



Target Article

Thinking Ahead on Deep Brain Stimulation: An Analysis of the Ethical Implications of a Developing Technology

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Deep brain stimulation (DBS) is a developing technology. New generations of DBS technology are already in the pipeline, yet this particular fact has been largely ignored among ethicists interested in DBS. Focusing only on ethical concerns raised by the current DBS technology is, albeit necessary, not sufficient. Since current bioethical concerns raised by a specific technology could be quite different from the concerns it will raise a couple of years ahead, an ethical analysis should be sensitive to such alterations, or it could end up with results that soon become dated. The goal of this analysis is to address these changing bioethical concerns, to think ahead on upcoming and future DBS concerns both in terms of a changing technology and changing moral attitudes. By employing the distinction between inherent and noninherent bioethical concerns we identify and make explicit the particular limits and potentials for change within each category, respectively, including how present and upcoming bioethical concerns regarding DBS emerge and become obsolete. Many of the currently identified ethical problems with DBS, such as stimulation-induced mania, are a result of suboptimal technology. These challenges could be addressed by technical advances, while for instance perceptions of an altered body image caused by the mere awareness of having an implant may not. Other concerns will not emerge until the technology has become sophisticated enough for new uses to be realized, such as concerns on DBS for enhancement purposes. As a part of the present analysis, concerns regarding authenticity are used as an example.

Keywords: deep brain stimulation, brain–computer interfaces, bioethics, neuroethics, authenticity, enhancement, inherent ethical concerns, noninherent ethical concerns

Deep brain stimulation (DBS) is a recent example of how technological development may give rise to ethical concerns. The number of articles discussing the ethical implications of possibilities and problems raised by DBS is increasing. Presumably this is at least partly due to the increasing number of patients with DBS implants—today more than 100,000 worldwide (Medtronic 2013a)—as well as current attempts to extend the use of DBS to include new indications, such as neuropsychiatric disorders, where large market shares are at stake (Benabid 2007; Lyon 2011). Thus far, DBS has been a recurring topic in leading bioethical journals such as *AJOB Neuroscience* and *Neuroethics*, and there have been many important contribu-

tions focusing on specific bioethical issues such as medical risks, consent, patient selection, and justifiable new indications (Bell, Mathieu, and Racine 2009; Dunn et al. 2011), or general features such as ethical challenges raised by DBS during research and clinical practice, respectively (Clausen 2010). However, most contributions discuss the current DBS technology. The ethical implications of DBS as a developing technology appear to have been largely overlooked by ethicists and philosophers taking an interest in DBS, and also in papers specifically discussing “the ethical future of DBS” (Bell et al. 2009) and “ethical challenges ahead” (Clausen 2010). This is noteworthy, considering that new generations of DBS implants are in the pipeline, and since there have

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been remarks on ethical implications on, for instance, new insertion techniques, improved patient selection, and new indications (Bell et al. 2009), as well as on ethical implications for DBS if other therapies were to improve. The exception is the question of DBS enhancement (Bell et al. 2011; Schermer 2013; Synofzik and Schlaepfer 2008), but also in that context the discussion of the conditions required to take us there and what may occur along the way is insufficient, a circumstance that we also address. Since new hardware is already underway, the ethical analyses of DBS must catch up in order capture and incorporate these developments.

Our aim in the present article is to examine how the fact that DBS is a developing technology impacts the ethical analysis of DBS, and, by doing so, to provide keys to an understanding of the ethical concerns that can be expected in the years to come. Before developing this objective further, some clarifications are made. The term “concern” can be misleading since it frequently is interpreted as referring to something that is ethically problematic. This is not the intended use of the term in the present article, unless the opposite is clearly stated. Not all “bioethical concerns” relevant in an ethical assessment refer to that which is ethically problematic. They may just as well refer to opportunities made possible by a technology or a scientific breakthrough. We therefore use the term “bioethical concerns” without a presupposed evaluative content. Instead, a bioethical “concern” refers here to a situation or specific features that elicit ethical reflection, but can be ethically desirable, neutral, or problematic. Further, not all technical modifications will be of such significance so as to have ethical implications, nor do all bioethical concerns have technical solutions. However, technical modifications that either improve the clinical effect of or decrease the risks involved in DBS arguably do influence ethical considerations. Conversely, if ethical concerns only reflect the current state of the art of a technology, then concerns related to the future development of DBS will remain unaccounted for.

