A Sociotechnical Imaginary for Neuralink

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Aishu Hombal
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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature  Date 05/09/2021
Aishu Hombal

Approved _____  _____ Date _____5/4/2021____
Dr. Hannah Rogers, Department of Engineering and Society

Abstract

Science and technology are consistently evolving and adapting in the realm of medicine. As such, the sociotechnical imaginary is a tool that can be used to demonstrate how specific innovations may potentially benefit or diminish the public good. Neuralink is a company currently developing a novel technology with primary applications as a medical device. The "Link" is a chip implanted in the brain using a surgical robot and is designed to connect the human brain with digital devices. This research paper analyzes the sociotechnical imaginary of the relevant social and scientific community involved with Neuralink. Documentary analysis and discourse analysis were utilized to decipher and interpret the components of the sociotechnical imaginary and their implications on society as well as the trajectory of convictions that have led to the development of the Link. The primary elements of the sociotechnical imaginary of the Neuralink social collective are as follows: human autonomy, improving public health outcomes, patient safety, and innovation in healthcare. The shared beliefs within the community are reflected in the design of the Link and emphasize why the Neuralink shareholders believe that their technology will convey social benefits. The STS research also considers limitations of the Link and the potential adverse repercussions on society for a holistic evaluation of the potential future the Link might bring. Challenges regarding the Link include the potential to exacerbate health disparities and ethical concerns involving human enhancement, privacy, and safety of patients. The sociotechnical imaginary analysis of Neuralink illustrated the potential of the Link as a social good in the field of medicine.

A Sociotechnical Imaginary for Neuralink

Artificial intelligence in medicine is advancing at an accelerating rate, contributing to the abundance of technology in healthcare (Hamet & Tremblay, 2017; Mamlin & Tierney, 2016). Applications of artificial intelligence in medicine include diagnostic analysis, machine learning for radiology, and automation of administrative tasks, all serving to increase the efficiency and quality of patient care (*AI in Healthcare*, 2019). The capacity for optimal outcomes increases as medical research and treatments adapt to the increase in technological capacity. A large selection of medical conditions has yet to be cured through standard research methods, further encouraging the exploration into novel methods of approaching healthcare. As such, it is worthwhile to invest in innovative companies aiming to revolutionize the healthcare sector.

Neuralink, founded by Elon Musk, is a company developing a novel medical device called the "Link," an implantable brain chip created with the purpose of augmenting human cognition and developing a connection between the human brain and machines via artificial intelligence (Musk & Neuralink, 2019). Neuralink's innovative methods to address medical conditions, which are incomparable to current research and treatments, are assessed in this paper using a sociotechnical imaginary. Sociotechnical imaginaries work to illuminate a vision of a potential social future that might arise in response to advances in science and technology and provide such developments with a normative analysis of their fulfillment (Jasanoff & Kim, 2009; Sadowski & Bendor, 2019; *STS Program » Research » Platforms » Sociotechnical Imaginaries*, n.d.). Analysis of the sociotechnical imaginary will provide insight into the shared beliefs of the actors involved in Neuralink and their outlook on the future development of neurotechnologies in

healthcare, as well as the social repercussions that would follow production of the Link (Jewitt et al., 2020).

Although Neuralink can be considered favorable to overall advancement of healthcare, it is imperative to recognize that only certain individuals will likely have access to the device while others may not reap the same benefits. This research paper will begin by providing historical examples of neurotechnologies that emphasize the evolution of shared beliefs constituting the sociotechnical imaginary, and then introduce Neuralink. The background will be followed by a discussion of the components of the sociotechnical imaginary shared by the Neuralink collective and offer the relevant limitations to conclude the analysis.

