Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-024-04268-8 OPEN

Rethinking human–technology relations: exploring the sociopolitical dimensions of invasive brain stimulation

Amanda van Beinum[1]✉

Approaching the meeting of human and technology as a relation involves recognition of the plethora of already existing connections and associations between humans and non-human artifacts, as well as how connections grow and change over time. When connection between human and technology is a relation, it has no clear beginning or end point, no before or after. Instead, there are variations and modifications in the strength and quality of the relation. This paper argues that adequate conceptualization of human-technology contact as an ongoing relationship rather than a discrete interaction requires a broadening of scope beyond individual human users and technological devices. Using the application of deep brain stimulation (DBS) for cases of mental illness as an example, the paper explores how a relational approach to analysis brings forward important ethical and social issues warranting further scrutiny. Historical narratives of device development interpreted through theoretical perspectives of critical disability studies facilitate consideration of how social preferences for "normality" shape user perceptions of safety and effectiveness of yet clinically unproven treatments. Exploring experiences of embodiment through critical disabilities and posthuman critiques foregrounds how vulnerability and resilience are constructed through relational networks of interdependence, themselves novel forms of care. Finally, application of interdisciplinary perspectives to the study of human-technology relations opens up new analytic approaches for studying questions of embodiment, agency, and control precipitated through the development, surgical insertion, and experimental use of technology. Expanding beyond human-technology interactions to analyze the complexity of ongoing relations facilitates an opening-up of discussions around implanted technologies like DBS and invites further investigation of how novel human-technology pairings have the potential to effect social and political change.

[1] Department of Sociology, York University, Toronto, ON, Canada. ✉email: amandavb@yorku.ca

Introduction

Approaching the meeting of human and technology as a relation, rather than an interaction, involves recognition of the plethora of existing connections and ongoing associations between humans and non-human artifacts, as well as how these connections grow and change over time. Unlike an interaction, which may be more or less confined to the interface between a human user and technological device (Schleidgen et al., 2023), relations between humans and technologies extend outward from device interactions and have implications for the broader organization of society (Kudina and Verbeek, 2023).

In this paper, I argue that analysis of the meeting of humans and technology as a relationship requires a broadening of scope beyond individual human users and material devices. While interactions may take place in the laboratory or clinic, human-technology relations occur across space and time as histories of technology development and different social and political responses influence the ways in which devices are prescribed, experienced, and perceived. As a result, in addition to exploring immediate experiences of device use, the social contexts of technological development and use as well as the cultural and political contexts of user experiences must be taken into account. This paper explores the use of invasive brain stimulation therapy in cases of mental illness and demonstrates how this type of relational analysis foregrounds new and important ethical and social issues warranting further consideration.

Brain stimulation technologies, devices which facilitate the direct (invasive) or indirect (non-invasive) application of electrical energy to neural tissue, represent a large and growing subset of presently available neurotechnologies (Sabé et al., 2023). Deep brain stimulation (DBS) is one of the most widely studied forms of invasive brain stimulation. In general, this pacemaker-like device involves the implantation of electrodes deep within brain tissue which are connected via subdermal wires to a battery stimulator pack implanted in the chest (Medical Advisory Secretariat, 2005). Parameters such as the rate, intensity, and location of stimulation can be modified depending on the target condition (Lozano et al., 2019), thus, DBS can encompass a wide range of device designs and indications. DBS has been approved for use in Parkinson's Disease and essential tremor in Europe and North America for over 20 years (Medical Advisory Secretariat, 2005). It has also received United States FDA approval for use in patients with epilepsy, as well as a Humanitarian Exemption classification for use in patients with obsessive-compulsive disorder (Lee et al., 2019). Experimental trials are underway to explore potential uses of DBS for use in patients with Tourette's syndrome (ClinicalTrials.gov ID: NCT06361004), major depression (ClinicalTrials.gov ID: NCT05716555 & NCT03437928), eating disorders (ClinicalTrials.gov ID: NCT05245643), obesity (ClinicalTrials.gov ID: NCT04453020), addictions (ClinicalTrials.gov ID: NCT05903495), chronic pain (ClinicalTrials.gov ID: NCT04085406), dementia (ClinicalTrials.gov ID: NCT05699330), cerebral palsy (ClinicalTrials.gov ID: NCT06122675), post-traumatic stress disorder (ClinicalTrials.gov ID NCT02091843), Schizophrenia (ClinicalTrials.gov ID: NCT02361554), and tinnitus (ClinicalTrials.gov ID: NCT04296097). The possibility of clinical markets in multiple disease conditions has promoted considerable investment into the technology (Neurotech Reports, 2022).

Like other implanted devices such as cochlear implants, pacemakers, and insulin pumps, DBS seems to call out for an analytic approach beyond the human-technology interaction (Berk, 2018). Implanted devices are continually present with and within the user, impacting embodiment on multiple levels. For many users of implanted devices, management of the human-technology relationship is a matter of life and death (Oudshoorn, 2020). In the case of DBS, insertion of the device into the gray matter of the brain, the privileged seat of power for modern cerebral subjects (Vidal and Ortega, 2017), raises additional concerns. Beyond its impact on individual embodiment, a number of scholars have suggested that inserting technology into the brain, especially devices with the capacity to integrate artificial intelligence, might fundamentally unsettle established ideas of the human self (Ienca and Andorno, 2017; Soekadar et al., 2021). On a philosophical level, implanted technologies like DBS appear to threaten the ability to draw distinctions between the categories of human and machine.

