Biotechnol. J. 2008, 3 DOI 10.1002/biot.200800187 www.biotechnology-journal.com

Review

Stimulating personality: Ethical criteria for deep brain stimulation in psychiatric patients and for enhancement purposes

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Within the recent development of brain-machine-interfaces deep brain stimulation (DBS) has become one of the most promising approaches for neuromodulation. After its introduction more than 20 years ago, it has in clinical routine become a successful tool for treating neurological disorders like Parkinson's disease, essential tremor and dystonia. Recent evidence also demonstrates efficacy in improving emotional and cognitive processing in obsessive-compulsive disorder and major depression, thus allowing new treatment options for treatment refractory psychiatric diseases, and even indicating future potential to enhance functioning in healthy subjects. We demonstrate here that DBS is neither intrinsically unethical for psychiatric indications nor for enhancement purposes. To gain normative orientation, the concept of "personality" is not useful – even if a naturalistic notion is employed. As an alternative, the common and widely accepted bioethical criteria of beneficence, non-maleficence, and autonomy allow a clinically applicable, highly differentiated context- and case-sensitive approach. Based on these criteria, an ethical analysis of empirical evidence from both DBS in movement disorders and DBS in psychiatric disease reveals that wide-spread use of DBS for psychiatric indications is currently not legitimated and that the basis for enhancement purposes is even more questionable. Nevertheless, both applications might serve as ethically legitimate, promising purposes in the future.

Received 28 August 2008
Revised 3 November 2008
Accepted 4 November 2008

Keywords: Deep brain stimulation · Ethics · Major depression · Neuroenhancement · Obsessive-compulsive disorder

1 Introduction

While many technological developments within the rapidly growing field of brain-machine-interfaces (BMI) or "neuroengineering" have posed ethical questions [1–4], one of the most challenging interventions might be electrical deep brain stimulation (DBS). Its application is certainly not only no longer speculative in nature, but already part of clinical routine in treating several neurological disorders. Correspondingly, effectiveness has been demonstrated not only in artificial lab environments, but also in randomized controlled trials, e.g., in advanced Parkinson's disease (PD) [5]. In addition, compared to classical ablative neurosurgical interventions, it is less invasive, fully removable, and adjustable [6]. Having proved its value in the treatment of various neurological diseases, including PD, general and segmental dystonia [7], tremor in multiple sclerosis [8] and – to a much lesser degree – partly also in cluster headache [9] and even minimally conscious state [10, 11], this new technology now raises the prospects of impacting disordered emotional and cognitive processing in psychiatric disease. In fact, some efficacy has recently been demonstrated in studies of treatment-refractory psychiatric disorders, such as obsessive-com-

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Abbreviations: DBS, deep brain stimulation; **MD**, major depression; **OCD**, obsessive-compulsive disorder; **PD**, Parkinson's disease pulsive disorder (OCD) [12–14], major depression (MD) [15–18] and partly also in Tourette's syndrome [19, 20], illustrating that psychiatric DBS has already started to become part of clinical reality. In a similar vein, it seems to be possible – at least in principle – to treat other disturbing behavioral traits: For example, it might be possible to improve obesity [21, 22] or impulsive and violent behavior [23]. Consequently, in the future one might even aim at improving mental states that do not reach the severity threshold for classification as a disorder, but still range in the "normal" range of emotional and cognitive functioning. Although there are no ongoing trials on DBS for enhancement purposes, recent reports demonstrate that DBS of the ventral striatum can be used to selectively induce emotions with positive valence [24, 25] or that hypothalamic DBS enhances associative memory in a person without any disease-related memory deficits [22]. Thus, as a hypothetical future scenario, DBS might be used to improve mood not only in patients with affective disturbances or to improve memory not only in dementia patients (as it is currently attempted, although with low success[26]), but also in affectively and cognitively intact persons.