As a final clarification, there are many ways of undertaking a bioethical analysis. The analysis and conclusions presented in the present article represent one of the results coming out of a 6-year project on the ethical implications of DBS and other brain-machine interfaces conducted at the Neuronano Research Center (NRC), Lund University, an interdisciplinary research team developing new generations of neural implants. We use a bottom-up approach where the analysis is based on the particulars of DBS and where the contextual circumstances play a key role. The emphasis is put on the complex dynamic and temporal aspects of bioethical concerns and the confluence of these features, and a developing technology and changing moral attitudes. This approach may, to some readers, sound like casuistry (Jonson and Toulmin 1988). However, we do not aim at deriving normative conclusions in the sense of providing guidance on what to do, that is, to provide recommendations on normative guidelines for DBS, so the resemblance to casuistry is only superficial. Instead, our analysis attempts to make explicit some of the underlying constituents and contex-

tual dependencies that impact—and interact in—an ethical analysis of DBS.

More specifically, the main objective of the article is to discern how ongoing and continuous changes, regarding both technology and moral attitudes, impact an ethical analysis of DBS, that is, to illuminate the contextual dependence and transience of bioethical concerns. Our aim is not to give a general introduction of or overview to the ethical concerns regarding DBS already identified and discussed, since this has been done elsewhere (Clausen 2010; Schermer 2011). Instead, we want to raise awareness of the hitherto largely overlooked features of the possibilities and limitations for developing technology to change current ethical concerns, thereby providing a key to thinking ahead on the moral challenges of DBS. We do not suggest that technology is the only key to predicting the ethical future of DBS, though the DBS technology is the main subject matter of this particular article. Within a novel conceptual framework for the analysis of ethical concerns, we choose to focus on the case of authenticity—a recurring and ethically challenging concern raised by brain modulation (Kraemer 2013).

DBS—A PACEMAKER FOR THE BRAIN

DBS, sometimes referred to as a neurostimulator or a pacemaker for the brain, is an invasive, chronically implanted device that uses electrical stimulation to alleviate dysfunctions of the brain. A rudimentary form of chronic brain stimulation occurred in clinical trials already in the 1950s (Delgado 1969; Hariz, Blomstedt, and Zrinzo 2010; Heath, Johan, and Fontana 1976). The technique had a revival in 1987, when French neurosurgeon Alim-Louis Benabid used high-frequency stimulation for symptomatic relief in movement disorders (Benabid et al. 1987). Ten years later, the U.S. Food and Drug Administration (FDA) approved the first DBS implant for patients with Parkinson’s disease and essential tremor. The results of DBS are often striking. When the stimulation is initiated, gravely distorted movements change into close to normal movement patterns. In February 2009, another DBS milestone was reached when the technique received the first FDA approval—a Humanitarian Device Exemption—to treat a psychiatric disorder: chronic, severe, and treatment-resistant obsessive compulsive disorder (Rabins et al. 2009). In clinical practice today, DBS is most commonly employed to improve motor function in conditions such as Parkinson’s disease, essential tremor, and dystonia, though there is extensive ongoing research to evaluate additional brain targets, as well as new indications such as treatment-resistant depression (Holtzheimer et al. 2012; Kennedy et al. 2011), epilepsy (Fisher et al. 2010), high blood pressure (Patel et al. 2011), anorexia (Lipsman et al. 2013), obesity (Hamani, McAndrews, and Cohn 2008), chronic minimally conscious state (Schiff et al. 2007), and Alzheimer’s disease (Smith et al. 2012).

Current DBS implants consist of three parts: a lead, the extension, and a pulse generator. The pulse generator is placed in the chest, usually close to the collarbone.

It resembles a cardiac pacemaker, and produces electrical pulses that pass along a wire, the extension, to the lead, which is implanted into the brain and where the actual stimulation takes place. The patient usually has two leads, one in each hemisphere. The most common lead is a needle-like device, 1.27 mm in diameter, with four cylindrical electrodes close to the tip. The electrodes can be activated and altered individually to control the stimulation field. The effect of the stimulation is fine-tuned by adjusting the general settings of the pulse generator, such as amplitude, frequency, and pulse width. A physician programs the general settings, but the patient can usually make minor adjustments by communicating with the pulse generator via a magnet. Consequently, the therapeutic effect, as well as stimulation related adverse effects, is adjustable post-surgery. In addition, the stimulation—and hence the effects on the brain—can be terminated either by switching off the pulse generator or, if required, by removing the implant from the brain (Medtronic 2002).