When thinking of human-technology contact as an interaction, the potential for inequality and the possibility for losing the unique strengths of either party is an outcome to be actively mitigated (Rogers, 2019). The extent to which devices like DBS infringe upon patients' personal autonomy, agency, and personality, for example, have been popular topics of recent discussion (Gilbert et al., 2018; Frederic Gilbert et al., 2023; Tacca and Gilbert, 2023). However, when implanted brain stimulation devices like DBS are analyzed as part of an ongoing relationship with humans, a position which acknowledges a longer temporality to how humans and technologies develop and exist in constant connection, additional possibilities and risks beyond users and devices become more apparent. Instead of attending to the pitfalls and potentials of individual interactions with the device, a relational approach acknowledges the socio-political contexts in which devices are developed, used, and shape social organization.

Methods

The first part of this paper presents a brief history of invasive brain stimulation devices for experimental use in mental illness. This narrative helps to contextualize devices like DBS as part of a longer genealogy of neurotechnology and psychosurgery. Concepts from critical disability studies are introduced to help foreground questions about the ideal invasive brain stimulation device user and conflicting objectives built into the technology. Understanding implanted brain stimulation devices as a product of psychosurgical and psychiatric histories, and the choice to obtain devices like DBS as occurring within specific social contexts, helps to establish the situated nature against which human users and material devices form human-technology relationships.

Part two of this paper explores how the embodied experience of living with an implanted brain stimulation device is influenced by social and political contexts such as understandings of disability and the organization of medical care. Expectations and fears about effectiveness of experimental devices, as well as anxieties around how technology will be perceived by others are also connected to power shifts within cultural and political landscapes. Analyzing the human-machine relationship through an interdisciplinary lens moves beyond questions of control and agency at the individual level to consider how implanted devices like DBS may impact social organization.

The final section ties these insights together to propose how understanding the contexts of human-machine relationships results in shifts in thinking about the future of implanted brain stimulation devices. Concerns about agency, control, and infringement on the idea of the human remain focused on individual components of human-technology interaction. In contrast, when the human-technology connection is centered as an ongoing socio-political relationship, questions about community, sustainability, access, and the potential for widespread social change emerge.

The unique contributions of this paper are twofold. First, though overviews of the history of invasive brain stimulation have been published, most focus on DBS more generally rather than narrowing in on the development of invasive brain stimulation technologies for experimental use in psychiatric populations. Attending to the specific genealogy of invasive brain stimulation devices in the contexts of psychiatric populations helps to identify larger sociopolitical contexts of present-day human-technology relationships. Changes to embodiment such as anxieties around the visibility of scars also take on new significance against histories of experimental psychosurgery and persistent stigmas. A second key point is the necessity of integrating interdisciplinary perspectives when analyzing human-technology relations. Experimental use of implanted brain stimulation technologies in psychiatric populations inherently crosses disciplinary boundaries—this paper demonstrates how concepts from the social sciences, including critical disability studies and critical posthumanism, can better inform comprehensive and situated analyses of the ongoing relationships between humans and technology. Possibilities for future research studies and potential questions guiding future work are posed throughout the paper to emphasize this point.

Who is DBS for? Technoableism and histories of psychotechnology. The proposed use of invasive brain stimulation devices such as DBS to treat psychiatric conditions is based on a biological understanding of mental illness, an epistemic approach which establishes psychiatric symptoms as originating in the material structures of the human brain (Schwartz and Cocoran, 2010; Sobstyl et al., 2022). Biological understandings of psychiatric conditions, first theorized in the 19th century, were initially a means of moving away from moral and religious understandings of mental illness (Shorter, 1997). The medicalization of mental illness as a concern originating in bodies, brains, and genes (rather than the soul) resulted in a change in responsibility for diagnoses and treatment from the church to the hospital. This shift in thinking was beneficial for some patients who had the means to pay for medical cures and thus rid their bodies of bothersome symptoms (Killen, 2006). For others, especially poor and marginalized populations, understanding of mental illness as residing in the body has resulted in social programs of progressive sterilization and extermination (Stahnisch and Kurbegovic, 2020).

Advances in genetic research and the development of psychotropic medications have led to expansion and further refinements of biological psychiatry theories to the point that they are the most widely held understanding of mental illness in present practice (Walter, 2013). Today, increasingly specific models of neural pathways endeavor to illuminate where and how specific interventions such as neurostimulation can help to reengineer brains back to "normal" states (Gardner and Ellington, 2019; Rabinowitch, 2020). As Vidal and Ortega (2017) have argued, a scientific focus on the biology of the brain has at the same time become embedded more broadly within Western culture, producing "cerebral subjects" in which the workings of brains are commonly held to be responsible for all aspects of human personhood. Walter (2013) notes most psychiatrists take a nuanced stance regarding the role of biological versus environmental factors in producing mental illness. Nevertheless, the dominance of a biomedical, "neuropsychiatric" approach to the study and treatment of mental health conditions persists and results in a preference for individualized, brain-based explanations and treatments (Arzy and Danziger, 2014). The use of neurostimulation technologies as treatment for mental health conditions such as major depression is emblematic of a biomedical approach. Experimental use of brain stimulation devices to directly affect mood, perception, and cognition in turn reinforces understandings of these processes as primarily physically located in the brain (Lozano et al., 2019).

Psychiatrists began using electrical stimulation as part of the treatment for mental illness in the late 1930s. The administration of electricity was primarily used as a means of causing systemic shock. Delivering electric current to the body was a cleaner and easier way to provoke therapeutic seizures than prevailing practices of the time which included insulin, Metrazol, or malaria (Scull, 2022). Despite a lukewarm acceptance by neurologists and outright rejection by some psychologists, electroshock therapy (ECT) was in widespread use by psychiatrists practicing in Europe and North America within a few years. Around the same time, psychosurgery (neurosurgical interventions for psychiatric illness), most often through the process of frontal lobotomies, was also in development as a promising solution for relieving symptoms (Scull, 2022). Initially, both treatments were considered modern, scientific, "cutting edge" solutions to the problem of persistent mental illness. Over time, ECT was increasingly used as a cheap tool for establishing order in psychiatric inpatient wards, while lobotomies became popularized as a "magic bullet" cure for general depression, malaise, and other psychiatric symptoms affecting the outpatient middle class (Johnson, 2014). General, non-medicated ECT and frontal lobotomies fell out of widespread favor in North America by the 1960s as psychopharmaceutical approaches became preferable. However, a small group of surgeons, psychiatrists, and patients remained interested in specific, targeted electrical brain stimulation and focal lesions for the treatment of persistent pain and psychiatric symptoms.