This rapid expansion of DBS to indications where it bears only questionable effects and where it includes highly vulnerable populations (*e.g.*, psychiatric or dementia patients) underlines the urgent necessity to quickly develop and implement stringent ethical criteria for its application. The associated specific ethical concerns, however, have only rarely been addressed so far (for first recent discussions see [27–29]). In contrast, misleading arguments and unclear ethical criteria still often bias stringent societal and ethical discussions. We demonstrate here some of those misleading arguments that must be avoided in societal discussion regarding the potential application of DBS for neuropsychiatric and behavioral indications. As an alternative, the common and widely accepted bioethical criteria of beneficence, non-maleficence, and autonomy allow a medically applicable, highly differentiated context- and case-sensitive approach. Moreover, we show that cognitive and mood enhancement by DBS in mentally intact persons is not intrinsically unethical and that the same criteria apply as for DBS application in disease states. These criteria reveal, however, that widespread use of DBS for psychiatric indications is currently not legitimated and that the basis for enhancement purposes is even more questionable.

2 The unfortunate term "psychosurgery"

First of all, societal discussion about the legitimation of psychiatric DBS should abandon any historic allusions to the infamous term of psychosurgery. For several reasons procedures such as "frontal lobotomy", popularized in the 1930s and 1940s by psychosurgery pioneers such as Egas Moniz, Walter Freeman and James W. Watts [30, 31], differ clearly from modern stereotactic DBS (see Table 1, left column). Thus, the term "psychosurgery" is associated with misleading, negative historical and cultural biases and rather blurs than clarifies ethical and factual issues at stake. Consequently, it must be eliminated from stringent discussion. Benefit, harm and representation of patient's will in the case of psychiatric DBS should be analysed in comparison with current neuropsychiatric practices such as ablative surgery (Table 1, middle column), neuropsychopharmacology or electroconvulsive therapy (ECT).

3 Interfering with or altering personality traits

On the first glance, the question whether DBS for psychiatric indications might alter personality or not seems to be one of the fundamental ethical questions [36, 37]. In particular, one might tend to ask whether psychiatric DBS alters personality or not to draw ethical conclusions from this fact. This can be done explicitly by taking personality change as a negative criterion for psychiatric DBS, claiming for example that "it should not be used to modify a person's individual character traits"[38]; or it can be done implicitly, for example by assessing DBS-induced changes of personality variables mainly under the category of "risks" [39].

This approach, however, seems utterly misleading. First, the question whether DBS for psychiatric indications alters personality or not is completely contigent on the respective concept of personality employed. The term "personality" is generally used with a wide variety of meanings. If one really wants to try to delineate normative questions from the fact whether DBS "changes personality or not", broad discussions will arise about which aspects it might include or not.

However, what is the most plausible candidate if one tries to still hold on to this concept and to achieve a consentable, interdisciplinary useful notion of it? Traditionally, in particular in the course of Cartesian and Kantian philosophy, it is assumed that there has to be a distinct, non-reducible entity

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Table 1. Differences in ethical, historical and societal variables between early psychosurgery on the one hand and current ablative surgery and DBS on the other. For illustration, description of variables is partly simplified. Variables of early psychosurgery are characterized based on current descriptions from [30, 32, 33] and on critical analyses that were already published during the era of early psychosurgery [34, 35]

Ethical, historical or societal variable	Early psychosurgery	Currently used ablative surgery	Deep brain stimulation
Medical indication	Often disturbing, intolerable patients with unclear, vague indication in an era without neuroleptic medication	Patients with reduced health-related quality of life and refractory to other treatments	atients with reduced health-Prelated quality of life and refractory to other treatments
Surgical method	Imprecise open surgery	Precisely planned, ablative sterotactic intervention (thermocoagulation)	Precisely planned, stereotactic insertion of electrodes
Selection of targeted brain area	Crude prior clinical observation	Hypothesis-driven; based on previous animal lesion experiments and patient studies	Hypothesis-driven based on lesional surgery (initially) and extensive prior functional neuroimaging data (currently)
Brain tissue damage	Irreversible lesion of larger brain areas	Irreversible lesion of specific small brain area	Largely reversible damage; removable hardware
Adaptation to effects and side effects	Impossible	Impossible	Constant parameter optimization to maximize effect and reduce side-effects
Patient information	None	Informed consent after counseling	Informed consent after counseling
Decision-making process	Treating physician only	Interdisciplinary conference and patient's own informed preferences	Interdisciplinary conference and patient's own informed preferences
Primary goal	Altering wholesale personality structures	Improving specific aspects of respective psychiatric disorder	Improving specific movement parameters or specific aspects of respective psychiatric disorder
Follow-up care	No specific	Interdisciplinary team	Interdisciplinary team, continuous follow-up dates
Treatment standards	None	Clearly defined inclusion and exclusion criteria intervention decided by committee on a case by case basis	Clearly defined inclusion and exclusion criteria; randomized controlled trials using sham-stimulation (recently)