DBS is a developing technology, and the current DBS technology is by no means a final, optimal product. From the first rudimentary stimulation devices of the 1950s, with features such as multiple wires hanging from the patient's head, to the entirely invasive systems of today, much has happened. In the past few years, rechargeable pulse generators have been introduced that increase the battery life time and hence the intervals between the surgeries needed for changing batteries, thus decreasing the risks for infection and skin erosion. Likewise, new modifications of DBS are to be expected. Such modifications could be realized either by new uses of, or by refining, the current DBS technology, or consist in mergers with other methods. In order to localize the stimulation with a significantly higher degree of accuracy than with bilateral leads there have been trials with three-dimensional (3D) stimulation, where five leads were placed to target the same brain nucleus, amounting to 10 leads and 40 electrodes in total for both hemispheres (Benabid 2007). The adjustability thereby achieved is a means to increase the therapeutic effect and reduce stimulation-related side effects. A higher degree of control over the outcome of the stimulation can also be achieved by developing electrodes designed for the intended brain structure or to downsize the current technology, possibly ending up with nanosized electrodes (Benabid 2007; Suyatin et al. 2013). Yet another example of new electrode design is non-rectilinear leads (Benabid 2008) or ultrathin flexible bundle electrodes. The former lead is characterized by its bent shape, while the latter is a multichannel neural probe with several ultrathin leads that unfold once inside the tissue, where, beside improvements in biocompatibility, a selection of the miniaturized leads can enhance specificity and reduce side effects (Mohammed et al. 2013).

More radical transformations of the DBS technology are also underway, for instance, by the use of a closed-loop real-time device that can both record neural activity and stimulate the brain. The operational principle of this device is that the implant in addition monitors the patient's neural

activity, and the stimulation is triggered only when specific neural changes are detected. These bidirectional implants have been tested for epileptic patients (Morrell 2011), and the first successful attempts in patients with Parkinson's disease have been reported (Santos, Costa, and Tecuapetla 2011). This development will probably be spurred further due to the main DBS manufacturer, Medtronic, Inc., launching a bidirectional DBS system (Medtronic 2013b). Additionally, a possible candidate for a merger with DBS is optogenetics technology, where light of specific wavelengths is used to impact individual cell types within the brain, a hybrid that due to its ability to control individual cells has the potential to transform the future of brain modulation (Gradinaru et al. 2009).

CONTEXTUAL DEPENDENCIES AND CHANGING CONCERNS

By paying attention to contextual dependencies, something important can be said about the kind of bioethical concerns that DBS could be facing in the years to come, including ethical implications of changes either in technology or moral attitudes. For instance, the very fact that DBS is a developing technology can be understood as a specific contextual setting or circumstance, one that gives rise to a particular set of bioethical concerns. Somewhat simplified, these particular bioethical concerns are raised because the technology is yet to be optimized. Some of the most worrying ethical concerns at present are a result of this contextual circumstance, such as most concerns related to known and unknown medical risks and possibilities. However, given the origin of these concerns in current shortcomings, it could be assumed that modifications of the technology or breakthroughs in science as well as an increased experience with DBS will make some of these initial concerns obsolete, whereas others will emerge. For instance, stimulation-induced side effects could be overcome with electrodes that can provide brain stimulation with a higher degree of spatial specificity. In short, one may hypothesize that most ethical concerns raised by the contextual circumstance that DBS is a developing technology are eligible to change. However, this in turn does not imply that the necessary technical modifications *de facto* will be undertaken, or that a technical modification will be sufficient to eradicate the ethical concern in question completely.

So, what bioethical concerns can emerge? Ethical concerns regarding DBS for enhancement purposes, that is, the nontherapeutic use of technology to temporarily or permanently overcome current limitations of the human brain, are one example. It is important to note that enhancement, despite incidental reports on for instance improved memory (Hamani et al. 2008), is not a feasible application of DBS given the current level of DBS technology. Before the medical risks involved in DBS decrease and the procedure becomes more accessible, DBS enhancement will not be a tangible option for healthy individuals. Until these, and maybe additional, prerequisites have been fulfilled, DBS enhancement is something that can be expected only when a certain

level of technical sophistication becomes available. Maybe the first examples of DBS enhancements are waiting just around the corner, but if so, these first encounters will appear as side effects in ongoing DBS treatments, and they will undoubtedly be more modest than common suggestions of cyborgs or radically transformed humans, which require a significant leap in the development of DBS hardware. Consequently, different stages in the technical advancement of DBS impact ethical concerns, either by raising additional concerns or by eliminating earlier ones.

