why it is possible to tolerate the 'strange' in the first place. As an example, Slatman again mentions the process of organ transplantation, in this case one of the first hand transplantations ever performed successfully. Interestingly enough, Slatman brings forward the fact that, in addition to the affective consequences of having an 'alien' organ, which we will discuss later on, the physical *Körper* itself also reacts to the 'new' organ. Many of the complications after organ transplantation are actually a consequence of the body's immune system fighting and attacking the cells of the alien organ. In order to counteract this mechanism of organ rejection, patients are subjected to anti-immune medication, which aim to suppress the body's defense mechanism against the 'intruder'. Slatman describes this process as a form of 'self-estrangement'. This anti-immune medication and the weakening effect it has on the body's immune system has many side-effects, which for example have affected the philosopher Nancy, who after taking the medication for his heart transplantation, developed cancer. Slatman mentions how Nancy describes the process revolving around the heart transplantation in his book 'The Intruder' (32) as something 'strange to myself with myself estranging me (32), as a way of 'fighting one alien with another alien' (p.77) (7). As such, it becomes clear in Slatman's line of argumentation that for being able to tolerate the strange, it is sometimes necessary to estrange the 'healthy' body. However, Slatman argues that this estrangement of the 'healthy' body is an intrinsic characteristic already present in all bodies. Perhaps not consciously, but that is exactly the estranging part as well. This last addition is in line with the overarching thesis Slatman develops in her book, which we will come back to later on.

A second point Slatman adds is the role of sensorimotor proprioception in toleration of the strange. In order to further develop this point, we need to tie back in the concepts of *Leib* and *Körper* we have discussed earlier. Let us take again the example of the hand transplantation. Directly after the transplantation, Slatman describes how the patient referred to his new hands as '*the* hands'. These transplanted hands felt numb to the patient, alien and even somewhat of dead weight as directly after surgery most of the nerves still had to regrow into the transplanted tissue, making movement difficult. After months of training and patience, the patient began to regain some of his functionality. What is more, the patient regained limited sensory experience of the hands. One important component of sensory experience is proprioception, a sensory component linked to motor movements. Due to proprioception, one is able to know one's body position in relation to the environment, as well as to other body parts. This awareness however, is usually an unconscious process, necessary to function in everyday life, and often not in the forefront. In this particular patient the regain of proprioception allowed for the ability to estimate the position of the hand in its environment. This in combination with the motor control eventually lead to recognition of the transplants as '*his* hands'. In order to physically trace the mechanism behind this regain in proprioception, scientists have looked at the brain areas of this particular patient using MRI scans and were able to conclude that the plasticity in the body schema which occurred over time in this patient was reflected in the plasticity of the brain found on their scans. The new hands had reclaimed the brain area involved in motor planning of the hands.

Putting this in terms of *Leib* and *Körper*, we could say that due to the regain of functionality and sensory feedback, the patient's hands have turned into *lived* body parts, a *Leib* instead of just a *Körper*. Slatman describes this development as a 'restoration of the body schema' (p.78) (7) and a regain of the 'phenomenological unity' (p.78) (7) of the body. This regained unity however, is not one which rejects the *Körper*-aspect of the patient's body. Instead, it is a form of embracing the inherent strangeness already present. More on this later on.

As one can imagine, the role of proprioception and sensory feedback is not only relevant in this particular case of the hand transplantation. In both of the case examples introduced in an earlier chapter, proprioception and sensory feedback are of importance to the patient's experience of the new tools.

Limits to the Strange

So far we have discussed the notion of Fremdkörper as used in Slatman's *Our Strange Body*, as well as which factors contribute to the body's ability to tolerate and incorporate the strange due to suppressing the healthy body or regaining functionality and sensory feedback. However, Slatman argues that in contrast to the example of the hand transplantation we have used as an illustration, "*not everyone will tolerate the body's additional dose of strangeness inevitably associated with such a transplant*" (p.81) (7). Slatman then set outs to answer the question what could be factors counteracting our ability to tolerate the strange?

Firstly, Slatman focuses on the fact that even though regain of functionality was an important contributing factor in the hand transplantation example, it is not a *sufficient* criterion for success of incorporation in the body schema. In order to do so, she brings in a counterexample of a patient of the French doctor Dubernard, who received a single hand transplantation after a circular saw accident. Although this patient too regained almost full functionality after the transplantation, the patient did not reach the state of phenomenological unity as the previously discussed patient did. Even though the functionality was intact, the patient explained to still feel a great distance to the hand and how it looked on his body. In fact, this patient even opted to amputate his transplanted hand not too long after the initial surgery. Although the doctors involved in this 'failed' transplantation attempt described the patient as difficult and not taking his medication, I think it would be too easy to write this patient off like that. Just as Slatman says, we cannot expect everyone to incorporate the strange as easily. Every *res extensa* cannot replace any other *res extensa* (p.127) (7), even if problems of functionality are no longer at the forefront. According to Slatman, examples like these make clear the fact that regain of functionality in itself, and as such incorporation in the body schema itself, are necessary but not sufficient developments when it comes to the process of incorporating the strange. Rather, emotional or affective tolerance is necessary. Through this last remark, Slatman also points out the components missing in theories of philosophers such as Merleau-Ponty, whose theory on the body schema needs to be supplemented as his analysis merely starts from 'handiness' and functionality.

The Strange 'I'

Having discussed what makes us tolerate the strange and what limits this tolerance, we will now briefly set out Slatman's central thesis we have already touched upon briefly: the inherent strangeness of the body which allows for incorporation of 'new' strangeness. As a rule the body already comes with an alien dimension to it.