termed ‘selfÄ, which would underlie the central core features of a person, functioning, *e.g.*, as the realizer of the unity of our experiences and of transtemporal unity, as the center of our perspective or as the bearer of the sense of mineness of actions and thoughts. Such a non-physical self would – by definition – never be able to be changed by neuromodulatory approaches such as DBS.

Obviously, it is highly implausible to assume the existence of such a purely mental correlation of the self. It seems much more convincing – and thereby much more productive with respect to neuroscientific and neuroethical investigations – to follow naturalistic accounts of the self that have been put forward in modern philosophy. According to these accounts, the self is best understood as the objective, biological-cognitive representational system with special characteristic self-representational capacities [40, 41]. This self-representational system is able to construct subjective representations of oneself based on one's actions, perceptions, emotions, beliefs, *etc*. The self-representations of this system are not built up by a homogenous monolithic entity – as it appears phenomenally and as it was construed by traditional philosophy – but by different modules operating on different levels of representational and functional complexity. The most basic of these (self-)representational levels consist of sensorimotor processes, while the most elaborated levels comprise conceptual and meta-representational processes [40, 41]. Consequently, we propose that the notion of personality is understood not as

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a purely mental self, but as a supramodal representational system with largely heterogeneous functional and (self-)representational levels. This corresponds with recent notions in psychology and psychiatry, according to which personality can be defined as a dynamic and organized set of characteristics in a person that uniquely influences his or her cognitions, motivations, and behaviors in various situations [42].

This naturalistic notion of personality bears several advantages: It does not assume an outdated dualism between personal and non-personal brain systems, but rather adopts a gradual continuum between very basic and more complex personal brain systems that are interrelated by bottom-up and top-down processing mechanisms. Likewise, it does not assume an artificial dualism between sensorimotor brain modules on the one side and cognitive or emotional brain systems on the other, but rather maintains a continuum where cognitive and mood representations are complex representations that largely build on more basic sensorimotor and vegetative representations. In other words: personality is understood as the complexity of a system in which low-level sensory, motor or vegetative states are important and are legitimate parts of it rather than being neglected. Only by this perspective we are able to understand recent findings from cognitive neuroscience revealing that seemingly complex, highly elaborated mental phenomena such as the experience of agency [41, 43] or moral reasoning [44, 45] largely build on low-level sensorimotor processes and emotional processes, rather than on abstract conceptual and metarepresentational processing. Based on this notion it would not make sense to ask whether a personality is affected by a certain neurotechnological intervention or not, but 'on which level' and 'to which extent' it is affected.

Consequently, according to this conceptualization, even DBS for movement disorders would affect personality on different levels: on the one hand by altering sensorimotor circuits (*e.g.*, basal ganglia processing), on the other hand by modifying non-motor circuits connected to stimulation targets (*e.g.*, frontal and limbic circuits connected to the subthalamic nucleus) [46]. Correspondingly, affection of higher cognitive processing levels has been increasingly reported over the last few years [47].