Beside changes in technology, moral attitudes also impact an ethical analysis of DBS. Bioethical concerns presuppose moral attitudes; technology alone will never create a bioethical concern. These moral attitudes, in turn, are dependent on contextual circumstances. They are molded by time and culture, and as such are subject to shifts and conflicts. The most fundamental attitudes could be described as the backdrop against which moral concerns are identified and elaborated; they are shaped by, as well as shaping, the societies and cultures we live in (Taylor 1995). Other moral attitudes spring from the fact that we live in value-pluralist societies, in which different groups or stakeholders, such as the state and other authorities, religious and local communities, and social movements and political pressure groups, promote their particular view of morality.

Moral attitudes can prevail over decades and centuries, or be quite transient, a momentary tempest in a teapot. Moreover, a change in attitudes can be both subtle and rapid. One example of shifting moral attitudes is the case of Louise Brown, the first successful “test tube child” born in 1978. Besides ethical concerns about the safety of this procedure, many concerns were raised regarding the “artificial creation of man,” that is, creating a human being by fertilizing an egg outside of the body. Today, however, the tide has shifted and the “creation” of children through in vitro fertilization (IVF) is seldom considered to be a moral problem. It is rather considered morally praiseworthy, since IVF has alleviated suffering for millions of current parents who otherwise never would have had children. In this instance the changes in moral attitudes occurred without any changes in the technology—which often is the case. A token of this change regarding IVF was the 2010 Nobel Prize in Physiology or Medicine, awarded to Robert G. Edwards, the scientist who developed IVF. Consequently, it is possible that some of the currently identified moral problems regarding DBS over time will cease to be considered as problematic due to shifts in moral attitudes, or that previously common and generally accepted practices will be perceived as problematic.

INHERENT AND NONINHERENT CONCERNS

Against the background of the contextual dependencies just discussed, we introduce a distinction between two kinds of bioethical concerns—inherent and noninherent. This distinction is here used as an analytical tool for detecting ethical concerns that could lie ahead for DBS. By employing this tool, some key features in predictions of upcoming ethical

concerns facing DBS are made explicit, for instance, discerning the particular limits and potentials for each kind of bioethical concern, and making explicit the conditions required, for each category respectively, for a bioethical concern to emerge or become obsolete. This has important practical implications. For example, if it can be demonstrated that a severe moral problem raised by DBS can be addressed by refinements in the technology, then there may be a moral obligation to do so.

One kind of bioethical concern arises from the DBS technology per se; these are concerns that address the defining features of the technology itself. We use the term “inherent ethical concerns” (IEC) for these kinds of concerns. This requires that we specify the properties necessary for classifying an intervention as DBS. Our suggestion is that the main defining features of DBS are (a) an electronic device (b) chronically implanted in the brain (c) stimulating the brain to alter brain function. If any of these features are lost, the intervention would no longer be DBS. Singling out the IECs identifies the bioethical concerns that cannot be impacted by refinements of the DBS technology, scientific breakthroughs, or an increased experience with the DBS procedures. Since the IECs are raised by the defining, unavoidable features of DBS they cannot be built away, nor be solved by more resources, more qualified staff, or new health care centers. Note that even though our current objective is to analyze the technology-dependent features of DBS, IECs are not restricted to technology. Some IECs are instead inextricably linked to the indication at hand, such as exemplified by the current, and historic, attempts to use DBS to reduce aggression (Franzini et al. 2013). In these circumstances, ethical concerns raised by the treatment of aggression address phenomena that are inseparable from the indication per se, and so ought to be classified as IECs. The inherent feature, however, does not imply that IECs are devoid of contextual dependencies. Whether an identified IEC, such as ethical concerns raised by the use of neuromodulation as a treatment of aggression, is understood to be problematic, neutral, or desirable is also dependent on and shaped by general perceptions of what is valuable and desirable in the context the IEC is discussed, that is, on our moral attitudes.

In short, we conclude that IECs are ethical concerns raised by the defining, inherent features, of DBS. However, whether someone then actually cares about an identified IEC is determined by preferences and values. An IEC is conditional, by means of assigned value; and it is relative, since the assigned value must be related to other things of importance for the involved parties—other values. Here this is exemplified from a patient’s perspective: In a study by Schüpbach and colleagues, 19 out of 29 patients reported that they did not fully recognize themselves after their DBS surgery. They expressed feelings of strangeness and unfamiliarity regarding their view of themselves. In addition, six of the 29 patients experienced an altered body image, a change that three of them expressed as deeply problematic: “I feel like a robot” or “I feel like an electric doll” (Schüpbach et al. 2006). Nonetheless, none of the patients, regardless of their various DBS difficulties, “wanted to stop the

stimulation and go back on medication only" (Schüpbach et al. 2006). These accounts are an example of the fact that in cases with conflicting values, a patient may judge feelings of alienation toward oneself an acceptable price for obtaining other, more valuable, ends. Consequently, in clinical practice the key challenge lies in assessing a specific IEC's relative importance, in assessing how important this concern is all things considered.