In order to make her point, Slatman elaborates on the distinction between internal and external intruders. Much like Merleau-Ponty and his embodied existence, Slatman describes the state of the 'healthy' body as one of silence. In a healthy state, we are not aware of most of our organs, bodily functions or other processes taking place. In that sense, our body presents itself with a form of transparency, which allows us to perform out tasks without consciously being aware of the body we are performing the tasks with. Compare this for example with the previously discussed situation of using a tool such as an hammer. This 'silence of the healthy body', Slatman explains, holds a certain inherent strangeness in itself. The 'internal' intruder, such as a tumor, does not always reveal itself. And that is often what makes this example of cancer such a terrifying one: you often do not know until it is too late. This unpredictability and hidden nature of the intruder are contributing to the internal strangeness we all carry with us. This strangeness applies to the body in the sense of *Körper* as well as when the *Körper* is touched and simultaneously becomes a *Leib*, in cases of for example pain.

According to Slatman, as well as Nancy by whom she is inspired, this internal strangeness forms solid ground for external intruders to actually be accepted. She introduces the simple example of having glasses. Most of us wear glasses without even being aware of the fact that we have them on, even though glasses would strictly fall under the category of prosthesis or 'add-ons'. According to Slatman, '*the tolerance of the strangeness of the prosthesis is enabled by the strangeness that is always in us already*'. (p.157) (7) An external intruder (a prosthesis) will replace or at times even remove something of the internal strangeness.

As such, the thing-like nature of our body, the inherent *Fremdkörper* aspect, is actually what allows us to expand our bodily boundaries. Through that, Slatman positions herself opposite to some of the first philosophers known to man, including Plato, who considered the *Körper*-aspect of the body being a weight bringing us down, with a strangeness that would actually stand in the way of our owning it.

Slatman's Achievements applied to the field of Neuro-Engineering

The previous two chapters have allowed us to draw both a general as a Slatman-specific phenomenological groundwork for reflection. In this chapter we will zoom in on one of the main questions of our thesis. Can the phenomenological concepts used by Slatman to argue that medical interventions can be well-incorporated by patients also be applied to the field of neuro-engineering? And if yes, to what extent? What are the conditions that actually obstruct such incorporation? In order to answer this question, however, we will also dedicate an intermezzo to answering the question why it seems relevant to single out neuro-engineering in particular within the whole variety of medical interventions.

In order to be able to assess whether Slatman's achievements in *Our Strange Body* would be applicable to cases within the field of neuro-engineering in particular, we will bring back onto the center stage the two case examples of Ms. A and Mr. B we have discussed earlier.

First of all we have looked at what might help a patient tolerate 'the strange', namely regain of functionality and presence of proprioception or sensory feedback in general.
Let us take the example of Ms. A, the patient with ALS who received a BCI. The devastating impact of ALS is the fact that with the disease, almost all functionality is lost, due to complete loss of motor control. As such, for neuro-engineering to be able to bring back the level of functionality of these patients to completely normal, a lot needs to happen. The BCI of Ms. A, however, focuses on one subset of problems, namely that of communication. We could say that this new BCI succeeds in its mission: as one of the first and most advanced devices in the world, it allows Ms. A to use her computer to communicate her thoughts and wishes. However, as one can imagine the device has its limitations. Speed, accuracy and complexity of language is not at the same level as it once was.
The question now is, to what extent does this influence Ms. A's ability to 'tolerate' this 'strange', as Slatman discusses?
Answering this particular question is an interesting one, as it relates back to our previously mentioned discussion between 'is' and 'ought'. We might say that one or two good empirical studies looking into how patients such as ms. A experience the process of 'tolerance of the strange', might already do the trick. However, here we face a problem which might be relevant throughout the thesis. An empirical study can tell us how it *is* the case for certain patients, but does not necessarily lead to the conclusion that it *ought* to be as such. This very

classic problem is also referred to as the ‘naturalistic fallacy’. Looking at this thesis, we are working towards answering the question whether neuro-engineering and phenomenology can be on the same team, and if so, how they should shape to their collaboration in clinical practice. In order to answer the first part of the question, we take several *empirical* case examples to test whether the concepts as used in phenomenology (e.g. the role of ‘sensory feedback’) in a similar way apply to these neuro-engineering case examples. From there we make a leap to the question in the next chapters, how can everyone in this field apply this knowledge? What is worth noticing and pointing out is that this seemingly big leap is closed off with assumptions that we have not made explicit as of yet. Although we take empirical cases to measure whether the concepts used by philosophers such as Slatman apply to neuro-engineering, we do not necessarily claim that this is how it always *ought* to be. At least, what happens is that we make an overview of the *practical* use of these concepts in the neuro-engineering field, and aim to communicate this practical use in the form recommendations for experts in the field. However, these recommendations are first and foremost completely nuanced, as we will see later on, with the aim of doing justice to the already very versatile range of examples we bring forward in this thesis alone. Secondly, the mere fact that some concepts *might* be applicable, is actually already a large part of our claim, as we are trying to create awareness. Without giving away too much of our conclusion, our recommendations aim to make experts in the field *aware* of the ability to apply certain phenomenological concepts or combinations of concepts to clinical practice, and their potential use and benefit. The fact that the clinic is very nuanced and versatile, and every *is* does not always imply an *ought*, is already accepted as a part of this effort.

Let us now move on to another concept used by Slatman. Secondly, we have the point of sensory feedback to address. Interestingly enough, in the case of the BCI of Ms. A we cannot really speak of sensory feedback in the sensorimotor sense of the word. By using the typing software, Ms. A is able to communicate to the outside world. However, the process of typing, and the success of doing so, is not something Ms. A experiences physically, as she would when for example opening and closing her mouth to speak. Rather, the feedback is indirect, just as we receive feedback when correcting a text we have written down on the computer. Perhaps we could argue, the feedback has mostly occurred during the training period, where Ms. A was performing multiple tasks per day in order to adjust the software to her own personal ‘brain-waves’.

