A post-phenomenological assessment of the Neuralink BCI

Exploring how post-phenomenology can enable technological assessment

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Your secret science conquers nature's cruel laws

but inside your wires lie a million mortal flaws

—Miracle of Sound, the New Black Gold

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Abstract:

Neuralink is the most recent brain computer interface being developed which has recently begun human trials. Technologies can alter how we engage in the world, sometimes in ways we did not anticipate or intend, meaning Neuralink requires investigation to see how it will impact its user in this manner.

In this thesis, I will investigate Neuralink using Don Ihde's post-phenomenology to assess what it can reveal about this technology, and how it alters the manner in which users will perceive and engage with the world. While post-phenomenology has been used to analyse BCI's more broadly by Richard Heersmink before, Neuralink demonstrates a significant technical advancement over these previous iterations of BCI technology, necessitating a fresh post-phenomenological investigation.

This thesis will proceed as follows. First, brain computer interface technology more broadly will be explained. This will allow for Neuralink to be examined in-depth so that a precise understanding of the technology can be reached to understand what makes it similar or distinct from other BCI devices. This will allow for an accurate post-phenomenological analysis to proceed in the next chapter. There, Neuralink will be analysed in light of the six types of post-phenomenological relations as proposed by Don Ihde and Peter-Paul Verbeek in order to compile a compressive understanding of the manner in which it alters the user's perception of the world. Finally, these insights will be discussed to ascertain what they can reveal regarding how users will interact with the world based on Neuralink's design and what can be understood from this.

Post-phenomenology is a descriptive rather than normative philosophical approach. Therefore, future research directions will be proposed through combining post-phenomenological mapping with the value sensitive design approach as proposed by Ibo van de Poel. This approach may enable values to be translated into tangible design requirements for the Neuralink and other devices based on insights gathered through post-phenomenology, but in a manner that can addresses weaknesses of this theory.

Keywords: Neuralink, post-phenomenology, BCI, VSD, technology assessment

Chapter 1: Post-phenomenology & Neuralink

Neuralink is the most recent company working on brain computer interface (BCI) technology to have captured the public's attention with their recent developments, founded by the prolific tech billionaire, Elon Musk (Leffer, 2024). This device is designed to enable the user to interact with devices such as their computer without the use of the neuromuscular system, which they no longer have control of, allowing them instead to interact with these devices through their neural activity. While the technology is still a long way from the capabilities that Musk envisages (Hamilton, 2022), Neuralink has been making demonstrable and tangible progress that can deliver both therapeutic and, potentially, enhancement applications for individuals. The technology is still in its early stages of development, with human testing only having recently begun (Levy, 2024). However, the company has also been granted FDA approval to work on more technologies such as their blindsight device (Reuters, 2024), a BCI to give blind people a means to visually perceive again as well as further human trials for Neuralink. As it is still in the early stages of development, this presents an opportunity to assess the device and better understand how it will shape its user's experiences. This can help to ascertain insights regarding its design that may be problematic before it becomes more widespread among the general population. Neuralink warrants scrutiny. Previous technologies such as Google Maps, Snapchat, and drones show how seemingly benign or even beneficial technologies can have drastic privacy invasions that its users did anticipate. This may have been due to a lack of oversight in the design process, or an incomplete understanding of what negative behaviours these technologies would promote from their users. Neuralink will be recording the user's neurological data, among other things. While the technology has the potential to be of great benefit to users, by giving them a degree of autonomy in their lives again, it could also have negative design aspects that harm the user or encourage unethical behaviour. For instance, such technologies as Google maps and Snapchat show cases where there can be a dark side to this help or enjoyment. Users of these technologies have had intimate data regarding their location shared or used in ways they did not envisage. This can be used to facilitate stalking (EDRi, 2017). In the case of drones, negative behaviour of users was facilitated through the technology, such as being used to spy on people in competition environments, (Linehan, 2024) which may not have been anticipated initially. According to Aydin (2021) emerging technologies have much more potential to radically impact us as individuals and how we experience and interact with the world. This only heightens the need to ensure these technologies are understood comprehensively. Unlike most other tech CEOs who chose to remain subtle regarding their support for political campaigns, Elon Musk has become increasing politically vocal in recent years and will be officially joined the incoming Trump administration. He will have an increasing role in shaping the United States government's capacities to challenge private tech companies through his plans to overhaul government bureaucracy (Garrett, 2024). He will also likely play a key role in guiding the Trump administration's policies regarding technology and enjoy more political power than the average technology CEO as a result. Technologies he is involved with developing should therefore be understood, given the power he will have to shape policy that affects them. By exploring and properly understanding the relationship that is created between Neuralink and the user, how it will alter their experience of the world can be understood as well as what the widespread adoption of this technology might entail for humanity. This can enable a more comprehensive and accurate assessment of the technology itself and facilitate a more ethically desirable design. The research question that I aim to answer then is:

How can post-phenomenology assist in the assessment of the Neuralink BCI

To answer this question, I will first need to answer the following sub questions: **A)** *What exactly is a BCI?* What are the unique features of this technology, how does it work, and what are its limitations? Through an in-depth investigation of how this technology works, a better understanding of what Neuralink is and its impacts can be realised, and a more accurate assessment of its design can be reached. From this I will move onto Chapter 3 which will address sub question **B)** How does *post-phenomenology describe Neuralink?* Here is where the post-phenomenological analysis of Neuralink will happen. American philosopher Don Ihde's post-phenomenology (1990) as well as additions proposed by Dutch philosopher Peter-Paul Verbeek (2008), who sought to account for certain technologies that do not fit neatly into the four categories Ihde had envisioned, will be used for this post-phenomenological analysis. A comprehensive evaluation using post-phenomenology will provide a more complete description of the human-technology relationship created by Neuralink which will then inform its assessment. Finally, Chapter 4 will focus on discussing the research question *How post-phenomenology can assist in the assessment of the Neuralink BCI* and propose some future research directions. Post-phenomenology is one of several frameworks that could be used to assess a technology. It has particular relevance here for several reasons. Noland Arbaugh, the first human to receive the Neuralink will be the focus, but insights from other forms of BCI will also inform this analysis. Arbaugh became paralysed from the neck down during a swimming incident. Since then, he has been dependant on his parents to care for him and his ability to interact with the world has been severely limited (Benson, 2024). The Neuralink device allows him to use applications and use his laptop in a manner that was not possible with the mouth stick he used before (Neuralink, 2024). Based on his accounts from a recent Neuralink blog post, which will be explored further in Chapter 3, it is clear that how Arbaugh experiences the world has been altered because of the Neuralink. Therefore, a post-phenomenological analysis of the relation created here can be provide valuable insights.

There have already been some previous investigations into BCIs using post-phenomenology. They create a new means of interaction between the human brain and an external digital device, without the direct use of the person's neuromuscular system (Heersmink, 2013, p.3). According to Tbalvandany, et al. (2019) BCI devices such as Neuralink could become incorporated into a user's body schema. They note post-phenomenology is well suited to investigating how these external devices may be incorporated in a person's body schema and the user's experience (Tbalvandany, et al., 2019, p.232). However, their analysis is primarily to demonstrate the validity of using post-phenomenology to gain insights into BCI technology. They demonstrate how the various actions a BCI facilities can be described post-phenomenologically, but they do not offer a comprehensive exploration of each relation present in post-phenomenology. Richard Heersmink (2013) has explored BCI technology using post-phenomenology before as well. His analysis will serve as the starting point of my own. Heersmink explored previous iterations of BCI technology, with a focus on embodiment relations, rather than going into each type of relations described in post-phenomenology and evaluating BCIs in light of them. While his work provides a good starting point, it does not provide a complete post-phenomenological analysis of BCI technology, let alone Neuralink, to satisfy the research question. Additionally, given he was investigating BCIs more broadly, certain conclusions reached by Heersmink may not accurately apply to Neuralink, or may even be challenged by Neuralink as shall be explored. Given BCIs are a relatively new technology and nowhere near being ubiquitous, there is no established linguistic manner for discussing them. This leads to uncertainty regarding how they will affect us and how BCI mediated action should be understood and communicated (Kögel et al., 2020, p.7). For instance, there exists uncertainty regarding who or what exactly is in control of BCI mediated actions (Kögel et al., 2020, p.6, Mehta, 2024). By performing this investigation, a more comprehensive understanding of the relations created from a post-phenomenological perspective will enable a better understanding of BCI mediated actions, which can help with clarifying how this technology can be discussed further, and which will be beneficial to future discussions and evaluations.

Philosopher of technology Peter Paul Verbeek proposed his Mediation Theory which incorporates post-phenomenology as a means to assess technology. De Boer et. al (2018) argue that to a certain extent Mediation theory can allow for the ethical technology assessment when it is in what they call the 'weaker' form (De Boer et al., 2018, p. 309). This is where the post-phenomenological mapping, a key aspect of Verbeek's Mediation theory, can be used to enhance existing technology assessment approaches by providing an effective means of revealing ethical issues by exploring the different ways users will interact with the technology, (De Boer et al., 2018, p. 309). This enables the identifying and mapping of relevant values in the interaction with a technology which may be threatened or come into conflict, which they refer to as a form of ‘proto-ethics’ (de Boer et al., 2018, p. 312). However, post-phenomenology is not without its share of critiques as well, which must also be addressed in Chapter 3. My aim there will not be to disprove every and all criticisms of post-phenomenology; rather, I aim to demonstrate that despite some shortcomings, the theory has its merits which make it worth using for this assessment of Neuralink. Therefore, to what degree it can inform our ability to assess how Neuralink will affect its users remains to be seen.