For the other kind of bioethical concerns we here use the term "noninherent ethical concern" (N-IEC). The definition of N-IECs is a negative one, referring to all bioethical concerns that are not IECs. For instance, the set of ethical concerns arising from the specific circumstance that DBS is a developing technology are N-IECs, and since these N-IECs can be altered by technological advances, we should look into the specifics regarding where such solutions could be expected and obtained. Concerns based on crude brain stimulation, that reduces the therapeutic effectiveness and increases the risk of stimulation related side effects, or on mechanical damage to the brain due to the size or stiffness of the lead are both examples of N-IECs. The N-IECs would not occur without the technology in question, but these concerns are not inherent to the application at hand. Consequently, the N-IECs include concerns raised by adjacent technology, such as brain imaging techniques and stereotaxy required to implant the DBS leads, batteries that get depleted, risks of hemorrhage and infections, risks created by human errors, and so on. Many N-IECs are likely to be persistent; some N-IECs will probably remain even with an optimized DBS technology. As neurologist Helen Mayberg once pointed out, "there is no such thing as minor brain surgery" (Dana Foundation 2008). However, this persistence does not make the N-IECs inherent to DBS. Given enough time and development, perhaps also risks related to the surgery such as risks of hemorrhage and infections can be eliminated, and thereby abrogate these N-IECs. Another example of persistent N-IECs is concerns regarding justice. Who will get access to the procedure, considering factors such as the costs involved in DBS or lack of medical centers qualified for the procedure, when only a small number of those who could have benefited greatly from the procedure can be accommodated? Such concerns are likely to remain even with optimal implants. Nevertheless, these concerns ought to be classified as N-IECs, since they actually could be impacted by for instance a lowering of the cost of the implants, such as the device currently introduced in China (Hu et al. 2012), or new priorities and policies within health care.

What changes in the N-IECs can be expected due to the technological development of DBS? There have already been reports that the medical risks involved in DBS have decreased as a consequence of an increased use of and experience with the DBS procedure (Lyon 2011). If these results have general validity, then continuous improvements of the outcome of DBS could be expected, especially when adding the technical development. Some hands-on measures could be to use tissue-friendly, free-floating and minute implants to minimize the negative impact on the brain, to continue to improve the life span of the battery in order to avoid fre-

quent changes and thus new surgery, and so on. However, even if technology has the potential to eliminate some ethical concerns, the complexity of technological modifications should not be neglected. It is not unlikely that trade-offs could be made between, for instance, improved clinical effect and increased risks of harm, or minimizing one risk of harm while increasing risks of another. One example is new designs of electrodes, such as non-rectilinear leads (Benabid 2008), which have shapes and dimensions different from those of the currently used leads. These novel implants are likely to increase effectiveness and reduce stimulation related side effects, but there could be trade-offs such as an increased risk of harm if the need to explant the implant were to occur, thus potentially impacting the much appraised advantage of reversibility. Further, trade-offs between degree of improvement and for instance costs must be expected. In health care, "good enough" is more common than "optimal."

When ethically assessing DBS or other developing technologies, we need to keep in mind that there is a difference between the state of the art of the technology and how this technology is being (mis)used. Reports of poor outcomes, misplaced leads, faulty patient selection, and so on might seem contradictory to the expectations of improved results over time. According to Okun and colleagues (Okun et al. 2005), the explanation usually is that the DBS procedure has been performed at centers that lack adequate expertise. Due to the widespread reports of good results achieved in reducing movement dysfunction, and the promising results for new indications such as neuropsychiatric disorders, DBS has, as we have argued elsewhere (Johansson et al. 2013), presumably been spread prematurely to centers less qualified for the procedure (Okun et al. 2005). Reports of misuse are, however, not a reason to doubt the ongoing improvement of the DBS procedure *per se*.

CASE: AUTHENTICITY

There are two reasons why we have chosen to highlight the question of authenticity. First, we want to provide an ethically challenging example (beyond mere medical risks) of N-IECs and IECs. Further, we want to provide a novel take on the ongoing discussion of authenticity and DBS by showing how the current ethical concerns regarding authenticity are potentially transient, either as a consequence of their attitude dependence or by an improved DBS technology. However, since the term "authenticity" is ambiguous, some clarifications are necessary. We use a narrow, pragmatic interpretation of the term, fitting for the purpose of discussing a certain cluster of ethically interesting cases raised by DBS. Since a comprehensive characterization of the different questions within this cluster is not within the scope of the present article, we use the label authenticity, while still acknowledging the problems with such an approach.