Lastly, we have discussed how Slatman adds to the components of functionality and feedback, the need of affective or emotional tolerance for ‘the strange’. She makes this point more clear by explaining that one functional *res extensa* is not the same as any other functional *res extensa*. Unlike the previous examples of hand transplantations, which in their exterior mimicked hands, the BCI’s such as used by Ms. A do not have an exterior easily identifiable as a body part or even humane tissue. At first sight, we might then argue that this last criterion of affective or emotional tolerance, might already be difficult if not impossible in BCI’s. Although the internally placed brain implant is not visible to the patient, the external device is always in view and very much present as an attached screen to the wheelchair. Will a patient ever really tolerate this? On the other hand, we have also discussed examples of other inanimate tools, which have proven to be possible to incorporate in the body schema. Hammers, glasses, hats, we have been able to look beyond these and use them as tools within our body schema. Therefore, in the case of neuro-engineering, we might expect the same. For now, we will leave this point of emotional or affective tolerance in the case of neuro-engineering undecided, as we will elaborate on this more when discussing case example B, as well as in the next chapter where we will discuss how on this particular subpoint made by Slatman, neuro-engineering and phenomenology could collaborate.

Before moving onto example B, we might first want to discuss one of the assumptions we might have when wanting to compare Slatman’s achievements in medical interventions in general to neuro-engineering in particular: is neuro-engineering really a different ‘ball game’?

Intermezzo- Neuro-engineering: really a different 'ball game'?

How come we are going out of our way in this thesis to apply Slatman's achievements in the field of medical interventions general to the field of neuro-engineering in particular? Can't we just assume that these neuro-engineering interventions behave in similar or parallel ways?

These are of course very fair and relevant questions, which even partially overlap with the main questions of this thesis. Of course the aim of this thesis is to specifically apply the phenomenological efforts to the field of neuro-engineering in particular in order to even come up with practical guidelines for doctor and engineers working in this field. Therefore, it is mostly this specificity of the aim which has pushed us to not just assume that Slatman's ideas can be applied to neuro-engineering as well, but to thoroughly investigate this. Nevertheless, in general, neuro-related issues are often considered to be a separate class, even apart from the particular motivations driving this thesis.

What seems to be underlying the effort to look at neuro-engineering as a different class at all is the general tendency to separate anything neuro-related from the rest of the possible list of physical diseases. Years of discussion about the distinction between body and mind might have conditioned us in this way. Without even scratching the surface of this debate, we mention the concept of dualism introduced by Descartes which might underlie most of the arguments. Ever since we have come to think in terms of 'the body' and 'the mind', in 'physical' and 'non-physical', the brain in the public eye has acquired the status of the 'magic organ', where perhaps both worlds meet. It is with this underlying assumption that we tend to think of neuro-related diseases as different than others.

Is this different classification of neuro-engineering completely justified? I would actually argue that in the end, it is not. Although I have spent most of the paragraph before this one elaborating on what would make neuro-engineering a different class, I think the results and line of argumentation of this thesis will eventually lead to a result which will show us that in fact, neuro-engineering and phenomenology will be on the same team in a similar way as any other medical field would. After all, the phenomenological application to neuro-engineering has great parallels with its application to other medical fields. And that it is exactly this realization which will allow us to make sure that phenomenology and neuro-engineering indeed end up on the same team, even if intuitively one might to put neuro-engineering in a 'different class'.

Now let us take a closer look to Mr. B, our patient with paraplegia. The neuro-engineering device as currently designed by scientist would allow him to regain some functionality due to electrical stimulation, bypassing his spinal cord injury. By thinking of walking, the walking itself will actually be initiated due to the spinal cord and brain interface which is part of the mechanism.

If we again apply the criterion of functionality as brought forward by Slatman, we could say that indeed, the neuro-engineering device is one which delivers to a certain extent. Under stimulation and due to the brain implant which uses the brain's own waves as an initiation for the walking pattern, the patient would be able to stand in an upright position and move about in a reasonably smooth manner. Other aspects of the spinal cord injury however, such as bladder control or pain experience, is not necessarily addressed or tackled by the current neuro-engineering devices. Intuitively, we might think that the regain in motor response in itself could be a very valuable addition to the quality of life of the patient. However, if we look at large scale patient preference research, many patients agree with Mr. B from our example: the chair itself, the lack of mobility itself, is not the major concern. Rather, the sometimes embarrassing an limiting problems of bladder control, but also the extreme pain and spasticity due to the injury, are more clearly present and therefore often have priority for the patient (33,34). We might therefore wonder whether the functionality we aim for at first glance, is indeed real functionality for the patient or just leaves the patient stuck in a state of focus on the body image. Exactly in this careful consideration lies again a beautiful meeting ground for phenomenology and neuro-engineering, which we will discuss in the next chapter.

The point of sensory feedback is also a difficult one. The concept of feedback is of course very important in the process of locomotion. Any movement in our legs leads to a change in our muscles, which in their turn fire to communicate their position and strength. Due to this, locomotion continuous to be a smooth, synchronized movement. Therefore, scientists have always been interested in incorporating feedback in their neuro-engineering devices. One of the first successful spinal cord stimulators in paraplegic monkeys indeed contained a sensory feedback component, by recording the dorsal root ganglions in the spinal cord (which are responsible for gathering all the sensory feedback information coming from the hind limbs) and feeding this info back into the spinal cord stimulation processor, which activates and steers the locomotion pattern.