Some doctors sought to combine elements of both electrical and surgical techniques—observing the effects of targeted electrical stimulation in order to identify where permanent brain lesions should be made (Delgado et al., 1968; Leblanc, 2023). The development in 1947 of the stereotactic frame, a device which allowed surgeons to pinpoint surgical targets in the brain, resulted in a rapid expansion of psychosurgery (Spiegel et al., 1947; Gildenberg, 2004). The new precision neurosurgery quickly became a primary treatment for conditions such as Parkinson's Disease (Gardner, 2013). Along with the stereotactic frame, targeted brain stimulation devices assisted with transforming psychosurgery's reputation from crude lobotomies to a more targeted, objective, and "scientific" neurosurgery (Gildenberg, 2001). Collecting electrical data directly from brains allowed psychiatrists and surgeons to work around difficult patient behaviors and unreliable symptom reports, making systematic data collection and precise interventions increasingly possible in severely mentally ill populations (Delgado et al., 1968; Baumeister, 2000).

In addition to the primary objectives of collecting data about the brain and assisting with locating surgical targets, doctors noticed that direct, targeted electrical stimulation seemed to have therapeutic effects (Hariz et al., 2010). But despite this potential, neurostimulation devices remained largely experimental for the first two decades of use due to their cumbersome nature—after insertion, electrical probes projected out of the skull and transmitted signals by radio or through direct wiring to external battery and data collection devices (Hariz et al., 2010; Gardner, 2013). Experimentation with location and degree of frequency of targeted electrical stimulation was therefore often conducted in the operating room and primarily used to select targets for ablation (Hariz et al., 2010). Notable exceptions included ethically questionable work with electrical "self-stimulation" of the brain by American psychiatrist Robert Tulane (Baumeister, 2000), human and animal experimentations with radio-controlled implanted neurostimulation devices conducted by Spanish neurophysiologist José Delgado (Horgan, 2005; Hariz et al., 2010), and experimentation with psychosurgery for the treatment of violent criminals and "epileptics" (Gildenberg, 2004; Spiegel et al., 1947).

As Gardner (2013) has pointed out, the expansion of implanted brain stimulation as a standalone therapeutic treatment was jump-started by the invention in 1957 of the battery-powered cardiac pacemaker patented by American medical device manufacturer Medtronic. By the early 1970s, modified pacemakers and some dedicated neurostimulation devices were being used by a handful of neurosurgeons to treat chronic pain and movement disorders (Fishman et al., 2019). In a landmark 1987 publication, the French neurosurgeon/neurologist team Benabid and Pollack outlined their strategy of high frequency targeted brain stimulation for successful treatment of tremor, ushering in what has been called the "modern era" of neurostimulation (Benabid et al., 1988, 2009; Hariz et al., 2010; Krauss et al., 2021). Despite its origins and long history of experimental use in psychiatric patient populations, "modern" design and testing of neurostimulation as therapeutic treatment for mental health conditions such as depression has only recently (re)emerged (Bari et al., 2018).

As much as current practitioners wish to push past the "checkered history"[1] of psychosurgery and electro-shock, it is undeniable that implanted brain stimulation devices are a refined product of a lineage of at times harmful psychiatric therapies (Sabé et al., 2023). Initial reports on the clinical benefits of targeted electrical stimulation make this connection, noting how early implanted brain stimulation devices produced "therapeutic effect[s] comparable to that of electroshock," (Bickford et al., 1953). José Delgado, regarded as one of the originators of implanted brain stimulation, worked under the supervision of John Fulton, the neurophysiologist credited with introducing the idea of frontal lobotomies as a treatment for psychiatric distress (Horgan, 2005; Faria, 2013). The stereotactic frame, an essential tool used for the insertion of implanted brain stimulation devices, was initially developed as a means of making frontal lobotomies more precise (Rzesnitzek et al., 2020). Positioning the emergence of implanted brain stimulation devices such as DBS for the treatment of psychiatric conditions as a recent spinoff of successful work in movement disorders like Parkinson's Disease elides a more honest historical accounting of the field's origins. As Johnson (2014) has noted, the rhetorical positioning of DBS as significantly removed from histories of psychosurgery also serves to close off important opportunities for weighing the social and political implications of its use in psychiatric populations. A relational approach to the human-technology nexus insists on a broader historical lens and takes into account how implanted brain stimulation technologies like DBS trace their histories back to electrical and surgical experiments with adults and children with psychiatric illness, many of which have a questionable ethical basis (Delgado et al., 1968; Baumeister, 2000; Faria, 2013; Casey, 2015).