In DBS for psychiatric indications modification of personality is not an unwanted, coincidental side effect of psychiatric DBS, but rather the main intended outcome of the procedure – and not only *via* modification of low-level sensorimotor levels, but also directly *via* affection of conceptual and metarepresentational levels. If mood and cognitive behavior did not change in a patient with OCD or with MD in both its low-level sensorimotor/vegetative and high-level conceptual and metarepresentational components in response to stimulation, DBS could not be considered an effective treatment. Indeed, both psychopharmacological and psychotherapeutic interventions have exactly the same goal in aiming to positively influence and thereby alter aspects of personality such as mood and cognition in psychiatric patients. Thus, the ethically decisive question is not whether DBS alters personality or not, but whether it does so in 'a good or bad way' from the patient's very own perspective.

4 Ethical criteria for psychiatric DBS

To obtain ethically coherent and clinically applicable criteria for DBS in psychiatric diseases, there is no need for specific criteria: the same criteria as for DBS in movement disorders or as for any other biomedical intervention apply [48], *i.e.*, DBS has to (i) benefit the patient, (ii) do no harm to the patient, and (iii) reflect his preferences and overall will.

4.1 Benefits of psychiatric DBS

To provide benefit to a patient, DBS has, first of all, to be proved to be effective and, preferably, to be more effective than both non-surgical measures and ablative surgery. Although recent studies on OCD or MD have clearly demonstrated effectiveness of DBS in some patients resistant to pharmacotherapy and behavior therapy [13, 15, 16], 50–75% of OCD [13, 14] and 25–50% of MD patients [15–17] fail also to show a long-term response to DBS treatment, and the individual prognostic predictors for enduring therapy response still remain unclear. Despite these caveats, psychiatric DBS is a targeted, hypothesis-guided and thus more effective approach than traditional treatment approaches, at least for some well selected patients. Compared to psychotropic drugs, it reversibly modulates only specific dysfunctional brain networks known to mediate mood and reward signals, but not widespread neurochemical brain circuits, many of which are unrelated to the pathophysiology of OCD or MD [16]. This superior effectiveness is reflected by the fact that DBS was the only treatment in the psychiatric patients studied so far that was able to reduce symptom levels of MD and OCD, respectively, after many years of chronic disease and after many different unsuccessful treatment attempts using psychotherapy and psychopharmacology.

To provide an actual benefit to the individual patients, however, DBS must not only be effective,

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i.e., improve scores in OCD or MD rating scales, but also demonstrate that these abstract improvements indeed are associated with an actual improvement of the individual patient's abilities to achieve personally valuable goals, *i.e.*, goals that are valuable in light of his or her individual psychosocial situation and on the basis of his or her particular, individual evaluative concept of a good life. This ethically highly important difference has been overlooked for a long time in DBS for movement disorders. Both research and clinical practice have focused initially only on the motor outcome, but have neglected quality of life independent of motor function and, in particular, normative and psychosocial factors that are easily missed with quantitative outcome parameters (*e.g.*, with movement scores or quality of life scores) [49, 50]. It is only very recently that the question has been asked as to whether improvement in motor behavior does indeed lead to a relevant overall improvement quality of life [51] or whether only certain subgroups receive an overall benefit from the motor improvement (*e.g.*, younger patients) [52]. However, even if it was convincingly demonstrated that motor, behavioral and disease-related quality of life variables improve after DBS surgery (*e.g.*, by randomized controlled trials [5]), these measures might still present invalid surrogate parameter for the true benefit of DBS. As shown by a recent open interview study, many PD patients are not happier with their lives, go through tormented periods in their marriages or fail to resume professional activity after surgery – in spite of (or probably even due to) clear improvement in some of these outcome variables after DBS implantation [49]. Since the contributory factors to these psychosocial misadjustments do not seem to be specific to PD, it can be expected that, after rapid symptom modification in any chronic life-determining disease, similar problems could occur, *e.g.*, after DBS in OCD or MD. Therefore, clinical studies should not only ask whether DBS is effective, *i.e.*, demonstrate improvement on OCD or depression scores, but also whether it indeed allows the individual patient with OCD or MD to live a more satisfying life including the psychosocial dimension. Therefore, quantitative measures have to cover not only functional disease-related variables, but also psychosocial and more global quality of life variables, and need to be complemented with qualitative outcome methodologies.