However, this feedback in itself is interesting. Unlike feedback in a healthy physiological state, the neuro-engineering device does not allow for the conscious awareness of feedback for the patient. As we discussed, sensory feedback in the form of proprioception in a healthy subject is often an unconscious process. We need proprioception, we use proprioception, but we are not necessarily aware of proprioception. We are for example not continuously made aware of the fact that our feet are touching the ground. Only when the situation changes, and we suddenly feel 'the ground falling from under us' or our feet getting stuck behind a chair, that we are suddenly forced to pay attention to the sensory feedback which was once doing its job in silence. In the case of feedback of these neuro-engineering devices, however, the feedback is only fed back into the processor, which creates the algorithm for the walking pattern, This processor bypasses the spinal cord injury, as well as the possibility of conscious awareness for the patient. As such, the functional use of feedback remains intact, but the experience of feedback is lost. What is then the consequence for the patients tolerance, as Slatman would say? More on this when we discuss the role of sensory feedback and functionality in the next chapter.

Lastly, we have the point of affective or emotional tolerance to discuss. In the case example of Mr. B in particular we have an interesting situation: a device which provides electrical current takes over the locomotion of the patient. One would consider that to be perhaps quite a severe intervention. However, on the outside we might see little sign of such an intervention. Unlike the external screen in the case of Ms. A, Mr. B will have a device implanted into his spinal cord and vertebral column, which except for some scars from the surgery, will show nothing on the outside. The most important question in this setting then becomes, does that make the tolerance easier? If one is able to forget the device by actually not seeing the device? Or, as Slatman herself also argues, is the fact that the device is working so vigorously, without 'showing' itself, just a replacement for the inherent strangeness we have already discussed? Are we then indeed exchanging one strange for the other?

Again, we finish off our train of thoughts with mostly questions and no answers. The aim of the following chapters will be not necessarily to answer the questions that have passed, but rather to take them as an inspiration for and examples of the discussion points found on the border between the field of neuro-engineering and phenomenology. We will see how and why these discussion points can actually serve as stepping stones to build the fundament for a world in which phenomenology and neuro-engineering are 'on the same team'.

Phenomenology and Neuro-Engineering: On the Same Team

The previous chapters we have dedicated to introducing the relevant phenomenological concepts used by Slatman and others to describe the role and consequence of medical interventions. In addition, we have looked at to what extent the points made by Slatman would be equally applicable to the field of neuro-engineering. In this chapter we will zoom into answering another one of our main questions. Given this knowledge gathered in the previous chapters, could we indeed state that phenomenology and neuro-engineering should be on the same team? And if yes, how should we see this collaboration?

In the previous chapter we have discussed to what extent functionality, sensory feedback and the emotional and/or affective role of tolerance can be applied to neuro-engineering specific examples. Although we could confirm the applicability of these concepts to the field of neuro-engineering to a great extent, we have finished off with many open-ended discussion points. In this chapter we will acknowledge that we cannot answer as decisively as we may want or expect, which counts as the main and most general argument for a collaboration between phenomenology and neuro-engineering. We will also see how this result eventually relates to the practice of 'personalized medicine'. We will conclude this chapter with a brief intermezzo, answering a question which has perhaps already sprung to mind, how is this different from plain medical ethics?

Functionality, Sensory Feedback and Affective Experience: Variation, Variation, Variation

'Implantation does not mean nor amounts to embodiment- or incorporation.' (p.644) (35)

If applying the neuro-engineering case examples to the concepts used by Slatman has taught us one thing, then it is that there is an enormous amount of inter-patient variation in how and to what extent these concepts apply. We have seen how functionality in cases such as those of Mr. B can be a point of debate: is the functionality gained by a SCS stimulator for motor response really the type of functionality a paraplegic patient is aiming for? Also, we have seen how sensory feedback, although present, does not necessarily count for a better tolerance or incorporation of the implant in the body schema. In addition, when comparing Ms. A to Mr. B, we have also discussed how emotional or affective components play a role in our tolerance of neuro-engineering devices. Although we might expect Ms. A to have more difficulty in accepting the software required for communication, as it works through an always present computer screen, patients with an implantable device such as Mr. B also present with emotional difficulty to accept the implant, even though they are not visually reminded of the implant. As another illuminating example, in a series of patient interviews published by Dalibert (35), patients with SCS for the indication of pain commented on their view of the implanted stimulator. Dalibert brings forward two contrasting examples. First of all, Mrs. Bloemen is introduced, about whom Dalibert states the following:

"V*isually, haptically and affectively mrs. Bloemen cannot relate to or identify with the SCS. As she can see and touch the pulse generator under her skin she cannot identify with and incorporate the neuromodulation technology. It remains a tool or an instrument; it is not (a) part of her body*" (p.650) (35).

In contrast to mrs. Bloemen, mr. van Houten states the following about his SCS experience:

"*Mr. Van Houten is grateful for the neuromodulation technology that has not only become part of his body but has also enabled him to do things and to be part of the world –of life- again. In fact, he is so content with it that, as he told me later in the interview, he would like to have a zipper put in his back so that the world could see his implant, which he calls a pacemaker for his legs and back*". (p.641) (35)

Just as in our two examples, a similar device with a similar position within the body leads to a very different experience between two patients. In mr. van Houten's case, we could state that the implant is completely incorporated in the body schema and transparent to such an extent, that the patient himself wishes it would be more apparent with the help of a 'zipper'. Transparency in this case seems to be unrelated to functionality, unrelated to sensory feedback as such, but an affective or emotional issue, related to the patient and its specific being-in-the-world. Dalibert (35) goes on to explain how for mrs. Bloemen, not only her own view on the implant, but especially that of her husband is crucial for the experience of transparency. In a transcript part of the interview she states:

"*I don't like it that he [her husband] can feel it. At first you make jokes about it but at some point the fun stops." (p.650)* (35)

Not only does this statement illustrate the lack of transparency in mrs. Bloemen's particular case, but also the fact that mrs. Bloemen is very much focused on what Merleau-Ponty defined as ‘Body Image’. Instead of incorporating the device into the body and allowing it to disappear as any truly functional tool would, mrs. Bloemen is ‘stuck on’ the ‘Body Image’ of the device, making it hard to truly accept ‘the strange’. Whether or not a patient will turn out like a mrs. Bloemen is a difficult prediction to make beforehand. It requires careful consideration and conversation, allowing the patient to draw up possible scenarios involving neuro-engineering devices, their consequences, and the patient’s ability to accomplish the existential reconstruction necessary to leave the stage of ‘body-image focus’ and reach transparency. More on this in following chapters.

