these innovations, in spite of their effectiveness at stimulating deep brain targets, ought not to be considered as belonging to the category of DBS simply by virtue of the fact that they are not chronically implanted electronic devices. Unpacking this underlying assumption and the arguments in favor of it can augment the apparent rationale for the normative framework that Johansson and colleagues defend.

Granting this essentialist assumption, the practical utility of the distinction between inherent and noninherent ethical concerns remains opaque; given that DBS technology is continuously evolving and that both stable and transient ethical features will manifest at any given stage of technological development, analyses of ethical issues raised by DBS might be more appropriately framed primarily according to their direct normative import, rather than according to ontological properties that may prove increasingly difficult to characterize for clinicians, engineers, and ethicists alike. Indeed, perhaps the best clues to understanding the moral dimensions of DBS will emerge not by pondering its intangible ontology but instead by studying its material impact on human life, culture, and civilization.

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DBS Combined With Optogenetics—Fine-Tuning the Mind?

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Like Johansson and her colleagues (2014), we are convinced that ethicists should think ahead instead of just reacting to technological developments. We have recently ethically analyzed one of the possibly upcoming developments of DBS, namely, its combination with optogenetics (Walter and Müller 2013). In this contribution, we outline the idea behind this combination and discuss its potential benefits and risks for treating neurological or psychiatric disorders; we investigate ethical issues of optogenetics-based DBS; and using this example, we argue that Johansson and her coauthors' dichotomization into inherent and noninherent bioethical concerns is not useful for evaluating developing technologies.

Optogenetics is a rapidly developing field of research that provides new insights into the functioning of neural circuits and offers new opportunities to manipulate brain

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activity (Hegemann and Sigrist 2013; Pastrana 2011). In a nutshell, optogenetics works by transferring light-reactive molecules (opsins) into specifically targeted neurons in order to excite or inhibit them with the help of light. For the transfer of opsins into neurons, standard genetic engineering tools (transfection via viral vectors) are used. In the targeted neurons, the opsins are integrated into the cell membranes. When those cells are exposed to light of specific wavelengths the opsins change their configuration, causing an ion flux across the lipid cell membranes and thus a change in membrane potential. The result is either depolarization (excitation by blue light) or hyperpolarization (inhibition by yellow light). Thus, light (applied with the help of optical fibers or miniaturized light-emitting diodes [LEDs]) is used as an "on–off switch." Also, optic stimulation does not interfere with electrical recording, so that in contrast to electromagenetic stimulation, brain activity can be recorded during stimulation.

Today, optogenetics is discussed as a tool for improving DBS, for it would be much more efficient to stimulate specifically only those cell types in a region that are relevant for specific symptoms rather than to stimulate permanently all cells within a given area with current of a given frequency (Deisseroth 2012). The major drawback of DBS, namely, its lack of electrophysiological specificity, could thus be overcome, so that new options to specifically address the pathogenesis of different neurological and psychiatric disorders could become feasible (Sturm 2013).

Using the principles of Beauchamp and Childress (2013) as a convenient guideline, we briefly discuss ethical issues of optogenetics-based DBS. Regarding the autonomy principle, no novel challenges appear. Obviously, the ability to provide autonomous consent is crucial. Both neurological and mental disorders can reduce the capacity for autonomy, for example, by impairing underlying cognitive functions or the ability to evaluate risks. Mental disorders are not generally seen as precluding the ability for informed consent; rather, this ability has to be assessed individually and with particular care in the case of innovative interventions whose risks and long-term consequences are yet unknown. In addition, the principle calls for respecting autonomous decisions of patients for new and risky treatments.

Crucial are issues related to the nonmaleficence principle. In particular, a number of safety risks have to be considered. Most prominent are (1) genetic transfection, (2) immunoreactions (to adeno-associated viral vectors, which probably will be used for gene transfer), (3) toxicity of opsins, and (4) systemic adverse effects. Obviously, before optogenetics might be allowed to be used in humans, much more research is needed. This research would also involve nonhuman primates because of the specialty of their immune system—and whether risky experiments with them can be justified ethically is beyond the scope of the four-principle approach.

Due to these uncertainties, the evaluation of optogenetics-based DBS with regard to the beneficence principle is currently unfeasible, since its clinical effectiveness has not yet been proven. Also regarding the principle of justice only general conclusions can be drawn. For example, the fact that this technique addresses severe diseases (in terms of life expectancy and quality of life [QoL]) with high incidence and a mostly not self-inflicted etiology may be taken as support for advancing research in this field.