Based on this investigation, I will draw a conclusion on how suitable this framework is for technological assessment and in what circumstances. Post-phenomenology however enables a descriptive rather than normative assessment of a technology in question, meaning while it can illuminate aspects that could inform an ethical analysis, post-phenomenology itself cannot facilitate this analysis. Once a comprehensive understanding of the device has been reached, what is required to compliment post-phenomenology in order to address its major shortcomings for technology assessment? Here, I will propose some future research suggestions for how post-phenomenology can be used in technology assessment. While some critics of post-phenomenology have proposed their own means to address the issues within post-phenomenology, I will advance my own proposal in the context of technology assessment. Namely I will suggest using a post-phenomenological analysis with the value sensitive design approach, specifically as articulated by Ibo van de Poel (2013). This may be able to incorporate post-phenomenology into the design process for a technology and provide a means to compensate for its weaknesses in technology assessment. Let us now turn to investigating BCI technology.

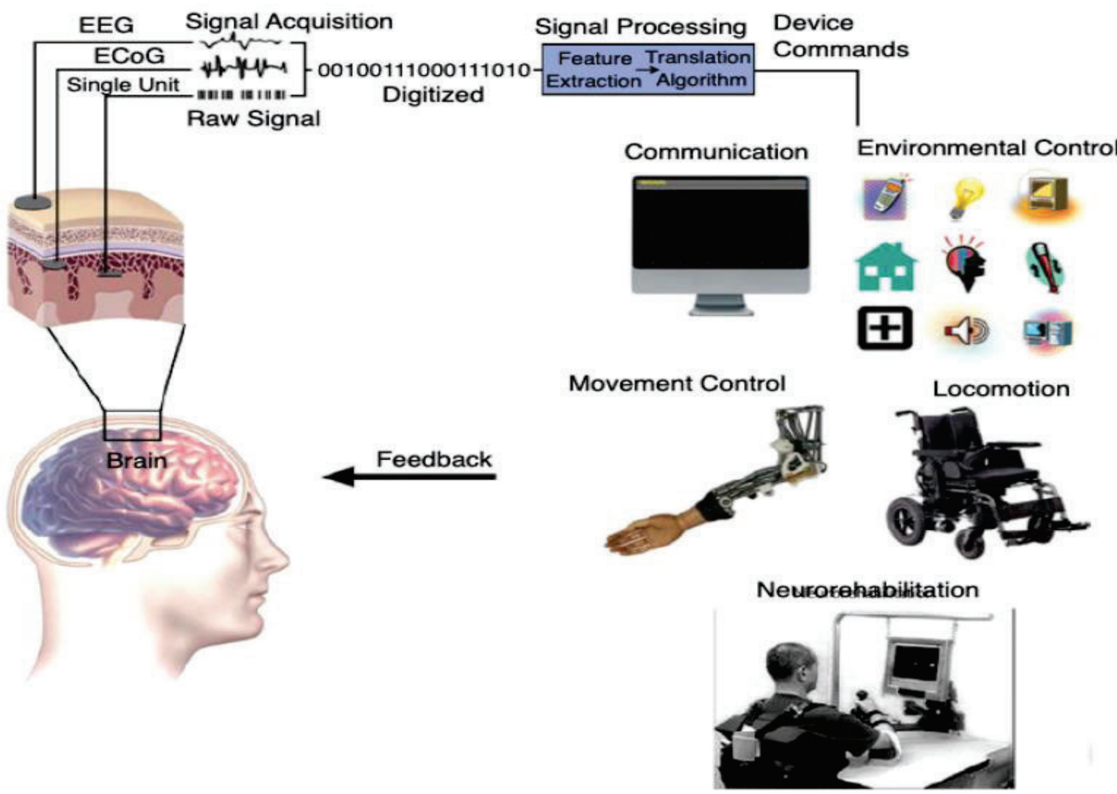
Chapter 2: Brain computer interface technology

2.1 An overview of BCI technology

While the technology may sound new and cutting edge to most, the theoretical aspects of BCI technology go back about a century. However, investigations with humans only really began in the 1970's (Shih et al., 2012, p.269). By the late 1990's there was success with using BCIs to enable patients with locked-in syndrome to control a computer, albeit at an incredibly slow and tedious rate. At the time it would take as much as 16 hours to 'type' a message at a rate of only two characters a minute (Birbaumer et al., 1999, p.297). Since then, the technology has progressed further, with companies like Neuralink having recently had their first human trials. Neuralink is now enabling a quadriplegic individual, Noland Arbaugh, to use digital systems through the device surgically implanted in his skull (Leffer, 2024). After a century of slow and incremental development, BCI technology is now becoming a tangible artefact in the world. While it is often discussed as a singular artefact, it is more useful to observe that a BCI is not necessarily just one technology but several different technologies coming together to create the artefact in question. BCIs can be viewed as being composed of four primary components: (1) signal acquisition, (2) feature extraction, (3) feature translation, and (4) device output (Shih et al., 2012, p.269).

To start, there is the component that must detect the user's brain signals so that they can be digitized and translated into commands for other systems (Kübler, 2020, p.164). This can take on a variety of forms, depending on how invasive the technology being used is. In the case of Neuralink, this is electrodes inserted directly into the brain tissue, the most invasive method of detection but also the most accurate means for reading brain signals (Willyard, 2024). For a computer system to make use of these brain signals is not a straightforward process, however. The signals of relevance for determining the person's intentions need to be filtered out from the background 'noise' of the brain's billions of active nerve cells to ascertain an intention the user has towards the computer system they are interfacing with (Kübler, 2020, 164). These features must then be translated into commands for the specific BCI-controlled application in question. While Neuralink is surgically implanted into the user, it is worth mentioning this does not have to be the case. However, less invasive techniques such as electroencephalography (EEG) come with the drawback of not being as accurate or able to read brain signals as clearly as the surgically implanted alternatives (Shih et al., 2012, 269). As I will be focusing specifically on Neuralink when I speak of BCI devices going forward, I am referring exclusively to the Neuralink unless specified otherwise.

It is also important to note a few things that BCIs are *not* for clarification. Firstly, BCIs do not insert into the brain's normal output pathways for signals, the peripheral nerves and muscles, but instead bypass them (Heersmink, 2013, p.3). This bypassing of the neuro-muscular system is how the device alters how the user experiences the world. The technology enables users to act in the world by using their brain signals alone rather than their body. The user and the BCI must work symbiotically to make these actions possible as both user and device have a form of autonomy and intention in these cases which shall become important in Chapter 3. A BCI does not read a person's mind either. The BCI monitors the users brain activity. When a particular pattern of neuron activation it has been calibrated to detect is detected, it interprets and sends commands to an external device, such as a robotic arm, that performs an action (Shih et al., 2012, p.268). These actions are determined based on what the BCI has been calibrated to associate with particular patterns of neural activity. The diagram below provides a visualisation of this process.



A visualisation of the BCI system and processes (Kawala-Sterniuk et al., 2021, p.3)

Although still a technology in its infancy, there are already a host of applications that BCI's can be used for, from the therapeutic to what could be considered forms of enhancement such as enhancements to memory and attention (Saha et al., 2021, p. 3). The main goal of developing BCIs right now is therapeutic. They are used to replace or restore functions to people with neuromuscular disorders such as a stroke, or spinal cord injury (Shih et al., 2012, p.267). Moving a cursor and typing words has already seen some success and there have been more recent breakthroughs enabling a person to play video games and multitask digitally (Leffer, 2024). The technology also has the potential, in a passive manner, to detect drowsiness and prevent accidents by extension (Saha et al., 2021, p.2).

2.2 Neuralink

While they are not the first to develop it, Neuralink is the most recent company to have captured the public's attention with their recent human trials (Leffer, 2024). The company has not broken new ground from a theoretical standpoint but has managed to take technologies and research developed elsewhere and place them into a wireless refined package (Hamilton, 2022, Leffer 2024). Although still in its early stages, the company's founder, Elon Musk, sees great potential in the technology (Hamilton, 2022) and will likely continue to push the envelope of what it is capable of, especially given Neuralink's recent success with implanting a person with the device, allowing them to use it (Mullin, 2024). One thing of note that sets Neuralink apart from other BCI devices is the sheer number of electrodes involved in its implantation. The device uses 1024 electrodes to meld with the user's brain which requires a specialised robot to surgically insert the chip and electrodes into their brain (Abrams, 2024). Like most instances of the technology, the Neuralink device has primarily therapeutic applications, which involve helping individuals with quadriplegia and other forms of nervous system damage that have left them without control of much of their bodies (Hamilton, 2022). However, there are potential enhancement applications for this technology as well. By controlling a computer game or other digital systems through the device for instance, it's possible for there to be a time reduction between the thought of action and the action being performed (Saha et al., 2021, p. 2). Noland Arbaugh is the first human subject for the Neuralink device who was fitted with the chip back in late 2023 (Mullin, 2024). Currently, the device requires periodic charging which is done through Arbaugh donning a wireless charging helmet (Leffer, 2024). Despite some issues with the electrodes coming loose (Mullin, 2024) Arbaugh has been able to use the device successfully for a plethora of tasks. According to Neuralink, during his first research session Arbaugh set a new record for human BCI cursor control, reaching a rate of 4.6 bits-per-second (BPS) (Neuralink, 2024). Since then, he has managed to surpass his own record and reach a rate of 8 BPS. Currently he is trying to beat the scores of the Neuralink engineers themselves which are at 10 BPS (Neuralink, 2024).

Diagram of the Neuralink BCI (Neuralink, n.d.)