Patient Preference Diagnosis

What everything boils down to is the fact that the experience of the patient, the embodied experience in the sense we have discussed earlier, can be very different, even if many of the basic concepts such as functionality are adhered to. And right here, is where the essence of phenomenology boils up and shows itself as useful in collaboration with neuro-engineering. Let us dive deeper into this.

In the last decades, medicine has come to realize more and more that a plain old diagnosis of the disease is not everything that falls under the umbrella of the medical field. Patient preferences, and shared decision-making are concepts that are becoming more and more prominent in medical research and practice. In an editorial comment in the highly esteemed British Medical Journal (BMJ) (36) these thoughts are very cleverly summarized in a ‘new’ form of diagnosis, named the ‘Patient Preference Diagnosis’ (PPD). The lack of PPD is described as follows:

“The doctor recommends treatment based on what is known of the patient’s disease, age, and general health, and using evidence on which treatments work best, but fails to discover what matters most to the patient” (p. 7745) (36).

Using the PPD and making it an integral component of any medical intervention, leads to a situation in which the doctor together with the patient draws out a map of the patient’s Being-in-the-world (as coined by Martin Heidegger) in relation to the possible medical interventions. Heidegger’s being-in-the-world denotes that there is always a ‘mood’ in which we encounter the things in the world. This mood involves the wishes, values and norms of the patient, as well as for example the patient’s vision on his or her body. An important part of these PPD conversations is to draw out the scenarios and possible consequences of each scenario within a patient's life to come to an understanding which is as well-rounded as possible. The authors of the PPD editorial recommend that in practice, the following can be done to come to an PDD:

"Instead, try adopting a mindset of scientific detachment, using data to reach a provisional preference diagnosis, and having a conversation with the patient. The authors suggest breaking this conversation into three elements: team talk (in which the patient is encouraged to understand that he or she is "on the team", option talk, and decision talk." (p. 7745) (36).

When drawing back the parallel to our particular case of neuro-engineering, we could say that any neuro-engineering endeavor requires a great deal of PPD before even starting the process. But more than that, it requires continuous attention during and after the process of implantation, training etc. What neuro-engineering in combination with phenomenology has thought us, is although we can formulate concepts that are important in the process of neuro-engineering, it boils down to the patient in specific to come to the conclusion whether and how the device is incorporated in the body schema and leads to a comfortable degree of transparency. It requires a form of existential reorientation. The fact that we position 'incorporation' as the ultimate goal in this thesis, is based on the idea that the neuro-engineering device aims first and foremost to repair and restore functionality to a basic functioning level, as close to 'normal' as possible. Any part of normal functioning when using our body as 'a tool', is the level of transparency we reach with our body. As previously discussed in the examples of the hammer as a tool, transparency allows us to perform the task without being focused on the tool itself, making the task easier. Therefore, it is not strange that a team of engineers, doctors together with the patient wish to reach a state of transparency. Is this really necessary? Could we do without? Well, the examples we have discussed of the current state of most neuro-engineering devices already how us that, although we are still far from a level of transparency we can reach when using a hammer, these devises are still tremendously helpful for the patients using them. Therefore, a neuro-engineering device can definitely work without reaching a full level of transparency. However, as we have also discussed earlier, reaching full transparency, and as such being able to 'ignore' the device while using it, makes the device as much a port of your 'normal' body as the original, now malfunctioning, body part. For the acceptance, or incorporation, of such a device into the rest of the body and the patient's life as a whole, we can image that to be a huge benefit.

In order to assess the actual level of 'incorporation' or 'existential reorientation', I suggest a form of 'Patient Transparency Diagnosis' (PTD), with which physicians, engineers and other neuro-engineering experts take the time *during* the process to together with the patient reflect on how the incorporation is going, and especially, on how to improve this if necessary. This is an idea very similar to that of 'personalized medicine', which is already up and coming in medicine. What we seem to be aiming towards is a form of 'personalized neuro-engineering'.

Personalized Neuro-Engineering

In medicine, personalized medicine is defined as a trend towards more custom-made medical prevention, advice and treatment (37). Often, within the medical field the concept of 'personalized medicine' has a strong genetic connotation. Due to the developments in genetic screenings in the last decades, scientists and doctors are now able to analyze a patient's genetic make-up and on the basis of that predict how a patient will react to a specific treatment, and especially, which treatment or combination of treatments would be most suitable for the patient. The success of this personalized medicine is in turn due to the emergence of 'Big Data': the collection and analysis of large amounts of medical data gathered in big databases. This vast amount of data in one place allows for the discovery of previously unknown correlations and causal factors in disease processes as well as in disease treatment.

In our case, we would be stepping away from a mostly genetic connotation of personalized medicine, towards a form of personalized neuro-engineering. In the next and final chapter, we will take into account the line of argumentation up till now and try to formulate a set of practical recommendations to make the theory behind phenomenology and neuro-engineering 'on the same team', especially within the context of 'personalized neuro-engineering' and 'PTD', come to life.

Intermezzo- Aren't we just doing medical ethics?

In these last chapters of this thesis we are working towards recommendations such as the 'Patient Preference Diagnosis' (PDD) which, as we discussed, touch upon concepts such as 'personalized medicine'. Within the field of medical-ethics, this same emphasis on patient preferences, but then from the perspective of patient 'autonomy' is discussed. How does this differ from our phenomenological endeavor?