Sociotechnical Imaginary

The social construction of technology (SCOT) theory argues that human actions influence the development of technology through collaborative discourse among relevant social groups (Bijker, 2015). A derivation of SCOT is the sociotechnical imaginary. A sociotechnical imaginary is composed of shared beliefs from a social collective that influence the progression towards a future possible world (*Methods Vignettes*, n.d.). Imaginaries can frame potential futures, connect beliefs across time, and promote or dissuade action (*STS Program » Research » Platforms » Sociotechnical Imaginaries*, n.d.). Moreover, sociotechnical imaginaries are often applied in developing visions of a feasibly improved future but analyzing the implications of novel science and technologies on social life can also impede the development of harmful technologies prior to their production. The use of imaginaries as a framework can provide detailed insight into the motivation and advocacy behind certain innovative technologies and serve as a justification to persuade potential investors that said technologies will contribute to the public good (*STS Program » Research » Platforms » Sociotechnical Imaginaries*, n.d.).

Furthermore, imaginaries produce systems of shared beliefs and meaning that contextualize technologies based on the past and into the future (Jewitt et al., 2020).

STS analysis using the sociotechnical imaginary framework will illustrate the beliefs of actors involved with Neuralink regarding the social implications associated with the technology as well as the foundation behind why the future that could be produced with Neuralink is desired. Assessment of the sociotechnical imaginary of the social collective of Neuralink will also establish how the shared beliefs are encoded into specific features of the technology. Examining the sociotechnical imaginary will demonstrate the manifestation of technologies into the social world and the corresponding positive or negative impacts they might bestow.

Historical Neurotechnologies Contributing to the Sociotechnical Imaginary of Neuralink

The lineage of beliefs regarding advancement of neurotechnologies for the benefit of society can be traced back to decades ago. The first endeavor towards translation of neural activity to control external devices was conducted in monkeys in 1966 (Evarts, 1966). The term brain-computer interface, synonymous with brain-machine interface, was coined in 1973 by the Brain Research Institute of the University of California, Los Angeles (Vidal, 1973). The Brain Research Institute stated their primary goal was to connect inductive mental capabilities of humans to the deductive abilities of computers. In fact, the brain-machine interface aimed to "elevate the computer to a genuine prosthetic extension of the brain" (Vidal, 1973). This aligns with Neuralink's mission to work towards a mutually beneficial relationship with artificial intelligence through integration of the human brain with computers.

The Department of Psychology at East Tennessee State University (ETSU) tested a brain-computer interface connected via an electrode cap on an individual with Amyotrophic Lateral Sclerosis, a neurodegenerative disorder associated with paralysis (Sellers et al., 2010). The

device was designed for long-term independent home use and allowed the individual to communicate through email and manage a research laboratory. The brain-computer interface successfully restored the independence of the patient and improved his productivity and quality of life in both social and work-related areas according to self and family reports (Sellers et al., 2010). As will be discussed further, Neuralink aims to improve human autonomy by creating a device that is accessible for the user to operate by themselves at home. This example of the brain-computer interface by ETSU shows the patient's ability to independently manage his device increased his social well-being and this serves as direct evidence that medical technologies can restore independence and increase social connectedness, which is what Neuralink strives to achieve.

The sociotechnical imaginary of the brain-computer interface is congruent with that of Neuralink's imaginary to rebuild people's, especially those with physical impediments, sense of autonomy and positively contribute to their social experience. Historical medical technologies, such as the brain-computer interface from ETSU, have established certain avenues of thoughts and beliefs that Neuralink has adopted while developing the Link, and shared notions of the Neuralink social collective will likely be embraced by other collectives with similar goals of developing advanced medical technologies.

Neuralink

At the 2017 National Governors Association, Elon Musk, the chief executive officer (CEO) of Neuralink, stated that artificial intelligence is an existential threat to the human race (Domonoske, 2017). Given that there is no regulatory agency overseeing artificial intelligence, Musk believes that risk from accelerating advancements in artificial intelligence is heightened and that regulation over artificial intelligence is necessary to protect human beings (*#1609 - Elon*

Musk, 2021). In fact, the current course of development implies that artificial intelligence will continue to evolve until machines achieve sentience and consciousness, which will fundamentally alter how society distinguishes human beings and machines (Lavelle, 2020). Thus, Neuralink was founded in hopes of equipping human beings with the ability to compete with rapidly advancing artificial intelligence.

