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# Neurotechnology and ethics guidelines for human enhancement: The case of the hippocampal cognitive prosthesis

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**Abstract**

Neurotechnologies offer both therapeutic and enhancement potential. In this article, we demonstrate how ethics guidelines can help with critical reflection on their potential for enhancement. We do this through the case of the hippocampal cognitive prosthesis. This prothesis developed in the US, has primarily therapeutic ends, with scope for enhancement. This technology raises several ethical issues, including as related to identity and memory, autonomy and authenticity. In the first section, we outline what we mean by enhancement, and introduce neurotechnologies generally and the hippocampal cognitive prosthesis specifically, with an introduction to generally relevant ethical issues. In the second section, we outline ethical issues pertinent to the hippocampal cognitive prosthesis and explore how ethics guidelines can help to promote essential critical reflection on a technology like this. Through all this, our emphasis is to balance between technological optimism and caution, especially where technologies have enhancement potential.

**KEYWORDS**

augmentation, cognitive prosthesis, ethics, human enhancement, identity, memory, neurotechnology

## 1 | NEUROTECHNOLOGY, HUMAN ENHANCEMENT, AND ETHICS

Neurotechnologies are generally developed for therapeutic purposes, in order to assist or replace motor, sensory, or cognitive abilities that are damaged as a result of injury or disease. However, they have considerable potential for human enhancement as well—the augmentation of human abilities beyond a "normal" level.[1,2] Human enhancement raises considerable ethical issues, however. In this article, we consider how the enhancement potential of neurotechnologies can be subjected to ethical reflection. We do so through a case study of cognitive neuroprosthetics, specifically the hippocampal cognitive prosthesis that was recently developed in the US. We show how recently developed ethics guidelines for human enhancement for the Horizon funding program of the European Commission[3,4] can be applied to this technology and can guide ethical decision-making about its development and deployment.

Neural (or cognitive) prostheses are typically "assistive devices" that contribute to the restoration of functions that have been lost due to neural damage. They do this by electrically stimulating nerves, whether externally, or as an implanted device.[5] A report on implants in 2005 by "The European Group on Ethics in Science and New Technologies" (Ref. [6], 23) noted that there were "no reliable scientific investigations concerning the long-term health impact of ICT implants in the body". This gap persists; such technologies are still relatively new. Electrodes can degrade, and even nondegraded implants can be rejected by the body.[7]

Let us first further clarify what human enhancement is and how it contrasts with therapeutic interventions. Human enhancement is a broad concept, incorporating many technologies, interventions, and applications. Common to all is the scope for improvement of human abilities beyond what might be considered "normal" or "natural". Technologies that enhance allow humans to *outperform, boost*, or otherwise *extend* their ordinary, everyday, or otherwise *typical* human capacities.[i] Such developments might be beyond those capacities afforded by one's own biological limbs or cognitive capacities, for instance. Sometimes, technologies are specifically designed for human enhancement. Some technologies, however, are developed for therapeutic applications, but can also be used, with few if any modifications, for human enhancement.

Jensen et al.[8] describe human enhancement as a modification "aimed at improving human performance and brought about by science-based and/or technology-based interventions in or on the human body". The definition seeks to capture a broad range of technologies, techniques, and processes, though some conceptual issues remain. Not least is the difficulty in distinguishing enhancement from therapy, defining "performance", and the persistent problem of normative terms to account for the baseline against which "improvement" is compared. Terms like "healthy", "normal", "average" etc. are not only problematic because of the immediate impact on those who are harmed or excluded by them. These terms also help to reify broader expectations of human identity and capacity and to shape this for future generations. The relation of human enhancement to human identity is unavoidable, since there are no human enhancement technologies that do not change (improve, enhance, upgrade, etc.) the human. For these and other reasons, authors have pointed to the need for guidelines or regulation of such technologies (cf. discussion in Coenen,[9] and Savelescu[10]).

Let us now turn to cognitive neural prostheses. These are devices that are directly implanted in the brain or on the skull to interact with neural processes in order to aid, restore, or replace impaired cognitive functioning. Their primary purpose is thus therapeutic. For their therapeutic application, they already raise significant ethical issues. These include issues of consent, given the potential risks and the irreversibility of implanted cognitive prostheses, which tend to create scar tissue even if removed. There are concerns about effects on autonomy and identity, since these devices affect cognition, and could affect mood and personality. There are also concerns about privacy, for instance about information storage and external retrieval, plus the management and use of data. All of which fits alongside questions about the kinds of data that is generated from and about the brain, and what such data represents.[11,12] For instance, there is not always sufficient recognition about the limitations of a model as it accounts for brain states. Such models are at best idealistic, and at worst poor descriptions of what they depict[13] yet they remain popular for the articulation of brain function, including in terms of minds and the subjective experiences with which they are tied.