For several reasons it is more difficult to determine the likely benefit in psychiatric patients than in movement disorder patients. First, studies with randomized controlled crossover designs are still rare and have studied outcomes in small number of patients only. Second, due to the fact that OCD and MD are both disorders at the systems level, their etiologies likely comprise various heterogeneous biological and social factors and individual personality dispositions, which are still only poorly understood and whose contribution varies largely in different individual cases. This makes it difficult to predict who will respond to DBS and who will not, and how other individual cognitive and mood subsystems might be affected by stimulation. Third, different OCD and MD subtypes are characterized by different symptom clusters and it seems that, as in PD, different symptoms are likely to respond differently to DBS, depending on the stimulation target and the specific disease profile. For example, DBS might affect emotional and cognitive components of depression with different efficacy and speed, thereby pointing to differences in the underlying biology [15]. Along the same lines, there is increasing evidence that certain symptom subtypes may be mediated by different neural circuitries that respond differently to different DBS sites and DBS parameter settings [13].

4.2 Potential harms of DBS

DBS to different targets is associated with severe short-term and long-term risks on both biological and psychosocial levels. These include: intracerebral hemorrhages, dysarthria, worsening of apathy, depression, cognitive impairments (*e.g.*, in verbal fluency, color naming, selective attention, and verbal memory [47]), walking disturbances [53], sudden symptom reoccurrence and aggravation in case of battery depletion (occurring as a function of programmed stimulation parameters, usually after 5–13 months in the case of higher stimulation current amplitudes such as those required for OCD) or of stimulation interruption, risking exacerbation of depressive symptomatology [13]. Adverse short- and long-term effects on a psychosocial level might comprise psychosocial misadjustment, suicidal tendency [54], severe disappointment and renewed desperation in the case of non-responsiveness to DBS [14].

While some of the neurological adverse effects have only been reported with respect to STN-DBS (*e.g.*, dysarthria), other psychiatric impacts have primarily been associated with DBS of the anterior limb of the internal capsule and nucleus accumbens region (*e.g.*, rapid mood elevation when DBS begins or affective worsening when stimulation was interrupted [13]). Nevertheless, one can extrapolate many features of the known risk profile of DBS for movement disorders to the rather poorly known risks of DBS for psychiatric diseases. This is

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particularly the case as behavioral and psychiatric side effects – harmful or beneficial – occur even in targets that presumably represent movement disorder targets [54, 55] but in fact form a junction where motor and non-motor functions are represented in a spatially very close area and are connected *via* reciprocal loops (*e.g.*, the subthalamic nucleus [46]).

Thus, in line with the above-mentioned naturalistic notion of personality, there is no strict dichotomy between "movement disorder targets" and "psychiatric targets", but a gradual continuum of closely interacting representational and functional levels. Since DBS of targets like the ventral capule/ventral striatum affects emotional and behavioral loops gradually and more than subthalamic or pallidal DBS, adverse mood and behavioral effects like anxiety, depression or even severe panic (but not necessarily cognitive impairments, [56]) might be more likely to occur [13, 57], thus rendering adverse psychiatric events the most expected risk of DBS targeted to treat psychiatric disease. Importantly, however, future studies still have to prove that this effect is not only due to the fact that psychiatric symptoms are possibly better monitored and captured given the psychiatric scope of psychiatric DBS studies that use psychologically trained staff and testing instruments that are generally not used in movement disorder DBS studies.