Neuralink is a company developing a brain-machine interface in the form of a chip called the "Link" that is implanted into the brain. The Link interprets brain signals registered from electrodes, which enable direct communication with external digital devices (*Approach*, 2021). The main goal of Neuralink is to develop medical devices for treatment, and eventually branch out into non-medical applications. The current focus of the company is using the Link to give patients with spinal cord injuries the ability to control computers (*Applications*, 2021). Additional potential applications of Neuralink include seizure detections, establishing sensation in and optimization of prosthetics, and the prevention and treatment of neurodegenerative diseases (Pisarchik et al., 2019).

The Link is designed with micron-scale threads that exhibit increased biocompatibility, flexibility, specificity, and bandwidth than current brain-machine interfaces (Musk & Neuralink, 2019). To address challenges faced by other brain-machine interface developers, Neuralink has increased the number of electrode channels and optimized the biocompatibility of the device, improved the scaling of neural signals, and advanced efficiency of neural signal decoding (*Approach*, 2021). Furthermore, the Link is designed to modulate neural activity through wireless connection, not just record or stimulate the human brain as in existing neurotechnologies, which vastly increases the potential clinical applications (Musk & Neuralink, 2019). Neuralink is also building a robotic system that neurosurgeons will be able to use to insert

a Link into a human brain while maintaining both the safety of a patient and the integrity of the delicate technology (Musk & Neuralink, 2019). The inspiration behind Neuralink is to give human beings the ability to communicate and integrate with machines in order to compete with artificial intelligence based on Musk's allegation of artificial intelligence being an existential threat. Musk has mentioned that he strives towards a "symbiosis with artificial intelligence" and human beings to ascertain a mutually beneficial interaction that will contribute to the survival of the human species in the future (*Neuralink Launch Event*, 2019).

The Sociotechnical Imaginary shared by the Neuralink Social Collective

To ensure that Neuralink will serve its purpose, the social collective involved in the development of the innovative neurotechnology must share certain notions about the human body, technology, medicine, and society.

To begin, the collective must believe in autonomy of the human body. Autonomy is the capacity for self-governance and freedom. Essentially, an individual has the ability to think and act independently of external influence (Christman, 2020). Human autonomy is a central value, especially in healthcare (Varelius, 2006). This has two implications in the case of Neuralink. First, in the case of treating individuals with spinal cord injury, the collective believes that granting people the ability to directly engage with technology will allow them to follow through with self-determined actions and reclaim their autonomy, which might have been negatively affected or taken away from them due to physical impediments. The Link would achieve this by recording neural activity, processing the signals in real time, and relaying the information to the Link. As users think about performing certain movements, those intentions would be decoded and transmitted to a digital device via Bluetooth. The ability to directly engage with a digital device would allow a patient with spinal cord injury to use the Internet and other applications on

a computer to complete tasks and communicate with others without the aid of a caretaker. Abating the physical burden of spinal cord injury by allowing the patients to accomplish their own goals and control their own actions would also serve to restore their confidence in their own functional capacity and productivity as a member of society. The value of reclaiming independence is also supported by Neuralink's goal to develop a technology that is accessible and easy to navigate, so that patients can take the system home and operate the device by themselves (*Approach*, 2021). Musk has claimed that initial human trails of the Link for conditions involving the central nervous systems may begin later in 2021, and as a novel medical device, the clinical trials could continue up to seven years before gaining FDA approval (Elon Musk, 2021; Van Norman, 2016).