Of particular ethical relevance are effects of optogenetics-based DBS on the mind and personality of the patients, which is also acknowledged by Johansson and colleagues as a major issue of DBS. However, there is no consensus on whether DBS-induced personality changes are generally ethically problematic, or only under certain circumstances, such as if the personality alteration causes suffering or occurs against the patient's will (Müller and Christen 2011). Using Johansson and colleagues' terminology, optogenetics-based DBS may indeed be an instrument to overcome ethical concerns raised by the contextual circumstance that DBS is a developing technology—namely, the more precise stimulation in terms both of location and of cell type could substantially decrease the incidence of stimulation-induced adverse mental effects and unwanted personality changes.

However, the possibility of increased fine-tuning of the brain stimulation to reduce side effects will also allow for better fine-tuning for nonmedical reasons, for example, for manipulating mood or personality for enhancement reasons; the Pandora's box for potential cosmetic psychosurgery is opened. It then can be expected that physicians would plead for limiting the patients' decisional scope about their stimulation parameters, at least for saving patients from stimulation-induced personality changes that, for example, would be harmful for the patients themselves (e.g., causing addiction) or for third persons (e.g., increasing aggressiveness). From the patients' perspective, this might be experienced as paternalistic limitations of their autonomy. The experience that one's own mood and behavioral dispositions become the object of shared decision making and technical manipulations could cause feelings of self-alienation. Although this issue has been already raised by recent DBS, it would be exacerbated through technological advances that increase possibilities of fine-tuning. In future, even the issue of "mind control" that has been raised by early proponents of brain stimulation (e.g., José Delgado) could become a growing concern.

This brief outline demonstrates the difficulty of drawing the line between "inherent" and "noninherent" ethical concerns. Shall we consider the ethical concerns of "fine tuning" of optogenetics-based DBS as a mere consequence of improvement in technology (a noninherent concern) or as a qualitative step leading to a novel kind of concern that is inevitably coupled to the nature of this technology? This is not just a practical problem of "drawing the line" between those two categories. Actually, from a purely logical point of view, "drawing the line" is a fundamental problem for a definition of two categories A and B where the second category B is merely defined as non-A. In addition, the dichotomization into inherent and noninherent ethical concerns requires an unambiguously defined "essence" of a technology.

Johanssen and colleagues suggest 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." The authors did not present any arguments on whether the features of this list are necessary and sufficient. It can also be doubted whether describing such an "essence" of a technology can really keep pace with technological progress. Is optogenetics-based DBS, where the mode of action is light instead of electrical fields, still "an electronic device"? What about thinkable techniques that influence neuronal processes over the skull, that is, that are not "implanted in the brain"? Is it suitable to use imprecise terms like "stimulation" in such a definition, although already current DBS involves a complex interplay of inhibitory and excitatory processes in different parts of neurons?

Another problem of this dichotomy is its lack of explanatory power. Johansson and colleagues give the "mere awareness of having an implant" and its impact on authenticity as an example of an inherent concern. But similar concerns about authenticity have been raised for heart transplants and for pharmacological treatment; therefore, this is no unique inherent concern. Furthermore, ethical assessments are subject not only to technological dynamics, but also to cultural dynamics. Cultural shifts in the appreciation of technology are at least as important as technological progress that may overcome so-called "noninherent" concerns. Finally, the mere observation that a refined technology can impact many ethical concerns is certainly correct—but trivial. What matters is an in-detail assessment of those novel technologies.

In sum, we do not see any use for bioethics to distinguish between inherent and noninherent concerns. As the possible combination of optogenetics and DBS shows, technological improvement might raise as well as solve ethical concerns that were not relevant at earlier stages of the technology.

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Why Authenticity May Be an Inherent Bioethical DBS Concern

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In their article, Johansson and colleagues (2014) propose to make a distinction between two types of bioethical concerns related to deep brain stimulation (DBS). First are *inherent* concerns, related to the DBS technology per se, which are "concerns that address the defining features of the technology itself" (Johansson et al. 2014, 27) The scope of such concerns is limited, because they only regard "the main defining features of DBS [which] are (a) an electronic device (b) chronically implanted in the brain (c) stimulating the brain to alter brain function." Johansson and colleague argue that many of the present concerns about DBS fall outside of this "inherent" concern definition. In fact, according to their proposal, only some technical, spatial, temporal aspects of DBS (like being located in the brain) are related to inherent bioethical concerns. The rest of the DBS effects, which have had such an impact on the bioethical debate, are, apparently, no more than side effects that are likely to disappear over time, and therefore noninherent bioethical DBS concerns.

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