Acknowledging the historical lineage of DBS helps to illustrate the importance of attending to the social and political contexts in which "modern" forms of implanted brain stimulation are used for the experimental treatment of psychiatric illness. Though the surgical procedures and technologies used in today's DBS devices are different from mid-century psychosurgery, there are similarities in the contexts of treatment development and implementation. Both cases involve physical interventions into the brain to affect psychiatric symptoms in conditions such as depression with no clear unifying neurobiological mechanism of action (Dean and Keshavan, 2017). As with frontal lobotomies, media reports of the use of DBS have tended to be overly optimistic, relaying personal success stories and downplaying potential risks (Frédéric Gilbert and Ovadia, 2011). Finally, both interventions have been largely targeted at patients for whom other forms of psychiatric therapy fail to produce consistent effects—a group specifically vulnerable to treatment search fatigue and potentially more likely to accept higher risk (Zuk and Lázaro-Muñoz, 2021). The presence of a shared developmental history as well as parallels between the contexts of implementation in both mid-century psychosurgery and "modern" DBS underscore the value in thinking about DBS use in psychiatric populations as part of an ongoing human-technology relationship rather than a discrete moment of interaction presented by a novel technological device. One can then ask, why does this relationship between humans and invasive technological interventions in the brain for the treatment of mental illness persist?

Invasive brain stimulation devices are disability technologies—techno-social practices which are targeted specifically towards people with mental health disabilities. Disabled people, as Ashley Shew (2023) notes, are often the first to use new technologies but are almost always left out of conversations about their design, implementation, or potential risks. While disability technologies are developed under the guise of improving and enriching the lives of people with disabilities, they are often designed according to the experiences and preferences of able-bodied engineers. This orientation toward the able body facilitates an easy transition from disability technology to commercialization for mainstream use, in many cases leaving disabled users behind. It also ensures much disability technology is constructed with the aim of returning the user to an able-bodied state—in other words, eliminating disability. Shew argues a prevailing culture of ableism (a preference for able-bodiedness) ensures commercial disability technology is often envisioned as a route through which disabled people can "return to normal." She uses the term "technoableism" to refer to the development and use of technologies which reassert ableist biases under the premise of patient empowerment (2023, 8). Many of these technologies, as Shew points out, seem to focus on achieving a level of able-bodied functioning or able-minded behavior at the expense of functions or features that might better assist and/or fit into the actual lives of people living with disability. Nevertheless, even though disability technologies may be harmful in some cases for the people they purport to help, they remain attractive within a society in which able bodies and minds are considered most valuable. Invasive interventions in the brain for the treatment of mental illness thus persist despite unknown mechanisms of action and the possibility for harm in part because they continue to represent, for many people, the last remaining chance at a return to "normal."

People with disabilities, especially those who use medical technologies to relieve and manage symptoms, are often acutely aware of the consequences of technoableism. Interviews with people with treatment-resistant depression, for example, reveal many are concerned about potential side effects and repercussions of experimental brain stimulation therapies (Cabrera et al., 2021). Though some attitudes, as the study's authors and a few participants note, are driven by fictional representations of violent psychiatric treatment such as depicted in the movie *One Flew Over the Cuckoo's Nest*, they also reveal how potential users are aware of how technology developed to return users to able-bodied and able-minded normality can miss the mark and leave lasting harm. Brain stimulation evolved from a trajectory of psychiatric treatments designed to "shock" patients back to a state of cognitive and emotional normality (Karamanou et al., 2013; Scull, 2022). Implanted versions like DBS resulted from experiments in making psychosurgery more precise. Brain stimulation therapies, even in their modern forms, aim primarily at returning patients to a state of "normal functioning". They also continue to present risks such as surgical complications and technical problems, as well as cognitive, psychiatric, behavioral, and psycho-social side effects (Clausen, 2010). From an able-bodied/minded point of view, these risks may appear minimal in relation to the potential for "normal" states of cognitive and psychic functioning. However, psychiatric patients' expressions of anxieties about side effects and their propensity to make historical connections to earlier ineffective and damaging treatments hints that the price of returning to "normal" may not be worth it for everyone.

Cabrera et al. (2021) also describe the opinions of patients and members of the public with favorable views of brain stimulation technologies. Tellingly, optimism in this group was not about a miraculous cure or elimination of symptoms, but rather about small changes in lifestyle that might be afforded through using brain stimulation in comparison to treatments like medication or counseling. People with positive attitudes felt invasive brain stimulation technologies would work, "quickly and effectively, reducing the need for waiting for months or years to see results (as with psychotherapy) or having to take pills daily (as with medications)," (2021, 1433). Whether and to what degree DBS can fulfill these user-centered demands should be a primary focus of research looking at this human-technology relationship.

Analyzing novel psychotechnologies (Chorover, 1973) such as DBS within the contexts of their development and alongside user-informed theoretical perspectives like critical disability studies helps to highlight what could be a major focus of work on human-technology relations: *who or what is this technology/relationship made for?* When disability technologies are made for the purposes of returning users to a presumed state of "normal," "sane," or "able mindedness," but the people most often using them are simply looking for a sustainable option for symptom relief, there may be disjunctions and inconsistencies in the degree to which attributes like agency, autonomy, and control emerge within the human-technology relationship.

Technologies like DBS represent a recent iteration of a long trajectory of electrical stimulation and psychosurgery to treat mental illness. Recognition of this history helps to inform understanding of which types of patients are most likely to be offered invasive brain stimulation, which seek out or consent to experimental therapies, and which patients might be inadvertently or deliberately excluded from design and use considerations. For example, as a device used to treat a biologically informed conception of mental illness, the experimental use of invasive brain stimulation excludes people who understand their illness as precipitated through social and political processes and as a result may tend to exclude certain users from the outset. Use of the devices in experimental settings also tends to attract different types of patients than when devices are approved for broader use. In an effort to protect people from application of untested therapies, experimental devices such as DBS for use in psychiatric conditions are often constrained to patient populations in which all other treatment options have failed (Casey, 2015). This population tends to be simultaneously well-resourced (having had the opportunity to try many other treatments) and desperate for a solution; unsurprisingly, surveys of DBS users with depression suggest most are well-educated and highly motivated white women (Leykin et al., 2011; Christopher et al., 2012; Youssef et al., 2021). When devices are developed and tested for use in this small subset of possible users, it increases the likelihood of harm once devices become approved for use in the broader target population. Use patterns of DBS for Parkinson's Disease demonstrate this phenomenon: devices are more likely to be prescribed to younger, white, male patients with higher incomes and better access to health insurance (Chan et al., 2014; Willis, 2014; Watanabe et al., 2022; Sarica et al., 2023). As a result, women, lower-income, and racialized people who manage to obtain DBS for Parkinson's Disease appear to be at higher risk of safety concerns. Kortz et al. (2021) reported that patients with Parkinson's Disease who did not fit the characteristics of the "normal DBS user" (i.e., white, male, insured) were significantly more likely to suffer from side effects such as device malfunctions and neurocognitive issues.