Secondly, the goals of the technology imply further belief that being able to connect with and use a digital device will provide a social benefit in the current culture. In fact, this notion can be further supported given the apparent need for technology during the COVID-19 pandemic (Uohara et al., 2020). The COVID-19 pandemic has disproportionately impacted older populations, individuals with pre-existing medical conditions, racial and ethnic minority groups, and those of low socioeconomic status (Tai et al., 2021). These population groups also happen to possess disproportionately greater amounts of individuals who are not digitally literate (Eibner, 2007). When the entire population is recommended to stay at home and limit close contact with others, the primary method for communication is through technology. The steep decrease in personal interaction due to social distancing poses a grave disadvantage to those who are not adept with technology. A lack of social connectedness significantly increases the risk for premature mortality, even more so than many other factors such as physical inactivity and smoking (Hudson, 2017), and the isolation caused by the COVID-19 pandemic is a public health

concern. However, those with access to and literacy in technology have experienced a marked increase in usage for social and interpersonal purposes, especially with the rise in social media. The use of technology to maintain social connectedness has mitigated feelings of loneliness, irritability, boredom, and even increased feelings of belonging, protecting individuals from the negative psychological effects that are associated with COVID-19 isolation (Gabbiadini et al., 2020).

Furthermore, education is an important establishment valued for its contribution to social development. During COVID-19, most public institutions have been closed to comply with social distancing regulations, and the majority of students have had to complete their education online. Technology has made it possible to fulfill educational requirements, while also allowing students to continue to interact with their peers and educators for a greater sense of normalcy. Beyond standard education, digital devices themselves provide immense access to resources that can benefit individuals in their academic, social, and personal lives. Higher use of technology is associated with fewer chronic illnesses, higher self-assessment of health and well-being, and fewer depressive symptoms (Chopik, 2016). Human beings are social creatures and technology enhances the frequency and potential for social interaction, making it a valuable social good. Consequently, for future non-medical applications of the Link, Neuralink established that the device could be used for direct communication between individuals using solely their thoughts. The shareholders and social collective of Neuralink share the belief that granting human beings' autonomy to utilize technology promotes improved social well-being for the general public.

Improving Public Health Outcomes

Another core conviction that is essential for the design of Neuralink is that advancing medical technologies will improve general public health outcomes. The Neuralink social

collective believes that technology can improve the methods through which professionals approach the field of medicine, which is then applied towards the betterment of society. The foundation of this belief is rooted in the value of human health in society. More specifically, the collective belief is that the applications of the Link will improve the quality of life for many patients who are affected by medical conditions, such as spinal cord injury or neurodegenerative diseases, that are incurable or have inadequate treatments to enhance outcomes. In a society that is widely dominated by technology, the Link can allow patients who are limited by their medical conditions to better interact with the digital world and therefore play a larger role in society than they might have been able to previously.

Studies have shown that health is a constructed social reality, and thus the body politic will be impacted by the general health of members in a society (Saltonstall, 1993). There are a couple different justifications for the value of health and the encouragement towards a longer life. The first of these is a moral justification, which emphasizes Kantian and Aristotelian thinking that improving public health promotes good and virtuous lives within a just society (Häyry, 2006). Additionally, an increase in overall health of the public could encourage people's rational duty towards themselves and others from the basis of utilitarianism (Driver, 2014). These justifications can be applied by Neuralink to claim that the Link will improve public health outcomes and therefore encourage better social lives for the collective. Current political ideologies are another justification for improving public health. For example, individuals with superior health have more opportunities for freedom from disease burden and overall better health of the public serves to increase equality of opportunity to allow people to pursue more endeavors that can cultivate enriched social lives (Häyry, 2006). In this case, Neuralink can work

to improve overall public health to provide individuals with greater agency to work towards their goals.

Moreover, greater efficacy of medical diagnostics and treatments is a factor of the imaginary agreed upon by the Neuralink social collective. Efficiency is demonstrated by the engineering of the flexible threads in the Link system to traverse only the desired location in the brain, and to cover more surface area with less material to optimize material usage (*Approach*, 2021). In addition, developing an adaptable algorithm based on neural responses from the Link indicates how treatments can be tailored specifically for the patient and evolve based on the progression of the patient's medical condition. The sociotechnical imaginary suggests that greater efficacy and better overall public health can improve the social experience of an individual by presenting them with more opportunities for prosperity. The Neuralink social collective believes the Link is an advantageous medical technology that will direct the lives of patients with currently incurable conditions towards convalescence.