While it has similar intentions in its development, Neuralink is different from most other technologies used in a therapeutic context, such as many anti-depressants or artificial hearts, in a significant manner. The latter are all a form of biomimicry. They are attempting to replicate an existing natural ability or organ the human body possesses and replace it and its function as closely as possible. Prosthetics such as hip replacements, for example, are attempting to substitute the existing functions of the body part they are replacing, the hip joint (*Hip Replacement Surgery*, n.d.). A pacemaker or prosthetic hip replaces the part of a person's body that no longer performs adequately, but it does so in a manner that mimics or closely imitates its biological predecessor. By contrast a Neuralink does not fit into this theory of design and implementation. The chip has no 'biological' equivalent in the person's body it is attempting to replace. Instead, it is a technological workaround to existing biological impairments, usually that the person's nervous system has been damaged to an extent that is beyond current medical technology to heal (Mullin, 2024.). It should be noted here that some forms of anti-depressants are some similar to Neuralink to a degree, but it depends on the particular drug being used. Nutraceuticals such as S-adenosyl-methionine (SAMe) are a form of antidepressant that can be prescribed to people with depression who have lower levels of SAMe than normal which can help with the symptoms of depression (Griffin et al., 2024), essentially supplementing their body with chemicals they are deficient in. Others such as SSRIs which introduce new chemicals to block serotonin uptake by the brain (Griffin et al., 2024). This would be similar to other forms of BCI such as the Motif Neurotech's BCI which is being developed to treat depression (Willyard, 2024). However, this is as far as the similarity would likely go. Rather than providing a new means to interact with the world, these technologies provide an alternative means of correcting a neurological condition than biomimicry. With SSRIs and Motif Neurotech's device, the user is ideally left absent of depression from their use. The user of Neuralink by contrast is not absent of their aliment, such as quadriplegia in Arbaugh's case, but now has a different type of capacity to the one they lost. Therefore, the technology is creating a new means of experiencing the world for the user, distinct from biomimetic therapeutic technologies. In this view, the Neuralink is more akin to an electric wheelchair or other devices such as Neil Harbisson's eyeborg antennae (Newitz, 2013) than it would to a device such as a pacemaker. Both these technologies are providing an alternative means of interacting with the world for the user that is different from the biological capacity that they have lost. How users will engage with these technologies is important to understand in order to fully grasp the nature of this relationship and what the consequences may be in order to better inform its assessment.

2.3 Philosophical Issues

When a designing a device that has to interact with the brain, a comprehensive understanding of the device cannot be reached without understanding how its designers understand the mind and cognition more broadly. This will inform their design choices. It is not entirely clear where Neuralink places cognition and thought. On the one hand, their desire to reach more of the brain through the use of invasive electrodes in order to detect more of the brain's signals would seem to indicate a belief of cognition taking place purely within the brain. This seems to be a form of contemporary Cartesian dualism, the assumption that cognition and thought are activities purely in the brain which has been problematized by these philosophers of neuroscience such as Bennett & Hacker (2003). According to them it is fallacious to ascribe cognition to the brain rather than the entire organism as there is not grounding for such an interpretation. The entire organism is what thinks, not just one part of it. As a useful metaphor of explanation, they explain:

"It is not the eye (let alone the brain) that sees" (Bennett & Hacker, 2003, p.72).

While the eye is used to see, the eye itself is not seeing but person who the eye is part of is. Essentially the brain alone is not a sperate entity from the body but a part of a whole system that is involved in cognition. While certain parts of the brain may activate during thought, this is not an indication thought occurs here. Ascribing cognition to the brain alone and not to the human being is therefore philosophically unfounded. Brains do not think, but humans do. It should be noted that Neuralink is embracing this focus on the brain because, as they explain, there are neural activities that corelate with desired intentions from the user. For instance, when a person intends to move a computer mouse, there is a particular pattern of neurons that activates. Neuralink aims to interpret these signals and use them as an *indicator* of the user's intentions. As they explain:

“By modeling the relationship between different patterns of neural activity and intended movement directions, we can build a model that can predict…in real time, the movements of a computer cursor” (Neuralink, 2021).

This is similar but still distinct from the notion of cognition as a purely brain situated activity that Beckett criticises. Neuralink is using brain activity as an *indicator* of the user’s possible intentions. The algorithm has to make predictions based on this neural activity for what the user intends. While brain signals may be indicators of thought, they are not the thoughts themselves. This approach would still raise problems for Bennett & Hacker since it implies a flawed understanding of cognition from their view. They note for instance how using a fMRI scan does not show the brain thinking but rather shows us a computer-generated image of brain cells and their pattern of activation. While there is a correlation, it is not the same as thinking itself, they argue (Bennett & Hacker, 2003, p. 84). While this approach may have its flaws, it has not stopped Neuralink from achieving their intended goals with the device so far, as evidenced by how Arbaugh has described his experiences with the device. For now, this approach is yielding results for Neuralink and may therefore have its merits when attempting to develop BCI technology. However, it is still possible that this approach may hinder further development of the device as Neuralink attempts to enable more ambitious abilities in the future.

2.4 Technical rollout issues

There are also a number of physical issues that affect the ability of this technology to become more widespread. To start, around 15–30% of individuals are just not able to produce brain signals strong enough to operate a BCI (Saha et al., 2021, p.4), although as the technology improves this may be alleviated. Neuralink was able to increase the sensitivity of the electrodes in their device through a software update after they came loose on Arbaugh to compensate for the loss of connectivity (Hale, 2024). The technology often needs to be very individualised to the patient. In the rehabilitation of stroke survivors for instance, the affected neural pathways need to be identified carefully. This is because brain responses will be affected by the location of stroke lesions (Park et al., 2016, p.2). While current neuroimaging methods are effective in identifying the exact location of these lesions, individualised BCI designs are still required for such rehabilitative uses (Saha et al., 2021, p.4). There are some possibilities for reducing or even removing this process for certain applications, however, such as drowsiness detection in healthy individuals (Saha et al., 2021, p. 2). There is also just the nature of the brain itself. Everything from ‘event-induced brain waves’, to ‘psychophysiological and neuroanatomical factors’ can all cause massive variation in the brain’s signals across time within an individual (Saha et al., 2021, p.3). This is partially why many BCIs require user specific- training and routine calibration. Neuralink currently requires daily calibration (Neuralink, 2024). Additionally, even two people using the same device can have vastly different experiences with a BCI based on their own personal perspectives (Tbalvandany et al., 2019, p.238). This makes it more difficult to produce broader conclusions about how the device will affect its users and society at large. Those with impairments will still need to go through this process given the individualized nature of their cognitive damage. Arbaugh has these sessions daily as part of the study. Whether this will be required going forward indefinitely remains to be seen. Inserting the electrodes directly into the brain is also not without its own challenges as well. These electrodes need to be made of rigid materials in order to successfully penetrate the brain tissue. However, this carries risks. As noted by Hong & Lieber (2019, p.27) the size and stiffness of the electrodes inserted into the brain tissue can trigger the body's immune system. This can cause Granulomas to develop, which is an inflammatory tissue response that can form around a foreign object (Levy, 2024). This can limit the functionality and longevity of these electrodes (Levy, 2024). Furthermore, the fixed position of these electrodes inside the brain means that not all of the neurons can be accessed, necessitating yet additional electrodes to reach more of the brain's structure (Musk & Neuralink, 2019, p 2) which in turn makes the prospect of Granulomas an even greater possibility.

Long term human testing is still needed as well to understand what this device will do to the body over time. Neuralink is in the process of conducting such tests with Noland Arbaugh as part of their Precise Robotically Implanted Brain-Computer Interface (PRIME) study (Neuralink, 2024). They also received FDA clearance for their second human test subject, who has only been identified only as 'Steve' as of the time of writing (Levy, 2024). Already with Arbaugh's Neuralink unexpected issues have been encountered, such as the effect of the brain's natural pulsations on the placement of the electrodes (Mullin, 2024). In essence, getting a BCI to work consistently across a long period of time is still a challenge as the brain is an both a delicate yet incredibly dynamic and malleable system. Long term studies are likely to reveal other issues the technology will need to overcome for it to achieve mainstream adoption. Now that the first sub question has been answered and a more comprehensive picture of Neuralink has been established, we can move to the post-phenomenological analysis of the technology itself in the next chapter.

Chapter 3: Understanding Neuralink through Post-Phenomenology

3.1 Post-phenomenology and Neuralink

Now that the Neuralink has been explained, this chapter will focus on answering the next sub question of this thesis: *How does post-phenomenology describe the relationship between a user and a Neuralink?* This chapter will be a post-phenomenological analysis of the Neuralink device and gain a comprehensive understanding of how the device will affect its user. Doing so will demonstrate the role post-phenomenology can play in ethical technology assessment through its descriptive nature. This analysis be done using the work of Don Ihde and Peter-Paul Verbeek. Neuralink has shared some insightful remarks from Arbaugh on their website. These choice quotes have likely been chosen for marketing reasons by Neuralink, in order to frame the device in a positive light. They do however provide us with insights into Arbaugh's experience which are of post-phenomenological relevance. Based on his own accounts, the device has had an impact on the manner in which Noland Arbaugh interacts with the world around him, which is distinct from that of other assistive technologies he had used prior to receiving the Neuralink. In a recent blog post for the company, Arbaugh made several points about using the device which are relevant from a post-phenomenological perspective. They indicate the technology has altered how he perceives and interacts with the world. To begin: (The emphasis was made by the Neuralink blog editors):
***"I haven't been able to do these things in 8 years** and now I don't know where to even start allocating my attention"* (Neuralink, 2024).

This uncertainty from Arbaugh indicates there has been a shift in how he interacts with the world from before, which is of post-phenomenological significance. The Neuralink has revealed new possibilities for interaction and experience than with previous other assistive technologies. Before receiving the Neuralink, if Arbaugh wanted to use a digital device, he was mainly confined to touch screen tablets and had to use a stylus with his mouth. This first had to be put in place for him by a caregiver, making him less independent (Neuralink, 2024). Not only could this stick only be used while he was in an upright position, but it also had a limited range of applications he could engage with. Prolonged use of this stylus also led to much discomfort, ranging from general muscle fatigue to pressure sores (Neuralink, 2024). Additionally, he could of course not speak while using this stylus. The Neuralink by contrast allows him to have a more pleasant relationship with technology and, by extension, experience of the world around him. Arbaugh describes his new situation as such:
*"The biggest thing with comfort is that I can **lie in my bed** and use [the Link]. Any other assistive technology had to have someone else help or have me sit up...It **lets me live on my own time**, not needing to have someone adjust me, etc. throughout the day,"* (Neuralink, 2024).