Let us first of all mention why it does not differ. Phenomenology applied to medicine, and medical ethics alike, aims to put the patient and its preferences, wishes and ideas at the center and forefront. Not only with the idea that this will benefit the patient, but also with the belief that this will help enhance the medical process and the success of interventions. As such, the aim of both is clearly overlapping.

However, if we look at the ethical concept of 'autonomy' in particular, we are talking about *allowing* the patient to express his or her wishes with regard to the treatment, and *allowing* the patient to act upon these wishes, as far as possible within the rules and limits of medical practice.

However, what our phenomenological endeavor, and the many case examples we have discussed, already show and will show, is that neuro-engineering endeavors have a large 'mystery' factor about them: due to their new and innovative character, the exact result of these devices in medical practice can be difficult to assess. Will the device actually be well-incorporated by the patient? Will the patient actually be able to live with this?

And more than the difficulty we might have in answering these questions, the patient himself has a tough job in trying to picture these hypothetical scenario's. Phenomenology seems to be able to give us tools in conversation, such as the PPD but also the Patient Transparency Diagnosis (PTD), which will help patient and doctors in discussing these matters. And although of course our ethical compass will eventually tell us to act upon the patient's eventual wishes, reaching the state in which the patient can make well-funded claims about the wish, is in itself already a challenge phenomenology tries to tackle.

Future Phenomenological Directions for Neuro-Engineering Endeavors

Having argued for the possibility and benefit of a collaboration between neuro-engineering and philosophy, we have reached the final and most practical chapter. If this collaboration in theory is indeed so fruitful, what does this mean for the everyday practice of physicians, technicians, patients and others involved with the field of neuro-engineering? How can they incorporate this potentially fruitful collaboration in their day-to-day practice? And what does this mean for the future of phenomenological concepts within the many neuro-engineering endeavors to follow?

First and foremost, before even attempting to answer these questions it is important to communicate the disclaimer that within the realm of this thesis, we will not be able to answer these questions sufficiently. Rather, we will attempt to translate the line of argumentation found in the previous chapters into practical guidelines which might be taken into account in everyday practice. As such, the following recommendations will form a first attempt and inspiration for the future (phenomenological) direction of neuro-engineering endeavors and not at all a sufficient guide.

Patient Preference Diagnosis

The PPD as discussed in the previous chapter is an important component to start out the endeavor of neuro-engineering with a patient. By starting out the conversation about the possible neuro-engineering device, and assessing the patient's possible existential reorientation on each of the alternatives and possible consequences of each alternative, the patient and doctor make sure they are on the same page.
If we take the example of Ms. A as discussed in the section on language and speaking the way the screen is designed and hooked up to the underlying software dictates the behavior of the patient. The patient will be 'at the mercy' of the software, its possibilities and inevitable restrictions. Dalibert (35) describes this commanding aspect of technology as a 'script'; technologies have 'scripts' inasmuch as they can prescribe certain actions (p.642) (7). Consulting the patient beforehand on his expectations of the software, his wishes for the display and his aims with the software, will allow the best possible starting point for the patient and its device.

Interestingly enough, this ‘practical tip’ might sound obvious, perhaps too obvious. Aren’t all doctors already up-to-date on this?
The authors in the original BMJ editorial must have asked themselves the same question . They answer it as follows:

“Most of you will already be making efforts to understand what your patients want, or will think that you are doing this. And many patients won’t know what they want to do even when the options are fully explained to them. So what do you say when a patient asks you to recommend a course of action? What you shouldn’t do, say the authors, is ask yourself what you would choose, or what you would advise someone you love. And you should beware of the tendency to think that the right treatment for this patient happens to the one that you specialize in or your institution performs a lot.”(p. 7745) (36)

Although doctors have experience in how to introduce their patients to concepts such as an implant, a stimulator, an electrical wire and so on, understanding what is going to happen and trying to picture what the experience of having such an implant in your body, are extremely different things. Especially when it is unknown to the patient what the complete set of consequences of such a device will be. How will the implant feel? What will others see of it? How well will it stay in place? Will it restrict the patient in any way? All questions that are answered differently depending on the patient sitting across from the table. Emphasis on the PPD as part of the medical process at least ‘normalizes’ the effort, and makes sure this almost ‘existential therapy’ is part of the routine.

Patient Transparency Diagnosis

Although the previously discussed PPD is already quite incorporated into the medical field, it is important, especially when it comes to neuro-engineering, to look at the whole of the process and assess its success. Most importantly is to realize what to judge this success by. Previously we have discussed the concepts of functionality, sensory feedback and emotional tolerance. However, what we were actually assessing were three concepts that in theory and often in practice lead to transparency and incorporation into the body schema. As one of the patients of Dalibert describes, as it ‘belonging to their body’. Dalibert describes this as follows: “*while embodiment of SCS is necessary to live with the technology, it is not sufficient to live well with it: the technology must be incorporated*”. (p. 7745) (35)

Therefore, it is important to throughout the neuro-engineering intervention process, as well as afterwards, have regular reflective conversations with patients on the level of transparency and incorporation of their device. These conversations will have to center around the actual current level of transparency, the desired level of transparency given the desired level of incorporation, as well as the importance the patient would like to adhere to the concept of transparency in the first place. These questions that will have to be asked to truly assess this, are to their core phenomenological, asking a patient to communicate his or her experience with the device form their perspective, within their situational being-in-the-world. It is here where doctors or engineers are asked to think as phenomenologists, and get to the core of the patient's experience. Not only will these questions lead to immediate feedback for the medical profession and its success in the field of neuro-engineering, but it will also allow for possible adjustments of the device to the likings of the patient. Imagine a mrs. Bloemen, who is self-conscious about her husband seeing the device in her back and as such seems to be stuck on the concept of ;'Body Image' as Merleau-Ponty discusses. Figuring out this underlying problem, and what is the assumption behind it (e.g. 'I am not truly feminine if I have such a bulge sticking out from by back') through phenomenological inquiry. This discovery might give opportunities to cater to her wishes, in such a way that mrs. Bloemen herself was not aware of. Perhaps, next time the battery of the device needs to be changed surgically, the surgeons can decide to place the stimulator on a for mrs. Bloemen more subtle location.