A basic understanding of the notion of authenticity is suggested by the British philosopher Bernard Williams: "Some things are in some real sense really you, or express what you are, and others aren't" (Jeffries 2002). A more

detailed characterization is made by the U.S philosopher Charles Guignon. He describes the authentic self as “the constellation of feelings, needs, desires, capacities, aptitudes, dispositions, and creative abilities that make the person a unique individual” (Guignon 2004). This description bears some resemblance to the former definition of personality traits according to the *Diagnostic and Statistical Manual of Mental Disorders (DSM) IV* of the American Psychiatric Association as “enduring patterns of perceiving, relating to, and thinking about the environment and oneself that are exhibited in a wide range of social and personal contexts” (American Psychiatric Association [APA] 2004). Within ethics these descriptive features often merge with a normative claim; the implication is that whatever is authentic is also morally desirable, whereas what is unauthentic is morally problematic. Something of value is lost if we fail to be authentic.

Questions of authenticity are often raised in relation to brain modulation and DBS is no exception (Kraemer 2013). DBS does have the potential to alter a person’s personality traits and dispositions. The alterations can occur as a side effect of the stimulation parameters required to obtain a therapeutic response, for instance mania, anxiety, or panic (Saleh 2011), or be the intended outcome of the stimulation as exemplified by the research where DBS is used to reduce aggression (Franzini et al. 2013). In addition, early experiments from the 1950s to the 1970s demonstrated that brain stimulation can induce flirtiness and feelings of love, sadness, aggression, and so on (Heath et al. 1976; Delgado 1969). Current writings on DBS commenting on these issues range from the view that no normative claims can follow from references to personality or personality changes (Synofzik and Schlaepfer 2008), to normative claims based on the “risk of becoming another person following surgery” (Witt et al. 2013). In addition, there are accounts making narratives into the key denominator, emphasizing the patient’s subjective experiences of authenticity (Kraemer 2013) or identity (Baylis 2013). Central questions in these accounts are the kind of or degree of alterations of our characteristic traits that are perceived as morally problematic.

Our analysis, in contrast, focuses on the potential transience of ethical concerns of authenticity; more specifically, it illuminates how and when current concerns can change depending on whether they are IECs or N-IECs. At a first glance, one may be tempted to conclude that concerns regarding authenticity must belong to the IECs. Issues surrounding alterations of core characteristics are seemingly quite far from apparent N-IECs such as risks of infection when changing batteries or electrodes out of place. Nonetheless, when taking a closer look it is reasonable to claim that many of the concerns regarding authenticity are N-IECs, as we next show. Consider altered perceptions and expressions of fundamental or defining personality traits appearing as a side effect of the stimulation, such as when mania or hypersexuality occurs as a consequence of a DBS setting necessary to enable regained motor function (Leentjens et al. 2004). As long as obtaining the desired effect without triggering the side effects is not neu-

roanatomically impossible—there may be neuroanatomical constraints resulting in side effects that a refined technology cannot tackle, for instance, that brain modulation targeting the brain’s reward system will impact other areas “rewarded” by the same nuclei—such concerns could be overcome or reduced with a refined technology that provide more spatially specific stimulation. Thus, they are N-IECs.

Another example of N-IECs is revealed in reports on the upcoming use of rechargeable batteries. These batteries can be recharged by the patient, thus decreasing the risks involved in replacing the battery, a procedure that for the non-rechargeable batteries requires surgery more often. Depending on the stimulation parameters, the procedure of charging the battery must, with the current technology, be undertaken daily or a few times a week, in comparison to physically exchanging the pulse generator, a replacement made on average every 3 to 5 years (Timmermann et al. 2013). Some patients stated that this—sometimes daily—routine acted as a constant reminder of the underlying disease or disorder. As a result, they ended up identifying themselves more with their disease or disorder in comparison to their prior experience with non-rechargeable batteries (Harries et al. 2012). Here, an intended improvement for the users created a concern that, from a narrative perspective, could be understood as a problem regarding an experienced loss in authenticity in terms of expressing that they felt less like themselves, and more like someone being impaired, more like a patient than a person. However, with improved rechargeable batteries, these experiences are likely to cease. Thus, these concerns are not inherent to DBS but stem from a currently problematic feature that can be solved by technical advances.