Patient Safety

The Neuralink community includes patient safety in their sociotechnical imaginary. This is demonstrated through the increased dedication to biocompatibility of the implant as well as design of the chip itself to minimize risk to blood vessels on the surface of the brain. In addition, developing the robotic system for neurosurgery increases the precision of the procedure, which reduces human error and risks that might have been involved in one of the most sensitive organs of the body. However, neurosurgery increases the liability risk for Neuralink, especially given that insertion of the Link is not based on immediate life-threatening need if the patient is harmed during the procedure. The risks of neurosurgery that may compromise patient safety are: vision

changes, impaired coordination, stroke, memory loss, and many others based on the area of the brain that is adversely affected (*Awake Brain Surgery - Mayo Clinic*, n.d.).

As there are always privacy concerns regarding technology, especially technologies that might be connected to the human brain, Neuralink is taking extensive security measures such as cryptography, defensive engineering, and security auditing built into each component of the Link to ensure the safety of users (*Applications*, 2021). However, it is too soon to know whether these security measures will be sufficient, especially given that many individuals, even without academic expertise, are able to hack into some of the most secure technological institutions to date. For example, a fifteen-year-old named Jonathan James was able to hack into the computers of the United States Department of Defense in 1999 (Stout, 2000), which shows that it is very hard to guarantee safety, especially for a device that is implanted directly in the brain. Similarly, the Link functions via Bluetooth and there are several known trojan viruses that can spread through Bluetooth (Bocetta, 2019), which can threaten the safety of patients. Neuralink will have to prove that their medical device is safe for insertion and that patients will be protected against potential malware or technological harm for the Link to be approved by the FDA and accepted by society as having more advantages than possible harms.

Innovation in Healthcare

In addition, the sociotechnical imaginary involves the belief that contribution to healthcare research through productive means can resonate throughout the medical community for generations moving forward. For example, Neuralink might allow researchers to map new pathways in the brain that can be used to further research in neuroscience, molecular medicine, and medical devices (Brown, 2020). Additionally, the development of the surgical robot for Link implantation helps to advance the entire field of robots involved with surgeries, which can then

be extrapolated for use in nearly every medical division (Brown, 2020). Regardless of the applications that might be used in the future, the Link also provides a mechanism for novel access to neural information and calls attention to the importance of research in the neurotechnology sector. The brain is the most complex organ in the human body with more questions left unanswered than answered, but part of Neuralink's imaginary is that their technology can pave the way towards a greater understanding of the brain.

Limitations of the Link in Improving Social Outcomes

Regardless of the vast potential benefits from Neuralink, one must acknowledge that the device will mostly be accrued by people with greater socioeconomic privilege, while remaining inaccessible to those without the same financial and social resources. Though novel technologies exhibit undeniable assets, Neuralink poses the threat of stark disparity in distribution of the technology. To be able to operate the technology assumes that the user is literate in both language and technology (Smith & Magnani, 2019). If those who are linguistically and digitally literate are given preferential treatment over those who are not, this could create further healthcare disparities and could put certain populations at a social disadvantage in comparison to others. Furthermore, the direct connection to digital devices implies accessibility and ownership of such devices (Pangrazio, 2014). Many individuals will not even be knowledgeable about Neuralink in order to potentially sign up for clinical trials, regardless of the medical conditions they have, simply because of lack of accessible technology and internet due to lower socioeconomic status, rural residence, or mobility limitations (Hudson, 2017). Similarly, health literacy, which is linked to higher education and socioeconomic status, is another driver in health disparities (Mantwill et al., 2015) that could be accentuated by Neuralink.

Neuralink is inherently aimed towards those with higher socioeconomic status, higher education, and larger public influence, and this could characterize the Link as a gate-keeping healthcare innovation (Weiss et al., 2018). As a private company, the potential inaccessibility of the Link to the common public or those who are under resourced might incite a cause for concern regarding the profit motives of Neuralink. Healthcare, especially in the United States, functions as a business (Sawyer, 2018) and novel medical treatments with a lower supply are usually the most expensive, which can again contribute to disparities in medical care.