Technological optimism is common to research on the brain, especially given a tendency to view the brain as "just a complex but physico-chemical determined machine".[14] In such cases, researchers do not simply present models that stand for the neural mechanisms; too often they take "seriously the hypothesis that it functions as a map-like representation and investigating how it does so. That is, they, treat these neurons as actually representing places".[15] These are just a few of the ethical issues at stake, and these are further exacerbated when the technology has human enhancement potential.

One neurotechnology with human enhancement potential is the hippocampal cognitive prosthesis,[ii] recently trialed on human participants in the US. An invasive stimulation device,[16] the prosthesis is "designed to restore the ability to form new long-term memories typically lost after damage to the hippocampus".[17,18] Researchers claim that the recent trial demonstrates improvement of about 35% for both short- and long-term retention of visual information.[iii]

[i]It is worth noting that "typical" is not free of epistemological or ontological bias, even if is not saddled with the same kinds of historical prejudices and harms that plague terms like "normal" and "natural".

[ii]A reviewer has pointed out that this is not a prosthesis per se, but rather a closed-loop stimulation technique. This is important to recognize since the term "prosthesis" promises much, and can create expectations for scope and application beyond the limitations of the technology as it currently stands. That said, it is useful for our purposes to engage with the description of the technology as it is offered by the research group developing it, and to explore the wide range of philosophical and ethical implications of a neurotechnology with enhancement potential.

[iii]Though neuroscientist Nick Ramsey points out that this is within a controlled environment, and not shown to be generalizable (private correspondence).

Enhancement from the hippocampal cognitive prosthesis could come from its use by someone with an impaired hippocampus, as well as from someone with a functioning hippocampus. Enhancement effects could include increases in capacity for new memory forming. One test of the new technology using delayed match-to-sample (DMS) human short-term memory tasks showed positive results that were "not limited to patients with either 'normal' or impaired memory function".[16] Although in a recent trial of this technology, the prosthesis remained external to the body, the technology made use of already-implanted electrodes of participants, and implantation of the prosthesis is a goal. While this technology is not yet at a stage where it will provide a replacement of the hippocampus, the research presents this as a future possibility. It is therefore a useful case study for exploring ethical and societal implications related to its enhancement potential.

## 2 | ETHICAL ASSESSMENT OF HUMAN ENHANCEMENT POTENTIAL OF THE HIPPOCAMPAL COGNITIVE PROSTHESIS

We now proceed to demonstrate how potential enhancement applications of the hippocampal cognitive prosthesis can be assessed. We will do so by application of the ethics guidelines for human enhancement that we recently developed, on the basis of extensive research and consultation, for the European Commission's Horizon Europe research funding framework.[4] These guidelines are now in use for Horizon Europe research projects with a potential for human enhancement.[iv] The guidelines are based on six key values with largely universal appeal: well-being, autonomy, informed consent, equality, justice, and (moral and social) responsibility. For each of these principles, specific guidelines have been formulated for the development and deployment of human enhancement applications. In addition, there are specific guidelines for clinical trials and safety and efficacy studies for human enhancement applications and for genetic enhancement applications.

Implanted neuroprostheses can significantly change how a brain works, which distinguishes them from the wearing of a prosthesis that can be externally connected and removed. Where these are used for enhancement we should consider that effects may be more than just improved memory or capacity for learning. They can also be *qualitative*,[20] which could include feelings of alienation, especially if the memories do not feel authentically one's own. The ethical issues described in the first section that apply to neurotechnologies generally are compounded by this particular technology. The hippocampus is a part of the brain typically associated with memory and learning,[21] yet there remains uncertainty about how this plays out in different kinds of memories, such as episodic or semantic, and in terms of memory as reconstruction versus retrieval,[15] as well as pertaining to context.[22] Memory is an essential component of human identity, and we need to consider the quality of memory that may be restored or enhanced by a prosthesis as well as any broader qualitative impacts.