So what concerns of authenticity are IECs? One example is concerns related to the users’ experiences of the implant itself, given that these experiences are not caused by the stimulation or other direct impacts of the implant on the brain. These IECs are raised by moral attitudes regarding the mere existence of a foreign object in the brain that alters brain functioning, which is an unavoidable part of DBS. Consequently, these concerns could not, in comparison to the previous examples, be impacted by an improved or even perfected DBS technology. An example of such concerns can be found in the previously mentioned study by Schüpbach and colleagues, in which 20% of 29 patients reported experiencing an altered body image due to the implant and three of those patients also described these changes as a problem. Quotes such as I “feel like a machine” (Schüpbach et al. 2006), “I’m under remote control,” and “I feel like a ‘Robocop’” (Agid et al. 2006) point to a feeling of alienation from the familiar self. Schüpbach and colleagues try to explain these findings in terms of an altered body image, resulting from a “difficulty in accepting psychologically the implanted material.” They support this claim by referring to similar responses documented among patients with pacemakers and implantable cardioverter defibrillators (Schüpbach et al. 2006). It is possible that some of the 19 patients who reported a feeling of strangeness and

unfamiliarity with themselves, expressing views such as “I don’t feel like myself anymore” and “I haven’t found myself again after the operation” (Schüpbach et al. 2006), could experience this due to their attitude toward the presence of the implant itself rather than as an outcome of the stimulation. If so, these concerns would be classified as IECs. However, equally noteworthy are all the patients who did not experience, or at least did not report, an altered body image as problematic. Further, it is likely that this position will be even more dominant, for instance, when the user has had the implant for many years or if the use of DBS or other brain implants becomes more common. As the example of Louise Brown indicates, the familiar is often perceived as less problematic than a practice that has only recently been introduced. Thus, the variety in the stands regarding whether an altered body image is perceived to be problematic or not, together with similar reports from patients with implanted artifacts in other parts of the body than the brain (Schüpbach et al. 2006), suggests that these experiences are to be classified as IECs, although a final classification may be influenced by future clinical observations.

DISCUSSION

Much could be said on the ethical implications of changes, regarding both DBS technology and moral attitudes. With this article we have taken a first step toward addressing this specific blank in the current discussion on ethics and DBS. The future is never fully predictable, but the distinction between inherent and noninherent bioethical concerns provides clues to understanding how present and upcoming moral concerns regarding DBS emerge and become obsolete, and to the type of changes possible for each kind of bioethical concern, respectively. Concluding how best to handle an ethical concern requires knowledge of what kind of ethical concern one is facing. This holds particularly for moral imperatives to search for technical solutions to pressing moral and medical concerns currently preventing—or resulting in major trade-offs for—the employment of DBS for patients who otherwise could have benefited greatly from this treatment regime. Conversely, even with a perfected DBS technology there will still be ethical concerns, some which will not emerge until the technology has become sophisticated enough, such as concerns on DBS for enhancement purposes. Though the emphasis in the present article has been on DBS as a developing technology, it is important to acknowledge that forthcoming ethical DBS concerns also depend on new scientific discoveries, since the neurobiological underpinnings for most indications suggested for DBS at present is far from understood (Lyon 2011). In addition, the development of alternative technologies could impact an ethical evaluation of DBS; for instance, noninvasive methods such as transcranial magnetic stimulation that achieve similar results could make the use of DBS redundant. Every attempt to make a prognosis of what ethical challenges DBS will be facing ahead should be undertaken with great care. Nevertheless, considering the rapid developments within neuroscience today, where DBS is just

one example, this task must still be done to avoid that an ethical analysis lags too far behind.

Common analytical tools, such as the distinction between ethical issues raised by research and clinical practice respectively, do not suffice for such a prognosis. That distinction does acknowledge that bioethical concerns are dependent on contextual factors, and that DBS may raise different ethical concerns dependent on the given circumstances, as in research and clinical practice, respectively, but these categories still are too rigid and rudimentary to capture some of the contextual dependencies relevant to an adequate ethical analysis of developing technology. Though changes to some extent are expected during the research phase, that model is less likely to detect changing ethical concerns once DBS becomes a standard procedure. There is an imminent risk that the ethical concerns initially identified in clinical practice are made to serve as an endpoint in the ethical reflection, without acknowledging that the ethical concerns raised by DBS will continue to change. So even if the distinction between ethical problems connected to research and clinical practice, respectively, is a sound and useful tool for talking about the ethical challenges raised by present DBS, there are nevertheless important aspects regarding changes in DBS technology that that distinction fails to capture.