The fact that exposure to harms from experimental and invasive psychiatric interventions has disproportionately fallen on women (Tone and Koziol, 2018), racialized people (Metzl, 2010; Meerai et al., 2016), disabled people (Ben-Moshe et al., 2014), incarcerated people (Ware et al., 2014), sexual minorities (O'Neal et al., 2017), and the poor (Killen, 2006) cannot be overlooked when considering human-technology relationships produced through implanted neurotechnologies, however far from "checkered" or "tumultuous" pasts modern treatments appear (Bauerle et al., 2023). The threat of psychotechnologies for these groups is twofold—first for the potential for intentional and unintentional unethical use, and second for the likelihood of exclusive and incompatible design.

Human–technology relationships always occur against a backdrop of political and social contexts. The concept of technoableism and the history of psychotechnologies such as brain stimulation help to highlight how this backdrop is informed by a cultural emphasis on the value of "normal" functioning bodies and brains, sometimes to the detriment of patients' wellbeing. This context continues to inform decisions to enter into relationships with implanted brain technologies as patients worry about the possibilities of harm and whether or not devices will actually meet specific needs and integrate with their lifestyles. In the next section, I consider in greater detail how different theoretical perspectives from the social sciences can help to inform a more nuanced understanding of experiences of embodiment of the human-technology relationship involving implanted brain devices.

What is living with DBS like? Resilient techno-embodiment. The experience of having a body that is both subject and object is something that applies to all beings, but one that can take on new elements of biosocial risk and responsibility when technologies are involved (Benjamin, 2019). Studies of human–technology interaction have explored how interactions between the subjective mind and the material body produce and influence cognition, as well as how implanted technologies modify these processes (Serim et al., 2024). A position of human-technology relations, in contrast, requires moving beyond a focus on the individual to consider how the embodied experience of having an implanted device is produced and mediated through sociocultural relationships with the world. Interdisciplinary perspectives from critical disability studies and critical posthumanism provide a theoretical basis for understanding the body and thus experiences of embodiment through relationships. Foregrounding the interconnections necessary for producing and remaking experiences of the body opens up space for identifying and evaluating the risks and possibilities produced through implanted neurotechnology and resulting human-technology relationships.

A prominent framework often used when thinking about human-technology embodiment is the "cyborg". The "cybernetic organism", or cyborg, was first described in 1960 as a potential engineering approach to enabling man's survival in space (Clynes and Kline, 1960). In the initial idea proposed by two psychiatric researchers, the cyborg was a man-machine hybrid assembled for the express goal of regulating bodily functions to "free" man to the new sensory and cognitive experiences of space exploration. Part of the cyborg design involved the ability of scientists on earth to administer antipsychotic drugs and other interventions without requiring the conscious knowledge or intervention of the cyborg subject. As a number of disabilities scholars have pointed out, emphasis on the use of technology for surveillance, control, and a maintenance of the "normal" body situates cyborgs from their inception within the lived realities of many disabled people (Kafer, 2013; Rasper, 2022; Shew, 2023). The histories of disability technologies like cochlear implants, insulin pumps, and brain stimulation all involve devices which monitor and maintain "normal" bodily states while imposing new limits, expectations, and risks surrounding what disabled bodies can and cannot do.

Science and technology studies scholar Nelly Oudshoorn (2020) has explored in detail the lived experience of what she calls, "wired heart cyborgs,"—people with implanted cardiac defibrillator (ICD) and pacemaker devices. Informed by a critical science and technology studies approach, Oudshoorn sets out to challenge the technoableist idea that implanted pacemaker/ICD technologies and the people who use them can be thought of as self-evident, independently functioning entities that are seamlessly combined and remain functional after one day of surgery. Instead, Oudshoorn shows how ICD users are sustained by a network of relations and intimate connections in social, mechanical, emotional, technical, and medical spheres. Oudshoorn calls these networked relations "techno-geographies of care," illustrating how "making ICDs and pacemakers work" involves uneven distributions of risk, vulnerability, resilience, and responsibility across multiple locations. Oudshoorn's study pushes forward the analysis of everyday cyborgs (Haddow et al., 2015) to consider how embodied human-technology relations are shaped by interrelated social worlds extending far beyond the clinic. Rather than an interaction limited to the interface of pacemaker and human body, Oudshoorn demonstrates how the embodied experience of living with a pacemaker implicates a range of relationships with the outside world.