Although Neuralink does not read his mind, Arbaugh can now simply 'think' where he wants the cursor on screen to move and it does so. He further mentions that he is now more connected to the world around him: *"[The Link] has helped me* ***reconnect with the world****…to* ***do things on my own again*** *without needing my family at all hours of the day and night,"* (Neuralink, 2024).

Based on this account of his experience with it, the device would seem to be distinct from his previous assistive technologies. Arbaugh now engages with the world in a new manner, without his neuromuscular system as he did very crudely with a stylus. This method has altered the possibilities of what he can and cannot do in the world around him. As was mentioned in the introduction, post-phenomenology has its share of critics. Certain criticisms of this framework need be addressed briefly before this analysis can begin. To start, Peter-Paul Verbeek drew attention to how Ihde's list of relations was not sufficient to cover all relations with technology. He therefore expanded this list with the cyborg relation. Ihde would likely accept the additions to his original 4 relations as he seemed to view Verbeek's work as building on his own. (Ihde, 2008, P.7-8) This addition augments post-phenomenology to be a more comprehensive means of assessing the Neuralink, so this criticism shall be incorporated into the analyses that will follow. However, cyborg relations themselves have also been criticized for placing the focus on the human rather than the technology, the very thing the theory is meant to enable us to understand (Mykhailov & Liberati, 2023, p.6). They argued the technology become 'concealed' rather than revealed when understood in this manner (Mykhailov & Liberati, 2023, p.6). However, while it may not place sufficient emphasis on the technology's intentionality, it is still acknowledging it to a degree. In the context of Neuralink, the device is also designed with the goal of aiding the user. Even if this relationship is symbiotic, it is clear that the emphasis is, by design, on the human user. Therefore, a theory that can account for this is suitable for the purpose of deepening our understanding of the relation between the user and the device. Post-phenomenology has also been criticised for focusing on individual level human-technology relations rather than the broader context of their use (Mykhailov & Liberati, 2023, p. 3). By focusing solely on 'I-technology', broader social or group interactions are ignored. Others such as Ritter (2021) and Arzroomchilar (2022), have also highlighted this weakness with post-phenomenology focusing on individual level interactions and experiences with little regard for the broader societal and political implications of a technology. Robert Scharff has also noted that Ihde's approach ignores how technologies are imbedded in our broader social context. Although he still finds Ihde's approach to have merit, ultimately it encourages a surface level examination of technologies as isolated tools and not as part of our broader existence. He concluded this leads to a shallower understanding of the technology (Scharff, 2022, p. 62). Kristy Claassen (2024) has gone as far as to argue that there cannot even be an individual level interaction with a technology and, by extension, an individual level analysis through post-phenomenology. These critiques may seem to call into question its capacity of post-phenomenology to inform our understanding of the Neuralink. However, Verbeek has argued that technologies not only have societal implications, but also unique implications at the individual level and that understanding them is a necessary part of technology assessment (Verbeek, 2015, p.16). Ihde would likely concur with Verbeek on how societal issues may not always been synonymous with individual level issues. Additionally, Ihde would likely mention that his intentions were not societally focused in the first place, but rather on the individual and understanding how technology will affect them (Ihde, 1990, p. 72). Phenomenology is about individual level perception and experience of the world. As Ihde is building on this tradition, broader societal aspects may have been outside what he intended to discuss. For these reasons, post-phenomenology should not be so quickly dismissed when it comes technological assessment. In addition, Neuralink is still in its infancy with a total of two users at this moment in time. Both are participating in a research study to better understand its effects on human physiology and further refine the technology. Given this fact, it is doubtful whether a fully insightful political analysis can even be reached about Neuralink at this time. How can we know the broader context of this technology when it is still being refined at an individual level and may more than likely grant extra capacities beyond those currently enjoyed by the test subjects? Without evidence, we can only speculate as to what these would be. Additionally, a comprehensive understanding of these broader social impacts cannot be reached without understanding the manner in which they impact how an individual experiences the world itself. That is happening right now with these PRIME study candidates. For now, the technology has not reached societal-wide adoption, however a technology's societal impact may not always be synonymous with its individual level impact according to Verbeek (Verbeek, 2015, p.16). As the technology is and will likely continue to be used by more and more people, this micro-perspective analysis of a technology is still worthy of investigation.

Post-phenomenology has been used to analyse BCI technology before. This investigation will be referring to Richard Heersmink's post-phenomenological analysis of BCI technology as a starting point. While Heersmink did not explore Neuralink specifically, he did attempt to address BCI's as a technology more broadly through post-phenomenology. As Neuralink shares much in common with previous BCI devices, having developed nothing new theoretically as previously mentioned, we can use his analysis as a foundation to start from. However, he did not explore all post-phenomenological relations and some of his conclusions, specifically regarding embodiment relations, may be challenged by Neuralink. Heersmink concluded that contemporary BCI technology during his analysis was simply too clunky as it required too much concentration for even minor actions and was too unreliable in its detection and interpretation of brain signals to facilitate an embodiment relation (Heersmink, 2013, p. 218). As we saw in Chapter 1 however, Neuralink is more advanced than previous BCI devices. Arbaugh's account of using the device also demonstrates that with Neuralink the technology is much easier to use than previous devices.

3.2 Don Ihde's Post-Phenomenological Relations

Phenomenology is primarily concerned with how humans perceptually experience the world (Ihde, 1990, p. 21). Ihde sought to expand upon this to account for the manner in which technology influences our perception. He built upon existing works of Merleau Ponty and Martin Heidegger from the phenomenology tradition and how they described the role of technology in human perceptual experience (Ihde, 1990, p. 41). They examined the manner in which human tools influenced our relationship to the world. Ihde attempted to merge their insights and build upon them into post-phenomenology. By examining the increasing role of technology in mediating our experience of the world around us, he sought to develop a post-phenomenological approach that accounted and explained for how we experience the world through technology. Ihde uses the concept of intentionality to highlight the link between humans and world. According to Ihde, we are always directed toward reality. We cannot simply "think," but we think something. We cannot just "see," but we always see something (Verbeek, 2008, p. 388). In a world where advanced technologies are becoming more and more prolific, many of the relations we have with the world are now either mediated by or directed at technological devices, thus we have intentionality towards technology (Ihde, 1990, p. 89). Ihde argued that that we are often to some extent mediated in our relationship to the world around us and that these relations with technology are distinct from regular phenomenological relations. (Ihde, 1990, p. 31). Ihde rejected the idea that technologies were neutral tools (Ihde, 1990, p. 165). Technologies are designed with purposes in mind and those design choices are inherently value-laden. As such, they will inevitably influence how we interact with the world by extension. Each relation we enter into with a technology alters our perception by revealing and concealing aspects of the world which will influence how we interact with it. These will be discussed as well. These mediations are not purely human in nature since they cannot occur without these mediating technological devices, making them further distinct from more traditional phenomenological relations. (Ihde, 1990, p. 112). Ihde refers to the 'lifeworld' in his work on post-phenomenology. For Ihde, the lifeworld is the world of human experience which we engage with (Ihde, 1990, p.28). This world is shaped by culture and technologies which influence how we perceive and interact with it. In essence, it is the world around us as described in the tradition of phenomenology that Ihde is building upon. In post-phenomenology, Ihde distinguishes four main types of mediating relationships with technology: Background, Embodiment, Hermeneutic and Alterity, each of which shall now be applied to the Neuralink.

Background Relations

Although they are not the first type that he discusses, I will start with 'background relations' (Ihde, 1990, p.108) as these are the least intrusive into our phenomenological experiences, with each successive relation technology becoming more prominent in our perception. Background relations are when the technology and its interactions fade to the background of perception and become totally transparent. This relation conceals the active role the technology has in our experience of the world. In essence, we usually only become aware of these technologies when they stop performing their function hence, they are the least intrusive in our perception of the world. Technologies such as Wi-Fi or air-conditioning would-be examples of this as you usually only become conscious about such technologies in their absence. However, while they seem to fade from our perception, that does not mean they do not have any alteration to our experience, rather we just do not notice it as a technological transformation but assume it as natural. For instance, with air conditioning our perception of the environment is that it is naturally at the temperature the room has been set to. This in turn will alter how we interact with the world, for instance we may chose to stay in such a room for longer than we needed to, especially if the rest of the building is colder. However, if the heating system stopped working and the room become colder, we would become aware of this technological mediation. Background relations reveal a technologically mediated world as natural.

Embodiment Relations

The next type of relation that Ihde identifies are what he refers to as 'embodiment relations' (Ihde, 1990, p. 72). This is when a particular technology is taken into our experience and becomes part of the way we perceive the world, which is through that particular technology. By extension this technology alters the manner in which the world is perceived by the user. Since technologies are never neutral tools according to Ihde (Ihde, 1990, p.165), the manner in which they will alter our perception is important to understand as they will promote a particular means of viewing or interacting with the world. Glasses are an example of this (Ihde, 1990, p. 73). Ihde visualises the relationship at play here as the following:

(I-glasses)—>world

Ihde uses a '–' to show how the glasses mediate perception between the user and the world as I—glasses—world (Ihde, 1990, p. 72-73). However once the glasses have been embodied by the user they withdraw from perception and become a part of the way the user experiences the world which is through the glasses, hence the parentheses around them and an arrow towards the world where the intentionality is directed. (Ihde, 1990, p. 73). The glasses mediate between the user and the world. Ihde uses similar configurations for the other relations he describes. Embodiment rations can reveal the world though the technology. Glasses reveal the world to the user, while concealing themselves by becoming transparent to a degree as you focus on what you see rather than the glasses you are seeing the world through.