The limitations in accessibility to the Link will likely not be mitigated until the technology is able to be mass produced (Weiss et al., 2018), which is anticipated to be many years, or even decades, in the future, and this could be a major detriment in the justification of producing Neuralink as it might dissuade shareholders from investing in the Link based on the lack of time-sensitive results towards creating solutions that could be used by every individual. For instance, shareholders might decide to instead invest into other research solutions that are less innovative but have a greater historical foundation in producing results that can be easily mass produced for public use. There could also be social lobbyists that dispute the production of the Link given the potential for facilitating disparity. As such, potential inaccessibility of the Link must be considered as part of the sociotechnical imaginary as a factor that might negatively impact the public, and this might delay the progress of production and release of the Link.

Although disparity in access to the Link might arise, the potential to benefit even a subset of the population is worthwhile when compared to no benefit to the entire population (Kirkwood, 2010). It is impossible to predict what methods Neuralink will take to handle distribution of their device in the future, because the Link has yet begun human clinical trials. This research paper is not addressing normative claims about disparities in access to innovative medical

neurotechnologies, but rather is reflecting on the perspectives and values of the social collective of Neuralink that have led them to design their medical device with features encoding their shared beliefs.

Ethical Considerations

Ethical priorities must be considered regarding advanced neurotechnologies in a culture specific context, while still taking universal rights and global guidelines into account. The four main ethical priorities to consider with neurotechnologies are privacy and consent, agency and identity, augmentation, and bias (Yuste et al., 2017). Neural devices that are directly connected to the Internet open new avenues for privacy breaches such as data tracking and mental manipulation, which could compromise the ethical priorities of privacy, consent, and identity. Linking computational systems directly to people's brains enhances their mental and physical abilities beyond regular human capacities, indicating the need to enforce responsible innovation and engineering to protect the rights of users (Network, 2019). Members of the Yale IDC pose other ethical concerns regarding human enhancement including undeveloped regulation on such unconventional technologies, unintended consequences of the device, transparency if using the device, privacy violations, a potential black market for selling data, and a possible threat to free will (Dadia & Greenbaum, 2019). There is a negative connotation associated with the phrase "human enhancement" and framing the Link with this description could incite fear and doubt in the ethical standards of Neuralink. Additionally, if the Link is labeled as human enhancement and available to the public, this could potentially result in a paradigm shift of what society considers to be human as well as significant dissent in opinions on the matter. Though Neuralink aims to restore autonomy and freedom to users, inadequate security precautions when designing

the Link could put those same values at risk. The potential risk to autonomy and privacy could discourage shareholders from advocating for the development of Neuralink.

To address these concerns, it is imperative to recognize that implantation of the Link would be an entirely elective procedure, and all participants in future clinical trials and future users would be properly informed of all essential details to secure their safety and privacy. Neuralink has stated that they are going to implement a multidimensional security system to prevent possible threats and misuse of the Link, but it must be acknowledged that there are limitations in the protection Neuralink can provide, especially given the rapid advancement of artificial intelligence.

The ethical debates involving invasive neurotechnologies will influence the public perception of Neuralink, and subsequently impact the acceptance of the Link as a beneficial medical device for public good, which is a key factor in the aim of a sociotechnical imaginary. The FDA has granted Neuralink with breakthrough device designation, and to achieve FDA approval for human testing in the future, the company will have to demonstrate strict adherence to ethical codes and regulations (Whooley, 2020). One of the standards of medical research ethics is social responsibility, which states that research should promote social good or prevent social harm (Resnik, 2020). Based on the sociotechnical imaginary outlined, there is reason to believe that the social collective of Neuralink will work to ensure they meet the necessary criteria for FDA approval and subsequent distribution to the general public. However, if the public decides that the Link is an unethical medical device, the production of Link might be halted, or since Neuralink is a private company owned by the wealthiest man in the world ("Elon Musk Becomes World's Richest Person as Wealth Tops $185bn," 2021), the production and clinical trials might continue unless the FDA does not grant its approval. As mentioned