Critical disability scholars have pushed back against the cyborg trope, critiquing the concept of a human-machine hybrid as too simplistic an image to capture the layered social and embodied experiences of disability and the use of disability technologies. As feminist, queer, and critical disabilities scholar Alison Kafer (2013), argues in *The Cyborg and the Crip*, the non-innocent, transgressive, and political origins of the cyborg are commonly missed when "cyborg" is applied uncritically as a self-evident descriptor of a disabled person who uses assistive technologies. Indeed, many people with disabilities who use assistive technologies disavow any identification with the concept. When the term "cyborg" is used as a self-evident descriptor of what it is like to use technology as a disabled person, it situates disabled people as automatic cyborgs, technology as unquestioningly promising, and the future of disability as inextricably tied to technology (Kafer, 2013)—often, technology which seeks to eliminate disability in the long term (Shew, 2023). Scholars have additionally noted how in reality, "cyborgs" produced through human-machine pairings are exclusive experiences and not always comfortable, easy, or sustainable for long periods of time, realities which produce new and fractured forms of embodiment (Butnaru, 2021; Rasper, 2022). Arguing alongside Kafer, Hamraie and Fritsch (2019) caution that the symbol of the cyborg can construct people with disabilities as apolitical, representing a seamless integration of human and machine, while still existing within a model of "compulsory able-bodiedness" which sees the addition of machine components to human bodies as valiantly addressing a deficiency. Further, simple applications of the cyborg metaphor do not account for who builds the cyborg, often positioning engineers as able-bodied experts while disabled people become passive users at best or simply unnamed patients (Murray, 2020).

Challenging an uncritical reading of cyborgs, disabled people, and technology, Kafer encourages theorists to push the concept using perspectives from critical disability studies by acknowledging that human/machine interfaces are not always beneficial, developing an awareness of how many disabled people lack access to assistive technologies, accounting for how technologies are themselves the products of disabling work practices around the world, and realizing not all disabled people are interested in technological fixes or cures. Importantly, a non-ableist application of the concept of the cyborg is grounded in embodied, subjective experiences and considers the cyborg in political and social context, rather than as a simple metaphor (2013, p. 118). Taking this perspective seriously requires the study of human-technology relations to better understand the contexts in which human users decide (or are forced) to enter into and maintain (or reject) relationships with technology, and the consequent impact these choices have on how people experience the body.

Another approach to thinking expansively about human–technology embodiment is through the perspective of critical posthumanism. Posthumanism is an expanding theoretical field and has been conceptualized in a number of ways (e.g., see Herbrechter et al., 2022 for one overview)—my focus here is a feminist and critical posthumanism beginning from a position of critique of the central claims of classical humanism. A major theme of this line of thinking is to challenge the idea of the rational, autonomous individual as the central driver behind actions and experience (Braidotti, 2013). Posthuman frameworks explore and elucidate how the human is shaped by social and material processes and emerges as a specific and relational outcome of interactions with human and non-human others (McLeod and Fullagar, 2021).

Critical posthumanism is informed by theory in feminism, postcolonialism, and critical race studies which have emphasized how the concept of the "human" has never been universal or neutral but is rather informed and shaped by historical power relations which condition access to privilege (Wynter, 1984; Braidotti, 2022). Instead of the self-evident, rational, liberal subject ("Man"), posthuman subject positions are informed by assemblages of animate and non-animate matter which form new possibilities of relationality, political affinity, and inequality (Bennett, 2010; Chen, 2012). Importantly, critical posthumanist perspectives have a strong ethical component emphasizing the need for situated perspectives and an accounting for who, or what, is missing in our epistemic, ethical, and material relations (Barad, 2003).

When discussing posthumanism it is important to make the distinction between critical posthumanist positions and transhumanism, a theoretical stance not uncommon in discussions about implanted technologies. Transhumanist thinking also pushes "beyond the human," but preserves the centrality of the subject position of rational, liberal man. For transhumanists, the promise of human-technology fusion leads to a future in which disease, disability, and death can be entirely circumvented. The transhumanist approach furthers a Cartesian project centered on the conscious mind where the body can be easily replaced by technology (Hayles, 1999; Braidotti, 2022). As Braidotti notes, the dividing line between the two positions, "is that critical posthumanists abandon the liberal individual rendition of the human subject, whereas the transhumanists not only preserve it, but want to enhance it technologically into hyper-techno-individualism," (2022, 65). The distinction in subject positions becomes especially clear when comparing ethical positions of projects informed by each perspective, with transhumanists upholding individual autonomy and personal choice (Martins et al., 2019) while critical posthumanists emphasize the nomadic and relational subjectivity that distributes risk and responsibility across multiple human and non-human bodies (Gibson et al., 2021).

Instead of questioning how new relationships with embedded technologies like DBS threaten or change what it means to be human, a critical posthuman position starts from an understanding of how the definition of the human has always been exclusive, contingent, and changing over time. With this in mind, analyses which position technologies like DBS as having the potential to irreparably modify the category of "human" miss a larger ethical and political point about how this category has never been stable or inclusive of people with disabilities who might opt to use such technology. Analytic attention is thus focused on a broader network of social and material relations which make possible the specific embodied experience of living with technology (Lupton, 2019).

Gardner and Warren (2019) provide one example of a study on implanted brain stimulation devices using a posthuman approach. Drawing on ethnographic data collected from observations at a pediatric DBS clinic for dystonia, they argue that DBS implantation troubles humanist values of personhood and opens possibilities for re-imagining posthuman futures. For example, they explain that "…for such devices to work correctly, users are required to be tethered to specialist clinical teams, and hence, their autonomy [is] dependent on a network of relations of care," (p. 367). The authors also point out that DBS success is at least partially dependent on the user's ability to engage with the device and with their body. So, while some device users with the motivation and skill to engage with the technology may gain motor skills which allow some improvements in autonomy, they also become more dependent on the medical system for managing and calibrating the device as well as more aware of their bodies in ways they may not have been pre-DBS implantation. As the authors explain, DBS can induce, "the acquirement of a new orientation to the world" (p. 369). While Gardner and Warren's study focused on people using DBS for dystonia, similar themes about changing relationships with self, device, and others have been identified in interviews with people using DBS for treatment-resistant depression (Thomson, 2020). The interdependencies between persons, technologies, and medical systems precipitated by DBS use challenge assumed notions of individual autonomy and rationality and make the case for thinking about the benefits, risks, and implications of invasive brain stimulation treatments differently. Potential estrangement or alienation effects associated with DBS (e.g., see Frederic Gilbert et al., 2017) in which users' personalities change substantially post-implantation further complicates objective assessments of device effectiveness and identification of side effects (Kraemer, 2013). Acknowledging the interconnected and intersubjective aspects of DBS implementation emphasizes how the embodied use of neurotechnology is a multifaceted and relational process involving long-term processes of calibration and the possibility for side effects which extend beyond individual users.