Hermeneutic Relations

The next type of relation that Ihde explores are 'hermeneutic relations' (Ihde, 1990, p. 80). These relations are when you do not directly experience the world but observe or experience it through a technology. A hermeneutic relation will see the perceptual information you would normally observe be transformed through this technological mediation, depending on how it has been constructed to acquire and present information to the user. An example of such this relation would be a map of a city. When using a map, you are not experiencing the location it presents directly but you will hermeneutically know much about the location presented. The map mediates the information regarding a large urban area into a manner that is makes easier to comprehend. Ihde illustrates this relation in the following manner:

I—> (technology–world)

This configuration can be seen as an inverse of the embodiment in its visualisation. Here, the technology and the world form the system that the user engages with to perceive the world through. Our perception of the world can only happen through the technology, that is our perception is focused on the technology itself, in this case a map, which could be on a smartphone screen. In this relation, information or meaning is revealed through the mediation that the user could not directly access such as a view of a city's street network. It however conceals the direct perception of that information in this instance, there is no perceptual experience of the streets, elevations, or public transport infrastructure that are displayed. The technology transforms the manner in which it is perceived however, so our perception is of a configuration of them both, hence the parentheses. Instead of I—Technology—World, the 'I' here interacts with a world through its transformation by a technology. The use of an arrow is to indicate that intentionality is directed towards this configuration.

Alterity Relations

The final type of relation is what Ihde refers to as 'alterity relations' (Ihde, 1990, p. 97). These are relations where the technology can be characterised as an *other* as they appear to us to possess some degree of autonomy of their own. The technology is an 'other' that we enter into a relation with due to its seeming autonomy. An example of this would be a virtual assistant. When we interact with such a technology it appears as another agent with autonomy of its own when in reality it is not. In the alterity relation, the technology in question is autonomous to a degree when we interact with it. Ihde describes alterity relations as:

Human—>technology—(-World)

Here the world is in parentheses; according to Ihde the alterity relation may push the world to the background of perception and bring the technology to the foreground, although he notes this is not always the case, hence the '-'. Alterity reveals the technology as a quasi-other to interact with. The voice assistant which we engage with conceals the broader context the technology is in as we are focused on the technology itself.

Ihde's work is extensive in how much of human technology relations it can describe. Peter-Paul Verbeek however thought it did not sufficiently describe all human technology relations. To this end, he sought to build upon Ihde' relations by proposing additional formulations to complement Ihde's original 4. These shall now be explored as they enable post-phenomenology, and any analysis through it to be more encompassing by being able to discuss and explore additional forms of human technology relations.

3.3 Verbeek's Cyborg relations

Building on Ihde's work, Peter-Paul Verbeek sought to address the nature of new and emerging implanted technologies that Ihde's framework does not cover adequately by strengthening the embodiment and hermeneutic relations to account of technologies that had intentionality of their own. For Verbeek, certain technologies, not just humans, can also have intentionality (Verbeek, 2008, p.390). For instance, a radio telescope has intention that is directed towards the phenomena in space that it perceives. To this end, he proposed the 'cyborg relation' (Verbeek, 2008, p.390) to account for these relations. With cyborg relations technologies actually merge phenomenologically with the person using them, rather than being embodied in the way that Ihde envisages such relations as a result of this intentionality. Verbeek's cyborg relations come in two forms based on the type of intentionality the technology has (Verbeek, 2008, p.390). He refers to these as "Hybrid "and "Composite" intentionality (Verbeek, 2008, p.390-392).

Hybrid intentionality is where humans and technology "merge rather than interact" (Verbeek, 2008, p.388). By this Verbeek means instead of both the human and the technology having their own separate intentionality, they come together and create a joint form of intentionality that could not exist without them both. An example of this would be a prosthetic limb that uses AI to learn from the users' movements to better anticipate their desired actions. This experience of the world is not entirely human, and neither is the intentionality involved in how it experiences the world (Verbeek, 2008, p.391) as it requires both the technology and the user in order to experience the world with this intentionality. This is similar but not the same as the embodiment relation. Like in Ihde's embodiment relation, in hybrid intentionality there is a close association between the human and the technology that experiences reality. The intentionality involved in embodiment relations is also not entirely human either. The manner in which humans are directed at each other through a mobile phone can only exist by virtue of an intimate human–technology relation. However, in those relations, a distinction can still be made between the human and the technological artefact. The human still retains primary agency, and the technology tends to be more passive, merely facilitating the experience than actively partaking in it. Rather than merging, Verbeek argues in an embodiment relation that the human and the technology instead "share" the mediated experience (Verbeek, 2008, p.391). In contrast, the cyborg relation sees humans and technology forming a new perceiving entity with a new intentionality that only exists by virtue of their coupling. Rather than human intentionality being mediated by technology, this intentionality is part technological. Instead of an interaction between a human and a technological artefact, this coupling physically alters the human. This form of mediation goes beyond the embodiment relation of wearing eyeglasses or using a phone. In the cyborg relation there is no longer a distinction that can be drawn between the human and the technology (Verbeek, 2008, p.391). Rather, a new entity is formed, the cyborg. Verbeek illustrates this resulting hybrid intentionality cyborg relation (Verbeek, 2008, p.391) as:

(human/technology) –> world

Here the dash illustrates that the human and technology become a single phenomenological entity in parentheses that interact towards the world together rather than two separate entities. Together both human and the pacemaker have intentionality that come together as one phenomenological entity, each dependent on the other.

The other form of cyborg relation is one with, "composite intentionality" (Verbeek, 2008, p.391). This is where both human beings and the technological artifacts they are using have their own intentionality. An example of this relation would be using a smartphone in order to access a map application. Here there are two distinct forms of intentionality that interact rather than merge with one another. In this case, the technological intentionality is directed at making certain information that the technology "experiences" in the world accessible to humans (Verbeek, 2008, p.393). Verbeek views this as a means of strengthening Ihde's hermeneutic relation in particular (Verbeek, 2008, p.393) Like in a hermeneutic relation, the information is transformed here, but it is information humans are not able to access otherwise. While humans can verify the layout of an urban environment of a hermeneutic relation, we cannot perceive all of the additional environmental information such as weather, traffic and transportation timetables and quickly know the optimal route to take to our destination the way a map application does. This is transformed it into a medium that we can comprehend in the composite intentionality cyborg relation. The smartphone map application has intentionality towards the world, and humans have intentionality towards the result of this hermeneutic relation. The intentionality of both entities combines. Verbeek illustrates the composite relation as follows:

Human → (technology → world)

Here the arrow indicates how humans have intentionality towards the technology. The technology also has intentionality directed towards the world. For this relation humans can only experience the world through the manner in which the technology experiences it. The world is therefore experienced as perceived by the technology, hence these two are in parentheses. The cyborg relation reveals the user to the world as a hybrid entity where the technology is part of who they are. It conceals the individual level autonomy of the user and the technology as they are merge into one phenomenological entity in this relation.

These distinctions that Verbeek proposes may initially seem too narrow to be formulated as separate relations. If they still broadly fall under embodiment and hermeneutics, then is delineating them as new relations necessary? Verbeek's formulations however do allow for certain aspects of the technologies he has in mind to be better understood. For one, they account for the intentionality of the technology itself. This is not accounted for in Ihde's relations, which focus on how technology mediates human intentionality towards the world. Hybrid intentionality emphasizes how the technology itself has its own intentionality whereas in embodiment the user remains the centre of intentionality, meaning there is a more disturbed form of agency in cyborg relations. Consider the example technologies mentioned. Glasses are a more passive technology compared to an AI assisted limb. While both could be considered to facilitate an embodiment relation, the cyborg relation allows for the intentions of the technology itself to be accounted for. While the AI assisted limb could be considered to facilitate an embodiment relation in a very broad sense, the glasses would not constitute cyborg relations for Verbeek as they are a passive means to transform how one views the world, rather than having any intentionality towards the user or the world. With composite intentionality Verbeek illustrates another slight but significant difference from the standard hermeneutic relations which accounts for the intentionality of the technology in this type of relation as well. The intentionality's of the user and the technology in this instance coordinate as active participants together, whereas hermeneutics focuses on how a relation is mediated through a transformation with technology. Like with embodiment relations, this sees intentionality as almost exclusively coming from the user. When compared to a map, the smartphone has intentionality and agency beyond that of a map which presents a transformed view of an area to the user of a location.

With a smartphone, the phone itself has intentionality when the maps feature is used. The device engages with the user by observing their location and suggestion routes to a destination for them, based on how it incorporates knowledge of local transportation systems and geography to estimate the time of various journeys to the destination as well. These differences are significant enough to warrant inclusion in this analysis of Neuralink.