Here the importance of including the patient's 'narrative' emerges as well. For a patient receiving a neuro-engineering device for medical reasons, the body in itself has lost its transparency when it turned into an 'ill body'. Complete regain of transparency might therefore be difficult or impossible. However, the ultimate goals a device could reach is giving a patient the feeling of *'belonging somewhere again, as being part of life'* (p.647) (7). As Slatman herself describes in the example of Stephan Hawking, '*the various technologies allow Stephan Hawking to lead a more humane existence*' (p.144) (7). There is no straightforward, pre-existing mould in which we can poor every neuro-engineering device to reach this ultimate goal. As was clear from our examples, not even the location of implantation, the shape of the device or the workings of the device are easily generalized. For children, different criteria need to be met than for adults. For women, different aspects play a role than for men. And for woman A, different criteria are relevant than for woman B. One of the most important aspects that do underlie all of the individual examples brings us back to the distinction between *Leib* and *Körper*. Dalibert states the following about that:

"Implantation does not amount to the technology's disappearance. Rather its disappearance or transparency is a bodily process. While the technology becomes progressively embodied through a playful groping process in which gestures are central, it profoundly changes the way the body is present for oneself, which entails becoming attentive to and intimate with one's bodily materiality" (p.653) (7)

In this quote, it is put forward very eloquently, that for the neuro-engineering device to be successful, it is important and inevitable to focus on and be accepting of the *Körper* aspect of one's body. Not only for the physician, but especially for the patient this is a necessary assumption. In a way, with all the discussion about the distinction between Leib and Körper having taken place over the years, it is almost necessary to add the adjective 'permissible' when describing this assumption.

The *Körper* as a Necessary and Permissible Assumption

'The body as an object is necessary'. (p.78) (7)

In medicine, phenomenology over the past years has played a role in introducing concepts such as *Leib* and *Körper* which we have discussed and used previously. In these efforts, philosophers have mainly focused on pointing out the difference in perspective between patient, who experiences the body as lived, and the doctor, who experiences the body as a material object. Many philosophers have played a role in the noble goal of making this difference in perspective not only apparent, but also formulating ways in which this inevitable gap can be closed to further benefit the patient and the medical process.
As a perhaps unwanted side-effect, these efforts have made the *Körper*-aspect of the body within medicine a difficult one, often found with a rather negate connotation. Especially from the medical expert's point of view, it has been rather emphasized that a strictly material outlook on the body is detrimental to the patient's experience of the disease and medical intervention.
This in turn leads to the problem that the mere necessity of looking at the body as a *Körper* is no longer as relevant as it should be. Within the field of neuro-engineering, it is especially important to make this assumption permissible again.

How do we actually accomplish this renewed focus on the body as a *Körper*? The answer seems to lie in the concept of 'oscillations' as discussed by Carel et al. in the *Lancet* (38):

"Our suggestion is to try to move from viewing the physician's perspective as objective and the patient's perspective as subjective towards a greater appreciation of the oscillation from one position to the other. This oscillation does not denote an inconsistency. On the contrary: it marks the unique duality of the human body, which is capable of both subjective experiencing and of being experienced by others as an object. Recognizing the oscillation as key to understanding human experience in its openness and vulnerability might serve as a step towards contesting the expectation that doctors should be purely objective in their clinical practice." (p.2335) (38)

By allowing the patient and the doctor to oscillate, both separately and as a team, between seeing the body as an object, a machine with a problem to fix using engineering, and the body as *lived*, as body which needs to incorporate the engineering device as its own in order to be able to function properly, the doctor and patient will cover all relevant grounds of the process. While as we saw, functionality and sensory feedback pushes us towards a more Körper view of the body, it is necessary to have these aspects down in order to even move towards transparency. Once the physical constraints and necessities are addressed, we can focus on the emotional, and affective side of tolerance, the inter-patient difference which is tied to each patient's being-in-the-world and his wishes, wants and expectations that come with that.

The fact that we here seem to speak of oscillation to illustrate the process, however, must not fool us into believing that the concepts of Leib and Körper are any less intertwined than they actually are. It is worth noting that the Leib-aspect of the experience of the body in itself is very much linked to a knowledge of the state of the Körper, continuously making the one an inevitable (counter-)part of the other.

Conclusion

We started out this thesis by describing the public rivalry neuroscience and philosophy have found themselves in. In the last chapters we have built up an argument which would promote a completely different approach: one in which neuroscience as a whole (and neuro-engineering in particular) and philosophy as a whole (with phenomenology in particular), find themselves on the same team.

In order to reach this goal, we have started out by drawing a picture of the current landscape of the neuro-engineering field. By zooming in on two typical case examples in particular, we have been able to apply the relevant phenomenological concepts later on in the thesis. In addition to elaborating on the general concept of embodiment, in relation to theory's on body schema and body image from philosophers such as Merleau-Ponty, we have taken Jenny Slatman's *Our Strange Body*, and the concepts of functionality, sensory feedback, affective tolerance and inherent strangeness in particular, as points of reference. After applying these concepts to the field of neuro-engineering in particular, we were able to conclude that indeed the concepts were applicable, although discussion remained. Within the lacuna that these discussions left, we have found the room where neuro-engineering seems to need and be able to collaborate with phenomenology. We have discussed how previously discussed general concepts on tolerance after neuro-engineering interventions will never draw the complete picture for the patient. Indeed, the process involved in neuro-engineering is a very individual and personal one, much like as is already recognized in existing concept of 'Personalized Medicine'. In the lacuna that is found between adherence to the concepts of functionality, feedback and affective tolerance on the one hand, and the actual success of incorporation of the device by the patient on the other hand, lies a field where neuro-engineering and phenomenology overlap and are 'on the same team'.