Exploring how the human-technology relationship is an embodied reality also draws important attention to questions of refusal and of endings. Many invasive brain stimulation devices are implanted in the context of medical device trials. The inherent temporal nature of research studies renders responsibility for device removal as an important practical and ethical concern embedded within this human-technology relation (Sankary et al., 2022). The possibility that planned device removal after trial conclusion could pose harm to device users within broader social expectations of ableism must also be considered (Frederic Gilbert et al., 2023). Further, as Oudshoorn (2020) has described in the context of pacemakers, the intricacies of human-technology relationships do not end after bodily death. Technologies must be removed from bodies prior to cremation or burial as they pose a risk of explosion (in the crematorium) and of environmental contamination (in the graveyard). While technology implantation may have been an individual decision facilitated by a neurosurgeon, removal after death becomes a family responsibility managed by the funeral industry. Asking what it's like to live with an implanted neurostimulation device like DBS must also consider the social and political contexts of device refusal and removal, in addition to what it's like to die with such devices.

Approaching the human–technology relation as an embodied reality expands possibilities for further study. Scholars can attend to embodiment as an ongoing process and how neurotechnologies such as DBS impact this process across social and geographical difference. Drawing on perspectives from critical disability studies and critical posthumanism helps to better explore the figure of the cyborg as it relates to implanted brain stimulation devices, and how devices participate in an ongoing reconfiguration of assumptions about what it means to be "human." Importantly, a posthuman perspective does not view challenges to the concept of the human as inherently negative but rather as opportunities for inspiring potentially generative social and cultural shifts (Blackman, 2007). A critical social science perspective challenges the technoableist "hype" of brain stimulation technologies as novel solutions for mental health conditions to consider the extensive networks of care required for making implanted devices like DBS functional as part of the everyday lives of people with disabilities. The nuances of how resilience and vulnerability are impacted by the embodied human-technology relationship may offer insights into new possibilities for organizing supportive care.

These perspectives are of particular importance to the specific use of neuromodulation devices such as DBS for the experimental treatment of mental illness and intersect with histories of psychotechnologies in important ways. For one thing, patients and the public appear to remain pointedly aware of the historical connections between DBS and its experimental precursors. Focus groups, surveys, and online comments on news articles about advances in DBS for the treatment of psychiatric illness indicate the continued presence of mistrust of invasive brain stimulation technologies, especially those using electrical stimulation or involving permanent brain lesions (Cabrera et al., 2019; Cabrera et al., 2021). At the heart of such concerns lies an uneasiness about whether interventions such as implanted brain stimulation devices are truly meeting psychiatric patients' best interests. After all, as scholars have pointed out, a large community of practitioners and patients understood frontal lobotomies and ECT to be effective treatment according to the medical best practices of their time (Raz, 2013; Casey, 2015; Scull, 2022). The reality that "psychotechnologies" (Chorover, 1973) such as psychosurgery and brain stimulation were used to promote docility and subservience in populations deemed to be outside of desired social norms was not a deliberate medical objective but a repercussion of prevailing social contexts (Johnson, 2014).

The history of psychotechnology continues to intersect with individual experiences of embodiment as mentally ill patients contend with social stigma toward both mental illness and its treatment (Heney, 2023). Predominant cultural narratives about ECT and lobotomy position these treatments as aggressively imposed and debilitating for their recipients—being a person who actively chooses an invasive brain stimulation treatment despite this negative reputation may thus have undesirable social consequences (Cai Chen et al., 2023). DBS devices and the scars from their implantation are often noticeable, requiring users to navigate not only the physical experiences of these changes in the body but also the social repercussions of displaying visible difference. Where a person with mental illness may have previously been able to "pass" as non-disabled, the visible presence of a technology like DBS makes this less possible, resulting in changes in how people using such devices navigate their social worlds (Siebers, 2008). Becoming a person who uses a brain implant for the treatment of serious mental health concerns is a significant transition, and one made even more substantial given the weight of rhetorical histories of invasive interventions in the brain for the treatment of mental illness.

Understanding the embodiment of human-technology relations, particularly in the context of implanted brain stimulation devices like DBS, requires moving beyond ideas of individual autonomy or simple applications of the cyborg metaphor. Experiences of human-technology relations are shaped by complex networks of social and material factors that extend far beyond the individual. Critical disability and posthumanist perspectives challenge technoableist frameworks and emphasize the importance of recognizing how implanted brain technologies, like the concept and lived experiences of disability itself, are embedded within larger sociopolitical histories. A nuanced exploration of human-technology relationships is essential for understanding both the embodied realities and the broader ethical, social, and political contexts in which these technologies operate.

The future of human–technology relations in implanted brain stimulation devices. Historical understandings of the development of implanted brain stimulation devices framed through a critical disability and critical posthuman lens highlight the technoableist disposition of the field and the specific contexts in which users with mental illness understand and make decisions about this technology. Critical social science perspectives also point to the importance of attending to embodied experiences of device users as a means of discerning how lived realities of device use fit within broader sociocultural paradigms, such as the organization of medical care and device research trials. These insights are of vital importance to future work in the field of human-technology relations. Together, they suggest the need for a broad field of study that moves beyond concerns at the individual level to explore implanted technologies such as DBS as part of larger socio-cultural contexts.