However, under the assumption that DBS would be an efficacious treatment, one might do harm to patients not only by performing DBS, but also by not performing it. The chronic and partly even progressive course of treatment-refractory OCD or MD implies a constant increase in psychological suffering, work disintegration, social withdrawal, and partnership and family relation problems. Thus, also not performing DBS in psychiatric patients might one day posit specific, well-reasoned ethical justifications. Moreover, all pharmacological and psychotherapeutic treatments are associated with significant adverse effects, *e.g.*, agitation, sexual side effects, sedation, sleep disturbances, and night sweats in the case of depression treatment, often leading to non-compliance [58]. These adverse events have to be counterbalanced against the beneficial effects of DBS. If, in the future, DBS proves to be so superior in OCD and MD that especially patients who have not been on medication for longer time and whose social and physical life is not yet devastated by disease might benefit more from DBS, one will even be in the need to provide good reasons why DBS is not performed 'rather early' in the disease course. This scenario is still highly hypothetical and seems provocative on first glance, but presents a lesson recently learned with respect to DBS in PD [59–61].

4.3 Satisfying the psychiatric patient's will

Personal value preferences based on one's very individual concept of a good life are of special importance for both taking the decision to undergo a DBS procedure in the first place and determining adequacy of stimulation parameter adjustment in the further course of treatment. For several reasons, the capacity for autonomous decision-making and especially value choices might be associated with more and stronger confounds in psychiatric patients than in patients suffering from neurological disorders. First, preferences are strongly influenced by affective components, e.g., depression in both MD and OCD patients (up to 80% of the OCD patients undergoing DBS have comorbid DSM IV MD [13, 14]). Second, desperation is high in chronic, treatment-refractory and potentially deadly mental disorders. This gives ground to overhasty decisions in favor of DBS that potentially undervalue the facts that individual treatment response to DBS is highly uncertain, that some adverse effects might be deadly or lead to severe disability (e.g., in the case of hemorrhage) and that long-term cognitive, emotional and behavioral effects of psychiatric DBS are still largely unknown. The high desperation of treatment-resistant patients predisposes them in the case of non-responsiveness to severe disappointment and to suicidal reactions [14]. This complicates not only assessment of efficacy, but also patient management in demanding protocols and in the subsequent physician-patient relationship. Third, since psychiatric side effects, such as elevated mood or anxiety, might be more likely in psychiatric DBS, patients' preferences for or against certain parameter settings might be directly induced by the stimulation per se, but not reflect their general value perspective, unaffected by DBS treatment.

5 Ethical criteria for enhancement DBS in healthy subjects

The findings that DBS can alleviate anhedonia [16] or enhance memory function [22] plus the experience that patients can selectively choose stimulation parameters depending on how they want to feel, *e.g.*, calm for every day or more "revved up" for a party [62], open up a completely new application of DBS in the future. It could possibly be used not only for ameliorating psychiatric disease states, but also for enhancing mood and cognition in healthy subjects.

Traditionally, the ethics of "enhancement applications" of neurotechnologies have been questioned arguing that it is only justified to use a certain technology for therapy, but not for enhancement; or only for mental disease states, but not for healthy states; or only for mental states that function below certain statistic or biofunctional standards of normality, but not for normal or above-normal states. However, like the concept of personality, the concepts of enhancement/treatment, disease or normality are also not helpful for finding normative orientation but rather hamper than allow targeted discussion and decision-making (for a more detailed analysis see [63]):