From here on out we have moved on to argue for the introduction of 'Patient Transparency Diagnosis' (PTD), which will allow an engineer, doctor or any other relevant expert to use phenomenological inquiry as a way to successfully guide, facilitate and encourage the incorporation of a neuro-engineering device into a patient's body schema, eventually leading up to a satisfactory level of transparency and existential reorientation.

Lastly, we have discussed what practical recommendation and/or guidelines could be extracted from this line of argumentation. First of all, we have discussed the importance of a

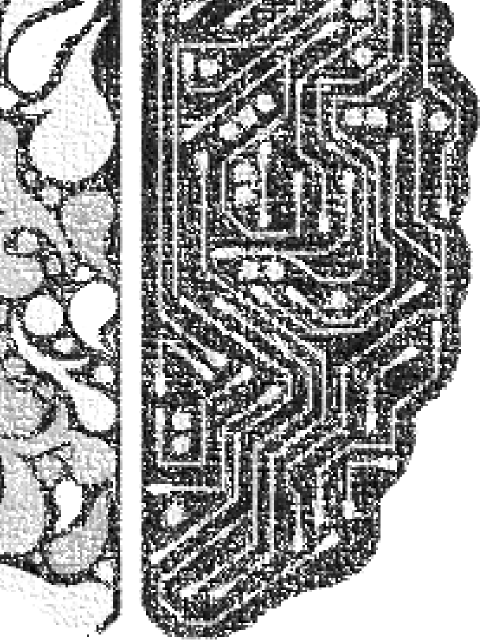
‘Patient Preference Diagnosis’ (PPD), which although more and more recognized in the medical field, deserves more attention as a way to start-off a neuro-engineering endeavor between a patient and his team of experts and warm up the patient for the existential reorientation which will follow from the process.

In addition to the focus on PPD before starting the neuro-engineering process with a patient, a PTD during and after such a process is also relevant when wanting to provide the medical field in general with feedback, and the patient in particular with possibilities to fine-tune the device.

Lastly, it is important to be accepting and welcoming to the *Körper* aspect of the body. In contrast to long present discussion on the body, *Leib* versus *Körper*, with the patient and the doctor being on respective sides of the two, it is more important to consider both the patient’s and the physician’s view on the body as one oscillating between *Leib* and *Körper*, with *Körper* playing a just as important and permissible role.

At the end of this thesis, we have almost made full circle. Having started out with the generalized public debates on concepts such as Free Will and morality, we have taken a deep dive into the phenomenological concepts underlying neuro-engineering, after which we have surfaced once again to explain their status in relation to everyday practice. Through that we have show, not only that phenomenology and neuro-engineering *can* be on the same team, but rather, that they *should* be on the same team, for the benefit of all parties involved. By making this claim, we might be doing a very non-phenomenological thing. The beauty of phenomenology, in contrast to for example ethics and morality underlying the current philosophy versus neuroscience debate, is the fact that phenomenology is not necessarily concerned with normative claims.

Rather, it aims to describe events as truthfully from a human’s perspective as possible. In this day and age where we are making the impossible possible, turning dreams of neuroscientists and sci-fi directors into reality, this type of analysis is what can make these medical endeavors more well thought-out. Whether Neuroscience likes it or not, human experience is an inevitable part of any MRI-research, EEG-result, brain-implant, spinal cord stimulator or any other neuroscientific intervention. Knowing why and how to use that aspect to the benefit of neuro-engineering in the medical field, as well as to the benefit of the individual patient, will be the progress which will make these endeavors grounded as much as exciting.



Afterword

The field of neuro-engineering is making the impossible possible and all of that in an impressively rapid tempo. In this study we have discussed how, in order to be successful, philosophers and neuroscientists should join forces on this endeavor. Especially neuro-engineering is a field which deals with, focuses on and builds forward on the human experience. In the effort to cure nervous system diseases, phenomenology and neuroscience should therefore be on the same team.

This afterword, however, I would like to use for a broader perspective of which this thesis is an example of an effort. The possible beneficial potential of a joint effort between phenomenology and neuro-engineering is just an example of how two fields, seemingly opposites even, can come together for the benefit of the bigger picture.

I myself embarked upon a double degree in philosophy and medicine out of an initial curiosity, not knowing how the two disciplines would turn out to form a synergy, a mutual reinforcement of the relevance of each of the fields to each other and in themselves.

Philosophy was once the mother of all sciences. And although the division of philosophy in subfields such as physics, medicine, chemistry and so on was the consequence of developments in these fields, it seems as if over the ages the fields have come to be ‘overly’ separated. This tendency echoes through in the fact that specialization, and even super-specialization are today’s ‘buzz’ words.

I would like to argue that collaborations such as the one described in this thesis are absolutely vital. We are embarking upon interesting and challenging times. We are now able to do the things we once held for ‘imagination’ or ‘thought experiments’, And as theory comes to practice, we can use all the help we can get.

This all starts, in my opinion, with education of the new generation of scientists, physicians, technicians and policy makers. Efforts, such as a double degree in philosophy, but also the emergence of joint degrees such as Clinical Technology, Nanotechnology, Medical Philosophy and Biomedical Engineering are small steps towards the realization of this ambition.

The future is joint, and I am happy to have played a small part in that effort.

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List of Abbreviations

BCI	Brain Computer Interface
CCU	Central Computing Unit
CI	Cochlear Implant
DBS	Deep Brain Stimulation
PPD	Patient Preference Diagnosis
PTD	Patient Transparency Diagnosis
RI	Retinal Implants
SCI	Spinal Cord Injury
SCS	Spinal Cord Stimulation

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