In their exposition of a "crip technoscience manifesto," critical disabilities scholars Hamraie and Fritsch (2019) suggest that a productive mode of critical inquiry for evaluating new technologies and their relationships with humans involves four central tenants. First, they suggest a more deliberate approach to integrating the knowledge and labor of people with disabilities as active participants in the design of novel technologies and advocates for greater accessibility. In the case of DBS for psychiatric conditions, this might take the shape of greater attention to online communities in which neurotechnology users share their experiences as well as seek and provide advice. In addition to research work designed directly with and for DBS users, such online spaces may provide insights into the emotional and logistical labor required for users to make their devices work for them, as well as the emotional and cognitive labor that goes into supporting others in disability community. User communities demonstrate how the human-technology relationship is not experienced in isolation but rather shapes and is shaped by the experiences and expectations of others (Gardner and Warren, 2019; Oudshoorn, 2020).

A second aspect of a crip technoscience approach involves attending to decisions and struggles around obtaining or refusing devices as productive sites of friction, rather than as indications of a challenge to be overcome. Analysis from this angle strives to consider how the human-technology relationship is not straightforward and is not always a route to able-bodied "normality" and assimilation. For some users, experiences of human-technology relationships are a means of pushing back against the constraints of able-bodied humanism (Murray, 2020). In other cases, as Benjamin (2019) notes, technological "glitches" such as devices which do not work with certain bodies or repeated refusal of insurance claims (Rossi et al., 2017) are informative locations of friction where larger socio-cultural processes and power imbalances become clear. Further analyses of these experiences can help to identify interactions between the individual and socio-cultural levels of human-technology relations.

The third aspect of the approach outlined by Hamraie and Fritsch (2019) underscores the need for thinking about interdependence as a "political technology." From this position, the "techno-geographies" (Oudshoorn, 2020) or "regimes" (Gardner and Warren, 2019) of care precipitated by the implantation of DBS devices can be explored as politically relevant instances in which new organizations of care, dependence, and interrelation can be explored. These interdependent networks of care challenge dominant models of individual responsibility common within Western medical paradigms and highlight how, in order for novel technologies to work, a multitude of human and non-human agents are required to coordinate in the service of care. Exploring the logistical and material repercussions of human-technology relationships as political tools expands analyses beyond individual harms and benefits to think about how widespread use of technology has the potential to inspire broader political and cultural changes.

Finally, and perhaps most importantly, Hamraie and Fritsch (2019) emphasize the need for a perspective of disability justice within critical analyses of novel technologies. Device users are not patients, consumers, or experimental subjects but rather agential political actors who hold inherent value in themselves, regardless of to what degree they adopt the use of technology. Rasper (2022) builds on this point to propose "Criptical Neuroengineering," a method of engaging with the field of neurotechnology engineering which sits with the tension between unjust and technoableist imperatives and the transformative capacities potentially offered through novel devices. Moving beyond an accounting of what takes place in the human–technology interaction, Rasper suggests that research should ask, "whose life gets (not) manufactured, by whom, as well as for what and why," (2022, 44). Taking such an approach seriously requires expanding the focus of analysis to include the people designing, building, using, and refusing devices, as well as past and present political and social contexts shaping such activities and their repercussions.

Conclusions

Critical perspectives from the social sciences including critical disability studies and critical posthumanism demonstrate how understanding the human-technology interface as an ongoing relationship rather than as a temporary interaction expands possibilities for productive analysis. When human-technology relationships such as those produced through the implantation of neurostimulation devices like DBS are considered within the contexts of their historical development and experiences of everyday embodiment, a larger field of analysis becomes possible. Historical context highlights how persistent anxieties about the legacies of ECT and lobotomies are not unfounded misinterpretations but instead may be indications of broader concerns about whether and to what degree neuropsychiatric technologies incorporate users' best interests. In addition, where some scholars remain concerned with the limits of human agency and control when technologies are implanted into the brain, the study of embodied experiences of implanted stimulation devices highlights how these capacities are produced and constrained as part of posthuman networks of care rather than solely at the individual level. A move from thinking about human-technology interactions to human-technology relations, especially when imbued with critical perspectives from the social sciences, permits a more nuanced and justice-oriented approach to the study of novel technologies and their applications.

Data availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the study.

Received: 12 February 2024; Accepted: 12 December 2024;
Published online: 23 December 2024

Note

1 Bauerle et al. (2023) blame "inadequate selection criteria and lack of oversight" for the unethical era of psychosurgery, arguing that "today's neurosurgical techniques have evolved substantially." While technology has undeniably advanced since the 1960s, it is untrue to state that neurosurgeons and psychiatrists practicing psychosurgery in the '60s had no oversight. A review of the practice of lobotomies at a panel discussion of the American Medical Association found reason to endorse the surgery (JAMA 1941). The procedure also received approval, including a recommendation that lobotomies should not be restricted to inpatients, by a conference of psychiatrists assembled through the US National Institute of Mental Health in 1954 (Scull, 2022, p. 159). Though Freeman and Watts famously took on an unprecedented number of lobotomy cases, psychiatrists across North America recommended the procedure as a common treatment for a wide range of mental health concerns.

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Acknowledgements

This work was supported by the ERA-NET NEURON project HYBRIDMIND, with funds from the Canadian Institutes of Health Research (ERN-174186). I sincerely thank the HYBRID-MINDS research group for providing the opportunity to develop the early ideas that shaped this paper and for their generous funding support for the manuscript.

Author contributions
Amanda van Beinum is solely responsible for the conception, design, research, analysis, and writing of this paper, and has approved the final manuscript for submission.

Ethical approval
Ethical approval was not required as the study did not involve human participants or their data.

Informed consent
Informed consent was not required as the study did not involve human participants or their data.

Competing interests
The author declares no competing interests.

Additional information
Correspondence and requests for materials should be addressed to Amanda van Beinum.

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