- The treatment/neuroenhancement distinction is not helpful in that this conceptual distinction is not analytically disjunctive: Since, in principle, every treatment aims at enhancing a certain state and is in fact legitimated only by the assumption that it will somehow improve a patient's quality of life, every treatment presents a certain form of enhancement [64]. Moreover, we do not ethically disregard enhancement measures in most other domains of our everyday life, but rather accept the use of cognition enhancing substances like coffee or wine or the use of cognition or mood enhancing behaviors like theater visits, school education or sun bathing. Common academic and public hypocrisy needs to be discarded: "We all like to moralize about enhancement technologies, except for the ones we use ourselves. […] There is often a striking contrast between private conversation about enhancement technologies and the broader public discussion." [64], p. 297). Thus, the real question is not 'whether' enhancement should be legitimated or not, but 'under which circumstances'.
- The concept of disease is not helpful in that what we call a disease state (i) depends highly on an individual's subjective experiences, preferences, societal role expectations, social support and socio-cultural values, (ii) eludes general interpersonal and theoretical consensus, and (iii) cannot be determined with sufficient clarity with respect to those states which are in question with respect to the enhancement debate. When should we, for example, consider flight phobia, premenstrual dysphoria or progressive memory disturbances or attention deficits as a "disease state"? And, in fact, if somebody suffers from his mood or memory disturbances and wants to get rid of it, why should he care at all whether his mental state falls under a general concept of disease or not?
- The concept of normality is not helpful in that it is difficult to agree on what the reference and reference class should be without requiring an endless number of extremely fine-grained reference classes and without making (implicit or explicit) normative assumptions. Should we normalize, *e.g.*, by age, by race, by socioeconomic background, by an individual's previous mental state or by a certain combination of these variables? Even if it was possible to establish certain reference classes, for example by age, how then can we find consensus about how to determine the normal range of a certain mental function? For example, to what extent do happiness, creativity or spirituality typically prevail? [65]. But even if it were possible to determine a normal range of a certain mental function, *e.g.*, by large epidemiological studies, the main problem still remains: normative implications do not necessarily follow from statistical normality, but have to be differentiated from each other. This can be demonstrated by a double dissociation: There are statistically normal states of mental functioning that assume disease value and that might be legitimately treated (*e.g.*, decreasing memory capacities or executive functioning in aged people) as well as statistically abnormal states that do not assume any disease value and that should normally not be treated (*e.g.*, high intelligence, absolute pitch, reduced intelligence in a supportive social environment) (for a more detailed analysis see [63]).

Again, as a more productive alternative, the common and widely accepted bioethical criteria of beneficence, non-maleficence and autonomy allow a clinically applicable, highly differentiated context- and case-sensitive approach. However, these criteria reveal that, although not being intrinsically unethical, DBS is not yet ripe for enhancement purposes:

- There are no systematic studies on enhancing effects of DBS on mood or cognition in healty subjects, leaving the criterion of evidence-based effectiveness – not to mention the criterion of benefit – unfulfilled.
- The afore-mentioned risks of harm receive much more weight in an enhancement application than in a disease application since it is less likely that they will be outweighed by the likely benefit: A person suffering from a disease like treatment-resistant MD is much more likely to receive a positive net benefit from an intervention than a person who suffers only from some form of melancholy or dysphoria. And, in turn, the risks of side effects like dysarthria or minor hemorrhage will seem much less acceptable for

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a mentally intact person than for a person suffering from a severely impaired mental state. Moreover, depending on the stimulation site, DBS might even foil some of the expected enhancement effects, *e.g.*, by increasing rather than decreasing impulsivity [55] or by facilitating rather impeding weight gain [66].

6 Conclusions

Although application of DBS is not intrinsically unethical – not even if applied for the purpose of neuroenhancement – each application needs a detailed, case-specific ethical analysis based on the criteria of beneficence, harm and autonomy. Even DBS for movement disorders does not sometimes meet these criteria completely: true individual benefit (rather than mere effectiveness with respect to motor improvement) is often not documented well enough, harms like psychosocial misadjustments and long-term cognitive deficits are still insufficiently investigated, and autonomy might be confounded by one-sided information about benefit and risks of harm presented on "patient information days". In particular, current attempts to use DBS for treating complex neurocognitive disorders with manifold cortical and subcortical neurodegeneration such as Alzheimer's dementia [26] seem to need a much more thorough ethical assessment. DBS for psychiatric indications poses even more ethical challenges with respect to the three ethical criteria, illustrating that the time is not quite ripe yet for wide-spread clinical application in these indications – not only due to the current lack of scientific data, but also due to currently unmet ethical requirements. But once these requirements are met, it might become a truly revolutionary treatment modality for psychiatric patients resistant to traditional methods – and thus a relief for humans afflicted with the most disabling disorders known to humanity.

We thank three anonymous reviewers for their valuable comments and the "European Platform for Life Sciences, Mind Sciences, and the Humanities" sponsored by the Volkswagen Stiftung for their financial support.

The authors have declared no conflict of interest.

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