One of the strengths of our approach is this ability to pinpoint the temporal conditions required for a bioethical concern to occur. Here follows a condensed overview of these ideas, exemplified with the IECs. Even though the IECs are inherent to DBS, these concerns can still emerge in different phases of the development of DBS:

- *Current concerns.* These are the IEC that are currently present. Two such IECs have been mentioned already: the attempts to use DBS for treating aggression (Franzini et al. 2013), and an altered self-image in terms of the feeling of alienation to one’s own being after having DBS implanted (Schüpbach et al. 2006).
- *Foreseeable future concerns.* These are ethical concerns that can be foreseen but will not become current, and thereby actual, concerns until certain prerequisites have been achieved. One example is the concerns raised by the use of DBS for enhancement purposes; another is the concerns raised by the use of bidirectional implants.
- *Unforeseeable future concerns.* Finally, there are IECs that at present elude our moral radar and therefore might appear “from nowhere.” This is a lesson learned by experience. The protests within the deaf community when cochlear implants were introduced are but one example. In short, these are the IECs that will take us by surprise and that may occur at any point in time.

Our previous claim that ethical concerns are dynamic holds true also with regard to these mentioned categories. Ethical concerns that today belong to foreseen or unforeseen future concerns will likely, with time, be the current concerns of the future, whereas other ethical concerns arise as the foreseen and unforeseen ethical concerns at future points in time.

An example of the difference between the second and third categories can be provided by bidirectional brain implants, that is, the closed-loop system that both monitors and selectively stimulates the brain in a real-time response to the neural activity detected (Morrell 2011; Santos et al. 2011). When these implants become refined enough, they will likely make possible an unprecedented form of brain modulation. Some but not all ethical concerns created as a consequence of modulating the organ that is the seat of cognition, emotions, and volition can be foreseen. Over time, this technology may become powerful enough to alter our current understanding of these and other features, all central for our self-understanding as human beings. As a consequence, this may impact or even transform our views on morality, society, health, productivity, and leisure. Such changes will not appear overnight, and their full impact belongs to the unforeseen future IECs. Given a sufficient transformation of our mental constituents, such a transformation implies that the outcome cannot be grasped from our current position.

We end with some final comments on the distinction between IECs and N-IECs. We have developed and used this distinction to gain new insights into the ethical concerns facing a changing DBS technology. Though the present article has focused on some key features in a prognosis of upcoming ethical concerns, the distinction as such is not limited to discerning future concerns; it can also be employed for current as well as past concerns. In addition, it seems reasonable to assume that it can be of use also when analyzing other emerging and developing technologies. In the interest of brevity, we have chosen not to include a discussion on the relevant similarities and differences between our conceptual framework and established forms of technology assessment (TA). It deserves to be noted, however, that there are similarities between some approaches within TA and the key ideas of this article, but also important differences. Somewhat simplified, the main concern within, for instance constructive TA (CTA) is how ethics (and societal concerns) could—and should—influence technology development, whereas the main concern of our analysis is to show how ongoing technology development, new generations of DBS, can influence current ethical concerns. Further, the distinction between IECs and N-IECs is not restricted to the analysis of technology. Regarding DBS, the distinction can, as we have shown, also be used for analyzing specific indications, such as aggression, or to illuminate constraints such as neuroanatomical limitations to the pursuit of technical solutions to some bioethical concerns.

With this article we hope to have provided distinct contributions both to the specific debate on ethics and DBS as well as to the field of neuroethics in general. By introducing the distinction between IECs and N-IEC, we pinpoint one essential—though hitherto overlooked—feature in the preparation for an ethical future of DBS, the limitations and possibilities of technology to continuously impact ethical concerns. It is important to bear in mind that the distinction between IECs and N-IECs is an analytical one. We do not

claim that drawing the line will be simple in all real-life cases. As we see it, the strength of this novel analytical tool lies not in it allowing us to classify each situation we face, but rather with its potential for novel insights regarding the transient nature of many of our ethical concerns. The model is just the means. The end is to analyze possible changes to currently identified bioethical concerns, and more specifically to emphasize that a refined technology, in this case a new generation of DBS devices, can impact many ethical concerns. Thus, this analysis is foremost, though not exclusively, a task for ethicists. Translational neuroscience is just one example of a rapidly expanding field characterized by constant development (Hof and Šimić 2010). Therefore, an ethical analysis must incorporate technological progress, where one must dare to think ahead in order to capture the complexity, dynamics, and rapid changes that characterize bioethics today.

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