3.4 Neuralink through post-phenomenology overview

Now that post-phenomenological relations have been explained, we can investigate which if any of them describe Neuralink. This will enable a more complete understanding of the relationship between a person and a Neuralink device. It would seem a BCI device does facilitate a background relation. Arbaugh has described how the Neuralink device is imperceptible to him:

"If I had lost my memory, and I woke up, and you told me there was something implanted in my brain, then I probably wouldn't believe you,"…*I have no sensation of it—no way of telling it's there."* (Leffer,2024). Ihde also makes a point of stressing we only notice these relations when they *stop* working. (Ihde, 1990, p. 112). An air conditioner is a background relation that only becomes noticeable when it stops performing its intended function yet will influence how we perceive the world all the same. In contrast, a BCI requires conscious intention from the user to operate. While the device is passively scanning, those scans are to detect brain signals which are indicators of intention. As Arbaugh mentions he needs to be using the technology, one must have conscious intentions towards it and the lifeworld around them. If a BCI stopped working, we would only become aware as we attempted to use it, not the moment it ceases to work. In this manner, background relations may seem to not adequately cover the relation the person has with the BCI. Using the BCI to interact with the world through external technologies immediately brings its existence back to the user's attention. However, as was mentioned in chapter 2, a BCI consists of several components. One of these involves the detection of brain signals which then must be interpreted. This specific component of the Neuralink does facilitate a background relation as when the device is powered, it is passively scanning to detect these signals even when Arbaugh is not actively trying to use the device. He would only notice it if it was to stop working, if his intentions were not being carried out by the device. Therefore, Neuralink does facilitate a background relation with the user, although this is clearly not sufficient to account for its entire impact on them.

Moving on to embodiment relations, we will begin with Heersmink's analysis. Heersmink concluded BCI's could not facilitate embodiment relations during his research as they could not become transparent (Heersmink, 2013 p. 10). In contrast to the experiences he drew from, Arbaugh's experiences the device as unintrusive, more reliable, and easier to use. He operates the

BCI in two slightly different ways. First, he can do so by attempting to instigate movement in his hand muscles and going through the mental process as he would have if he still could use his hand. This allows him to move a cursor on a screen with little effort. “It’s very intuitive,” he claims (Leffer 2024). He can also move the cursor by visualising where he wants it to move on the screen. He refers to this as “imagined movement” (Leffer, 2024). Arbaugh has mentioned he often uses both of these methods together. The main difference for his experience is that the former is more physically demanding, the latter more mentally demanding. Both methods allow him to multitask, meaning he can use the Neuralink to operate his computer and hold a conversation at the same time for instance. (Leffer, 2024).

It seems the Neuralink, therefore, may be able to facilitate an embodiment relation. The device is within the person’s skull meaning it could be considered embodied in a very literal sense. While it then becomes removed from their immediate perception it still evidently shapes the manner in which the user will interact with the world, becoming a form of (I-glasses). Through the device the user can interact with a plethora of digital devices in their environment, even when they are lying down, as Arbaugh mentions (Neuralink, 2024), and the desired device may not in range. This in turn means as a quadriplegic, Arbaugh has an altered perception of the world in this embodiment relation as more devices come in range for them to potentially use. The user and the device must work symbiotically in order for these intentions to be enacted. For an able-bodied person this does not change much about how they might interact with a computer such as how they might do with a mouse. For someone with quadriplegia however, an interaction that was once denied from them is now revealed through the embodiment relation. The device’s incorporation into the body schema allows for easy mental control over devices thanks to the surgical insertion of electrodes into the brain tissue, enabling the most accurate reading of brain signals through the passive scanning feature to detect brain signals with intention. These other technologies are revealed as available to the user of the Neuralink where they had once not been. These other technologies are accessed using the BCI itself as opposed to through the user and the other digital device alone. This leads to two forms of the embodiment relation that could be expressed. On the one hand, as the technology in question such as a computer is part of the lifeworld that the user is seeking to interact with, it could be characterised in a similar manner to how Ihde sees this relation, as (I-Neuralink)—world. Alternatively, if the user is interfacing with the device to facilitate another interaction with the world, the embodiment relation is a bit different. Suppose for example that Arbaugh wished to interact with his laptop in order to check the temperature somewhere far away. Here, he would be embodied in his relation to the Neuralink, however this form of embodiment would also be the beginning of a type of hermeneutic relation with his laptop.

There are some aspects of embodiment relations that may not entirely line up with how Neuralink works which draw into question whether it is facilitating an embodiment relation. According to Heersmink (2013), a characteristic of embodied tools is that they provide 'proprioceptive feedback' to the one who is using them, thus mediating how the user experiences the environment through the technology (Heersmink, 2013 P.10). Here, Heersmink refers back to Heidegger's description of using a hammer: the user could feel the nail they were hitting through the hammer (Heersmink, 2013 p.9). However, Neuralink does not yet provide any such 'proprioceptive feedback'. If Arbaugh was to try and steer his wheelchair or use a robotic arm with a BCI there is no proprioceptive feedback (Heersmink, 2013, P.10) since as a quadriplegic Arbaugh cannot feel or control his body nor are these technologies connected directly to his nervous system. Therefore, he cannot experience any proprioceptive feedback. According to Heersmink then, a BCI such as Neuralink does not facilitate an embodiment relation. Currently, Arbaugh cannot even access these more physical technologies with the Neuralink, meaning there is even less possibility for feedback. Supporting this, Tbalvandany, et al., (2019) also note that the process of interacting with computers through a BCI is not something the users can experience physically as they might when opening and closing their mouth to speak. The feedback in this instance is indirect. The user can visually see if their intended actions are being performed or resisted. This is still a form of feedback that the user can be aware of even if they cannot directly experience it as such (Tbalvandany, et al., 2019, P.235). This somewhat blanket statement by Heersmink is not without its flaws. For instance, glasses are the example that Ihde uses to illustrate embodiment, and yet they do not provide feedback in the manner that Heersmink is suggesting. While it could be argued they provide some tactile feedback by sitting on the user's face, this does not affect the way the user would navigate the lifeworld the way it would with a hammer or a crowbar where resistance to intention provides 'proprioceptive feedback'. Currently Arbaugh cannot control his wheelchair, but this is within the scope of what Neuralink aims to enable, (Neuralink, 2024). It could be modestly speculated here that in such a scenario he would think, and his entire body in the wheelchair moves. If he collided with an object he would have to change his course of action, just as one would with a car, which according to Heersmink can provide this type of feedback (Heersmink, 2013 p.11). While he cannot *feel* this feedback or resistance given the damage to his nervous system, he would still be *aware* of it, nonetheless. While this may not be 'proprioceptive feedback' it is still feedback of a sort. However, this objection remains only a possibility until such time as the Neuralink grants this ability.

BCIs both support and create a hermeneutic relation. As was explored in the embodiment section, Neuralink can support other forms of hermeneutic relations with technology. For instance, Arbaugh mentions how he can use the device to access the internet (Leffer, 2024), which like when using a smartphone can enable one to check temperature in other places, thus creating a hermeneutic relation. Here the Neuralink itself is not transforming or acquiring this information directly. This is not a hermeneutic relation in the manner the thermometer would be one, but it is enabling the user to enter into a hermeneutic relation with the computer. Additionally, Neuralink facilitates two forms of hermeneutic relations at the same time. As well as making information about the lifeworld accessible to the user, it can also make information about the user accessible to the lifeworld. This is facilitated by reading brain signals and enacting interpretations. Neuralink hermeneutically transforms the neurological information of the user into data that can be observed by others, and also into actions in the environment. The Neuralink records neural data from the brain and sends it to a digital device via Bluetooth, translating this neurological data into actions through the device. (Leffer, 2024). Here, the mediation of the digital screen is for the Neuralink user, but also for the other individuals in their lifeworld. The device can enable someone else to understand what a user is thinking to a degree, such as if they are moving a cursor to type words for example. While here the hermeneutic relation is primarily experienced by another, the user themselves will experience a hermeneutic relation to a degree through seeing their actions translated from thoughts onto a digital screen as well, it is just that the main subject of this mediation is other people, not the user who would already have acres to this information directly. However, Neuralink also has to observe neural activity for indicators of intention as was explored in Chapter 2, meaning it's possible for another agent to view this activity if it is recorded or sent to another device. The user and the observer are therefore experiencing two different forms of hermeneutic relation through the device. Additionally, the Neuralink will also turn those brain signals into a form of information that digital devices can use to enact the intentions of the user, thus supporting a hermeneutic relation with other technologies. For instance, rather than Arbaugh's computer detecting his mouse movements through a track pad or physical mouse, his intentions are sent via Bluetooth to move the mouse (Leffer 2024). The information is then transformed for this medium.

For the most part, the Neuralink will not facilitate an alterity relation as it will eventually fade to a background or embodiment relation which is at odds with an alterity one where the user becomes fixed on the seeming autonomy of the device such that they are always aware of it. However, its possible Neuralink could facilitate an alterity relation when it is initially adopted, as the user learns to use the device and have it calibrated to their neurological activity. The device must be calibrated to the user and learn to associate their brain signals with certain intentions and become better at predicting the user's intentions over time. A user could become absorbed by its seeming autonomy as they calibrate the BCI to the neurological activity and bring the device into their control. Currently, Arbaugh must calibrate the device daily and charge it every few hours (Leffer, 2024). During such times the device is revealed as an 'other' that Arbaugh must enter into a relation with and focus on.

The Neuralink does facilitate a cyborg relation with hybrid intentionality as well. As mentioned in Chapter 2, a BCI and a user have a symbiotic relationship. The device requires human intentionality for it to work as without human intentions, there is nothing for it to detect, infer, translate, and convert. The user in turn cannot act without the device converting their intentions into actions. Arbaugh cannot interact with many aspects of the world other than to act symbiotically with his Neuralink. This can be seen in how he explains playing chess: *"I just stare somewhere on the screen, and it would move where I wanted it to."* (Mehta, 2024). Arbaugh's description alludes to a sense of agency on his part. He is the one who moved the chess piece in question which shows how the Neuralink has been taken into his intentionality and a hybrid form has emerged. Arbaugh has intentionality towards the digital chess game and the Neuralink has intentionality towards Arbaugh that enables him to bridge the intentionality gap and control it. There is a combined intentionality here that arises from the two acting together.