previously, the legal ramifications if the Link was labeled as unethical would be unclear based on the linguistic specificity in legal systems, but the ambiguity may work in favor of Neuralink until legislation adapts to the possibility of a human-computer hybrid. The public relations team of Neuralink is not particularly active, as Musk often speaks on behalf of many of his companies, but based on his statement, "about half my money is intended to help problems on Earth" (Elon Musk, 2018) and the mission statement of the company to help medical patients, it is likely that Neuralink will listen to the public's opinions and respond accordingly to appease the public while emphasizing the apparent necessity of their technology.

The Future of Neuralink

In his latest progress update on Neuralink, Musk disclosed that the company implanted the wireless chip in a monkey who was able to play video games by controlling the electronic interface solely with its mind (Dosage, 2021). The next steps in the process of bringing Neuralink to the market would be human clinical trials. If Neuralink successfully demonstrates the expected results from the Link with medical patients, there would be incentive to increase production for applications beyond the primary scope of patients with spinal cord injury. A potential future application could involve real time monitoring of a medical patient's symptoms for increased accessibility to health care professionals and healthcare. For example, there are many instances when an individual experiences abnormal symptoms or sudden revelations about a condition they may be experiencing. However, with the time it takes to find a healthcare provider, schedule an appointment, and go in for a visit, many times the details of conditions can become ambiguous. It is a common phenomenon to experience symptoms sporadically throughout the day and fail to physically demonstrate them during a short health care visit. When this occurs, it is difficult for healthcare providers to treat conditions they cannot witness the

patient experiencing. The Link could allow individuals to record their symptoms instantly for ease of explanation at a doctor's visit. During a speech, Musk described the Link as a "Fitbit in your skull with tiny wires" (Interesting Engineering, 2020). Extrapolating this analogy, the Link could also provide doctors with insight from the neural activity of patients, and the information could be sent directly to the patients' electronic health records. The Link could be a mechanism to improve the doctor-patient relationship, which aligns with the efficiency, improved public health, and implication of technology in medical care aspects of the sociotechnical imaginary. However, one must also realize that the doctor-patient relationship could be improved in other, potentially simpler, methods such as automating more administrative and clerical tasks to increase the amount of valuable face time between doctors and patients. Implementing more empathetic characteristics, active communication, and creating agendas with patients are other ways to optimize time for a better relationship. There is no shortage in ideas, utilizing technology or not, to enhance the doctor-patient relationship, which poses the question of if the Link is a necessary endeavor or not.

Neuralink may even begin to implement the Link for non-medical purposes in healthy individuals. This could include applications such as granting people the ability to communicate with one another through speech synthesis, browse the internet through mental direction, stream music through their minds, and express creative works as soon as inspiration is incited to name a few examples (*Applications*, 2021). These potential applications that Neuralink has proposed illuminate values that contribute to their sociotechnical imaginary: interconnectedness and increased expression contribute to better social well-being.

Conclusion

As neurotechnologies have progressed, researchers and engineers have found more social benefits through novel applications. The sociotechnical imaginary that Neuralink possesses has branched off of years of innovation in the neurotechnology field, which implies a further trajectory of neurotechnologies implemented in medicine for the public good. The social collective of Neuralink possesses several common sentiments including the importance of human autonomy, the belief that technology elevates an individual's social experience, and value of the role of technology in the evolution of medical care, all of which are manifested in their design of the Link. The sociotechnical imaginary reveals the shared beliefs of the Neuralink community and the prospective implications of the Link on society. Analysis of the potential consequences of the Link presents the technology as a social benefit to medical patients because the company demonstrates the potential to improve patient outcomes and benefit healthcare research through a novel medical device with greater efficacy than current standards. In the future, the sociotechnical imaginary of Neuralink requires more investigation in the legal expansions and biomedical regulations that are necessary for maintaining current ethical standards, as well as the potential evolution of values regarding technology and humanity that might influence public perception of the Link.

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