A cyborg relation with composite intentionality is also facilitated through the Neuralink as well. The Neuralink device enables Arbaugh to interact with digital devices by bypassing the use of his neuromuscular system. By enabling him to interact with digital devices in this manner, the device is enabling an interaction with the world in a manner that is accommodating to his condition. By detecting his brain signals which it has been trained to associate with possible intentions and relay them to a nearby device, the Neuralink has a degree of intentionality of its own, directed at the users brain as it has to determine what the brain signals it detects might the indicators of, and then send them to the computer, bridging this intentionality gap between Arbaugh and his computer that exists since Arbaugh cannot interact with the computer unaided. For instance, when Arbaugh moves the mouse on screen, this action requires both him and the device to happen (Benson, 2024). While he is technically interacting with the world differently to how he would have if he was using his hands to do, the perception of the computer, from a composite intentionality standpoint with Neuralink, remains unchanged. On the other hand, the Neuralink can perceive brain signals which humans of course cannot. While these are the user's brain signals this does not equate to immediate comprehension because, as was explored in Chapter 2, brain signals are not the same as thoughts. Additionally, as was explored in the hermeneutic relation, other individuals can now view this brain activity. Therefore, the Neuralink does facilitate composite intentionality cyborg relation with Arbaugh to a degree but also for observers of Arbaugh's neural activity to degree as well.

As can be seen here, the Neuralink seems to have a plethora of relations and uses. Ihde himself understood that technologies could facilitate multiple relations and have different uses. To describe this, he noted that technologies have ‘multistability’ (Ihde, 1990, p. 144). This describes how the same technology can have multiple different uses and significance, that can even go beyond what the designers of a technology initially anticipated, in different contexts. According to Ihde, while a technology may have been designed with a particular use in mind, its function and significance can change across different environments or intentions (Ihde, 1990, p. 144). Take a knife for example. A knife can be used for cutting your food into manageable to eat pieces. It can also be used to open a package, or as a weapon to attack someone with. New emergent functions may also arise that were not initially foreseen when the technology was being developed. For example, the Apple air tag was designed to allow users to track items. Many users however have attached them to the collars of their pets as well, a function Apple did not intend (Neely, 2023). Neuralink also has multiple stabilities. As was previously mentioned, the device is designed with a therapeutic function in mind. Through being able to interact with other devices without their neuromuscular system, the user has more autonomy, much as how a wheelchair is a therapeutic technology with similar aim in mind. In one context it can be seen as an aid as it allows the user to communicate with others by giving them access to other technologies such as their computer where they could, for instance, type messages on social media or send an email. However, it can also have an entertainment function. Arbaugh has revealed that he uses it to play computer games (Leffer, 2024). Now that we have answered the second sub-question, *How does post-phenomenology describe the relationship between a user and a Neuralink?* and seen how the Neuralink facilitates each relation to an extent, what can this tell us about the device shall be discussed in the next chapter along with future research proposals.

Chapter 4: Discussion of post-phenomenological findings

4.1 Overview of the post-phenomenological insights

Now that the sub questions posed at the start of this thesis: **A)** *What exactly is a BCI?* and **B)** *How does post-phenomenology describe the relationship between a user and a Neuralink?* have been answered, the main question of this thesis**:** *How post-phenomenology can assist in the assessment of the Neuralink BCI* can be answered here. From this post-phenomenological analysis of the Neuralink BCI, it is clear the device goes beyond just embodiment relations as Heersmink's analysis focused on. It also does not exclusively fit into any of the relations that are proposed by Verbeek or Ihde, rather the device facilitates all of them to various degrees. Not all of these relations are equal in terms of what they can describe to us about the Neuralink. As has been illustrated some relations such as embodiment and the cyborg with hybrid intentionality are evidently more prominently facilitated by the Neuralink than alterity and the cyborg composite intentionality relations are as well.

Technologies conforming to more than one of these relations is not necessarily a new phenomenon. For instance, smartphones can have both an embodiment and a cyborg relation. Intuitively it might have seemed that the cyborg relation is the best to sufficiently explain everything of relevance for the Neuralink. While Verbeek briefly mentions BCIs as an example of a cyborg relation (Verbeek, 2008, p.391), such a singular use in assessment would have been too narrow to fully describe Neuralink. For one, the cyborg relation is too broad in its formulation to accurately describe Neuralink in its entirety. Verbeek includes several technologies together as all constituting cyborg relations with a person, even though these technologies can be quite different in their use, invasiveness, and level of intentionality towards the person using them. This means they actually have significantly different relations to the human they are implanted into. For Verbeek's cyborg relations, technologies such as pacemakers, antidepressant drugs and BCIs all fall into the same category (Verbeek, 2008, p.391). While they all facilitate a phenomenological relation to the world, a Neuralink is still significantly different from these other technologies. As was explored in Chapter 2, these examples Verbeek provides are all usually a form of biomimicry (Gerola et al., 2023 p.4). They attempt to replicate an existing natural capacity or organ the human body possesses and replace it as closely as possible. Essentially these technologies are designed to be a form of extreme embodiment or perhaps even a background relation where no alteration to the user's experience is created. By contrast, Neuralink is not emulating the function of a previous organ. It is a technologically based alternative to existing biological impairments, offering an alternative means of movement to the user to enable them to regain some level of autonomy in the world they had lost by granting them an alternative capacity to the one they lost.

Additionally, focusing on only the cyborg relation would also be too narrow of a focus. While the device does facilitate a cyborg relation, this is not where the analysis should end. The device also has a level of agency that other cyborg relational technologies, such as pacemakers, anti-depressants, and ocular implants, do not facilitate due to its requirements to scan and interpret brain signals before relaying their intentions to these devices. This is due to its plethora of functions as was explained in Chapter 2, (signal acquisition, feature extraction, feature translation, and device output). This technology also facilitates embodiment, hermeneutic, and background relations as was explored. By understanding each of the relations a technology creates a more comprehensive understanding of how it affects human experiences can be ascertained. Going back to smartphones, if the focus was only on the cyborg relation, smart phones would only be observed for how they transform the perceptual information we access through them. The embodiment and alterity aspects of the technology would be missed and thus crucial details of how humans relate to the technology would remain unexplored, such as how they allow for us to communicate with each other through an embodiment relation. This would lead to a less comprehensive description and understanding of smartphones from a post-phenomenological perspective. Therefore, while the Neuralink does facilitate a cyborg relation, only considering this relation a would be too narrow of an assessment. By performing this investigation, an understanding of all these aspects of the Neuralink can be gleamed. This in turn will enable a comprehensive assessment of the technology. This can help with clarifying how this technology can be discussed further which will be beneficial to future discussions and evaluations. From this a more comprehensive picture can be extrapolated for society, and all of the values that its design promote can be revealed and studied.

4.2 What post-phenomenology reveals about Neuralink

This investigation of the Neuralink through post-phenomenology, enables a deeper understanding of the device. Its design de-emphasises its role in shaping the user's experience, as it interacts with them in a subtle manner as seen through background relations. Through an embodiment relation, the technology allows for a person with Arbaugh's condition to interact with digital devices in an easy, intuitive, and comfortable manner (Neuralink, 2024). The device instead emphasises how he can engage with the world through electronic devices. It de-emphasises the need to move as he can do this comfortably from his bed (Neuralink, 2024). In this manner the device can also be seen as de-emphasising the need for physical presence and instead emphasises the technological possibilities of interaction with the world. It allows Arbaugh to better experience a hermeneutic relation through other technologies much like how able-bodied people would enjoy them through this withdrawing from attention (Leffer, 2024). This further illustrates how the device emphasises engaging with the world through technology. By facilitating ease of interaction, the user is encouraged to make use of other devices around them. It also emphasizes human intentionality and responsibility they have for BCI mediated actions, while concealing the role of the device in facilitating these actions, as Arbaugh's account of playing chess illustrates (Mehta, 2024). The cyborg relations illustrate how Arbaugh is seeing the device as part of himself. He notes how he moved a chess piece through the Neuralink, taking ownership of this joint intentionality that exists through the device. Although this is contested (Mehta, 2024) this is at least how Arbaugh personally experiences what is happening. This can be seen as in line with the mission statement of Neuralink to give autonomy to people in need (Neuralink, n.d) by enabling them to experience these actions as primary agent of intentionality as opposed to the technology. This is similar to how Niel Harbission sees his eyeborg antenna (Newitz, 2013). It is important to consider for these insights that this device is being designed for users who physically cannot move most of his body and require a device like Neuralink for such tasks. As such, while an able-bodied person would be able to do the same things Arbaugh can with it, they would presumably not enter into the same types of relation with the device as he does. The technology would not necessarily emphasise or conceal aspects of the lifeworld in the same manner for them, as it does for Arbaugh. Although it's possible the Neuralink could encourage them to interact with the world through electronics even more than they were before, this cannot be verified until such time as Neuralink begins seeing use with able-bodied subjects, if it ever does. Understanding that the Neuralink becomes largely transparent to the user as opposed to be being the very centre of the user's attention is important. It illustrates the degree to which Arbaugh sees himself as the primary or even exclusive agent with intentionality in control of BCI mediated actions. As seen when playing chess, Arbaugh considers himself to be the one doing actions (Mehta, 2024). Understanding this transparency of the technology and ownership of intentionality through post-phenomenology is important for understanding how users will engage with it, be altered by using it, as well as informing its design. It can enable a better understanding of potential ethical dilemmas in future, where undesirable actions may be facilitated through a Neuralink whether they were intended by the user or not.

While this analysis is extensive, post-phenomenology enables descriptive rather than a normative analysis of a technology. It can reveal much about a technology, but we cannot make an ethical evaluation with post-phenomenology alone as was explored by de Boer et al. (2018) with their weak reading of Verbeek's Mediation Theory (2018) of which post-phenomenology forms a key aspect. However, this descriptive analysis reveals a lot about the device and enable it to be considered in ways it would not have before. For example, by building upon Heersmink's analysis, we can see how Neuralink, unlike BCIs before it, could create an embodiment relation and that it also facilitates other relations and may fulfil such an embodiment relation to a greater extent than

Heersmink initially concluded, as well as better understanding of what it reveals and conceals about the world and how it will alter the manner in which one experiences the world around them when using the device. However, this descriptive analysis reveals a lot about the Neuralink and enables it to be considered in ways it would not have before.

4.3 Limitations

While the viability of using post-phenomenology to assess new technologies has been demonstrated, there are some limitations to this research that are worth mentioning. Neuralink was chosen for this thesis due both to a personal fascination with this technology and because it is also an example of a technology in the prototype stage that a wider audience is likely to be familiar with, given its recent human trials and the prominence of the company's founder, Elon Musk. Assessing a technology in this manner at this stage has its advantages. This early stage is a more optimal time to begin analysing a technology before it becomes mainstream and intrenched, after which, rectifying issues that are identified can be a more challenging task than if they are identified earlier in use and deployment. Additionally, because of its familiarity to most current readers, a better understanding of the research question and its relevance can be achieved. However, as of the writing of this thesis there are only two individuals who possess it and one of them has not been public yet about his experiences with the device. This means right now there is only one person's experiences to guide this analysis, and this was in an indirect manner by analysing statements published by Neuralink themselves and other indirect sources such as interview articles. While I attempted to contact Noland Arbaugh in order to inquire about his experience with the device such that I could acquire a more informed view of his experiences, I received no response. Although these sources did help to illustrate why post-phenomenology would be worth using to analyse the device, post-phenomenology is meant to describe the individual user's experience. None of these agents were likely to have been interested in understanding Arbaugh's experience with the Neuralink from a post-phenomenal perspective. While I believe referring to the quotes from Arbaugh Neuralink has provided, the article from Leffer (2024) which drew from an interview with Arbaugh, and research into BCI users conducted by Heersmink which examined BCI users more broadly was sufficient for this investigation, consulting with the user of a technology directly is ultimately part of the assessment process that is argued for here. Future research should take the opportunity to speak with Noland Arbaugh and any additional users of Neuralink at that time and inquire about their experiences with questions informed by post-phenomenology. This could enable this approach to be more accurate and possibly reveal even more insight into the device than were discussed here.

Additionally, this investigation drew on a single experience with the device. While at the time of writing this constitutes half of the Neuralink's total users, this is share is likely to quickly shrink as human trials progress. While the validity of an individual level analysis of a technology through post-phenomenology has been demonstrated earlier in chapter 3, having more experiences to inform an assessment would enable for a more accurate assessment. As Tbalvandany et al. (2019) noted that two different users can have different perceptual experiences with the same BCI (p.238) Therefore discerning which aspects are unique to how Arbaugh experiences the device compared to the broader average experience that individual users will have can be understood.

4.4 Future research directions

Now that we have analysed the Neuralink through post-phenomenology, how can what has been learned about the Neuralink be used to ethically design it? From this investigation it has been demonstrated how post-phenomenology can play a key role in the ethical assessment of technology by enabling a broader understanding of how a technology will alter the individual's experience of the world around them. From this a plethora of insights can be obtained to provide a richer and better-informed ethical analysis. As mentioned, while post-phenomenology is mainly descriptive rather than normative, de Boer et. a (2018) note it does enable a 'proto ethics' for assessing technology (p.312) This means that this 'weak' reading of Verbeek's Meditation theory means taking the phenomenological mappings of a technology, an aspect of mediation theory, and using it to augment an existing method of assessment. In this manner, post-phenomenology can play a role in revealing ethical concerns regarding a technology (de Boer, et. al, 2018, p. 312) that can then be addressed. Based on the analysis in the previous chapter, I agree with de Boer et. al (2018) that the 'weak' form of post-phenomenology is viable for technology assessment. This is a good start but not sufficient alone to enable ethical technology design or assessment that would avoid undesirable situations like those of Google maps, Snapchat, and drones mentioned in Chapter 1. Therefore, it would still require coupling with external theories or frameworks. Future research could examine ways of building on this 'proto ethics' to design Neuralink in a more desirable manner. One possible avenue would be to use the value sensitive design (VSD) approach, specifically, the VSD approach as proposed by Ibo van de Poel. This approach may be able to assess technologies such as the Neuralink while also addressing the weaknesses of post-phenomenology.

VSD has been around for some time, having been formulated by Batya Friedman (Friedman, 1996) as a means for translating ethical values into design requirements for a technology. However, for this future research suggestion I shall specify the VSD approach proposed by Ibo van de Poel (2013). Van de Poel notes how previous VSD approaches have not sufficiently explored how to translate ethical values into tangible design requirements and proposes a means to do so. (van de Poel, 2013, p. 253). As Neuralink is still in the early stages of development, its possible van de Poel's approach may be more applicable to guiding and successfully implementing values into its design. A joining of VSD with post-phenomenology is not without precedent, as Verbeek, et. al (2022), have advocated for a similar approach after Verbeek advocated for his Mediation theory exclusive approach to technology assessment (de Boer, et. al 2018, p. 300). However, this previous VSD approach was more interested in advocating for empirical research to inform VSD itself (Verbeek, et. al, 2022, p. 766), rather than an advocating for VSD in combination with post-phenomenology specifically for ETA. While van de Poel's work in the subject was referenced, an explicit endorsement of his VSD approach of value hierarchies over others was not made. Van de Poel's VSD appearance specifically provides a means of addressing the neglect for broader societal impacts of a technology within the post-phenomenology as identified by its critics in Chapter 3. Broader societal aspects could potentially be incorporated, as this approach proposes identifying values and formulating design requirements from them (van de Poel, 2013, p.259). This approach could be used to address the individualistic criticism of post-phenomenology, as tangible design requirements could be implemented which can be societally focused. This approach may be able to provide a more context-sensitive and ethically beneficial means of designing a new technology. This methodology can also be used with any number of different value configurations, so that a technology could be designed per contextually beneficial values.

Chapter 5: Conclusion: Towards a post-phenomenological informed means of technology

The research question posed was: *How can post-phenomenology assist in the assessment of the Neuralink BCI.* I believe that through this analysis of the Neuralink BCI it has been demonstrated how, as the following insights have been illuminated.

From this research we saw in Chapter 1 the relevance of coming to understand how Neuralink technology operates and the need to understand how it will affect its users and how they will experience the world.

In Chapter 2 what exactly a BCI it was explored and a detailed understanding of Neuralink in particular was established. It was shown the challenges that come with this technology and the extent to which it is different from other forms of BCI technology,

In Chapter 3 it then shown how despite its limitations, post-phenomenology was well suited to describing the Neuralink and that the device can facilitate each of the relations described by Ihde and Verbeek to a certain extent with some, such as embodiment and the hybrid intentionality cyborg, being more prominent than others. In summary, the Neuralink BCI device facilitates all of the post-phenomenological relations described by Ihde and Verbeek which provides a comprehensive means of understanding how the device will affect its users to a certain extent with some being more prominently facilitated than others. Here the post-phenomenological research into BCI's conducted by Richard Heersmink was evaluated in light of Neuralink and his conclusions regarding embodiment relations were reevaluated in light of this more advanced form of BCI.

As a background relation the Neuralink is an ever-vigilant watcher, always observing the user's brainwaves in order to immediately enable them to enact their intentions through which is withdraws and become quite natural for the user.

As an embodiment relation, the Neuralink is taken into the bodily perception and brings technologies into reach of the user that previously were not, allowing the user to interact with them as though they were within physical reach.

As a hermeneutic relation, the Neuralink transforms the information of the user themselves for others to comprehend but also facilitates additional hermeneutic relations through enabling the user to interact with other technologies around them.

During its initial adoption by a user, the device can facilitate an alterity relation as a user calibrates it to their neurological activity before it eventually becomes a background relation after enough time.

As a cyborg with hybrid intentionality a BCI and a user have a symbiotic relationship as without human intentions, there is nothing for it to translate and convert. The user in turn cannot act without the device converting their intentions into actions.

As a cyborg with composite intentionality the Neuralink is detecting his neurological activity and relaying potential commands to a nearby device, the Neuralink has autonomy of its own and bridges this intentionality gap between Arbaugh and his computer.

Post-phenomenology can provide a means to understand how people will interact with a technology such as Neuralink and how its specific functions will necessarily alter how the user will perceive the world. Through this comprehensive analysis, a broader understanding of the Neuralink's potential influence on a user has been gleaned and as per de Boer et. al's proto-ethics reading, potential ethical dimensions can be more readily identified.

Being able to assess such technologies as they are in development to better understand their effect on us as users and determine their desirability has become more important than ever before as the invasiveness of our technologies become even more acute. As Jean Luc-Nancy neatly encapsulated it when contemplating the nature of a heart transplant he received: *"Man becomes what he is: the most terrifying and the most troubling technician."* (Nancy, 2008, p. 170).

Whether these developments in technology will be is as 'terrifying' as Nancy speculates lies beyond the scope of this thesis. But if we are to become such technicians, we should do so in an informed and ethical manner, especially as these technologies become more invasive and precise in their capacities. As technologies begin to change, we must continuously evaluate them, the earlier the better, in order to fully comprehend their impact on us as individuals and our broader society. When it comes to ethically assessing new technologies in order to ascertain their issues and desirability, post-phenomenology can play a crucial role in informing how we understand these technologies which can enable a better and more comprehensive ethical assessment to be conducted. Future research can begin with interviewing users of Neuralink directly—ideally more than one—and use these insights to build upon this analysis provided. Future research could also investigate how to design the Neuralink by using these post-phenomenological mappings to augment Ibo van de Poel's VSD approach. This may offer a means of doing so for Neuralink and other technologies while also compensating for certain weaknesses of post-phenomenology.

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