In terms of therapy, it may be clear that improvement to memory function damaged by disease would be preferable, or that the potential to improve memory otherwise depleted in the course of aging would be welcome. It is less clear what kind of improvement the technology would offer if used for general enhancement purposes. For instance, would more accurate, more complete, or even just more memory constitute improvement? And how do we take into account that memories play a multifaceted qualitative role in a person's experiences of the world, i.e. memories cannot be easily described as simply good or bad, and the value of more or less memory depends somewhat on context. This is especially important if editing involves the "decoding and enhancing" as well as "inception and deletion of specific wanted or unwanted memories", or we consider what impact the "modification of single memories" may have on the memory network.[23]

Meanwhile, legislation and ethical oversight of enhancement technologies is patchy in the US and internationally. Although there is legislation governing clinical trials for therapeutic purposes, there are no legal frameworks for the research, development, or application of technologies as they pertain specifically to enhancement potential. The situation is not helped by the fact that *enhancement* is a very broad term, as we explain above, and the fact that the enhancement potential of technologies is not always promoted or even acknowledged. The cognitive prosthesis we consider here is therefore especially useful to this discussion, given the researchers recognize both therapeutic and enhancement potential. In the regulatory gap, guidelines can play a role (See also: Ref. [24] for available international guidance and recommendations, often focused on specific applications or contexts; Ref. [25], on the development of ethics guidelines for neurotechnology; the Food and Drug Administration (FDA)[26] Code of Federal Regulations—Title 21—Food and Drugs, which covers regulation of medical devices; The "American Academy

[iv]The full guidelines and methods can be found in Erden and Brey,[4] a version for EC guidance is in Erden and Brey,[19] and an abridged version has been published in *Science*.[3]

of Neurology, Responding to requests from adult patients for neuroenhancements",[27] which covers pharmaceuticals for neuroenhancement).

Thus in this section we explore more detailed ethics issues in relation to our ethics guidelines for human enhancement technologies. The framework we have developed seeks to promote a systematic inclusion of ethical values and principles in the design and development processes for human enhancement technologies, as per an ethics-by-design approach (see also Ref. [28]). While our full guidelines cover many ethical issues, in this section we identify just six that we consider especially salient for the hippocampal cognitive prosthesis: three on *individual* impacts, three on *social* implications.[v] We begin with the individual implications, the first focusing on memory.

We argued above that the hippocampal cognitive prosthesis could affect someone's memory, and in turn, their identity. As such, the following ethics guideline is especially relevant, since it suggests we avoid interventions that:

> Change the personality of an individual in a way that either distorts or limits their potential to maintain existing control over their identity. This includes, for instance, where an enhancement impacts on an integrated conception of self, i.e. as a self that persists in time (past and present), and as located in one person, or to a person's potential to live authentically, so that their actions are congruent with their beliefs, desires, and memories. Ordinary changes to personality and identity, as occur through a person's life, happen within a framework of decisions and actions, interpersonally and via introspection, and human enhancement should not disrupt this.
>
> (Erden and Brey, [4], 48)

It is not yet clear to what extent the technology in our case study would expand or limit a person's ability and freedom to make their own choices, and to have the full range of cognitive, affective and conative states that underlie human autonomy, but this uncertainty should give us pause for thought. For instance, we ought to consider the role of choice in memory formation, e.g. where people seek to remember or to forget, and how such decisions and actions affect autonomy and authenticity.

If we understand personal autonomy as the capacity of the individual to make choices and decisions that correspond with their values and preferences, and to reflect on their motivations as well as the potential to change their mind, all without impediment, then it is clear that memory is also critical for autonomy. Memory is an essential component of the ownership a person may feel over their current, past, and future decisions, choices, and actions, including the account that they offer pre and post hoc (to themselves and others). Thus decision-making incorporates not only the final judgments and outcomes of such processes but also the means by which a person arrives at their conclusions. This combines both their reasoning and the process of that reasoning, which necessitates a continuous, integrated identity as outlined in the guideline above. It is uncertain whether the memories developed with a hippocampal cognitive prosthesis would be experienced as part of oneself, or as somehow alien, which means that a continuous, integrated identity cannot be guaranteed. This is especially the case if such memories are experienced as somehow "enhanced", whether because they are more vivid, more detailed, or simply more extensive in comparison to one's pre-enhanced experiences.

The potential for *authentic* choices, decisions, and actions, namely as they reflect the sincere preferences and wishes of the person who chooses etc., requires that the person can reflect on their choices, say, in a specific context as well as more generally, and in the context of former choices, decisions and actions. We need to consider how, and to what extent the authenticity of a person is affected if a prosthesis contributes to the formation of memories integral to these processes. Actions and memories are constituted passively and actively: things happen to us; we cause things to happen, and the line between these may be hard to draw. But the perception of a person as actively *choosing* is an important component for autonomy and authenticity, and thereby identity, and it seems clear that memory is critical to these processes. Technology should not impact this without care for the implications and outcomes, especially as these impacts can go either way: technology can improve memory and thus decision-making, yet technology can also make memory "worse", including where we may be forced to remember things that we would rather not. In either case, there is an impact on decision-making.

The interrelated nature of memory, identity, autonomy, authenticity, and so on, as discussed in this article helps to show that the impact of such technologies is rarely limited to one facet. Indeed, technologies that impact an individual's mental processes, emotional states,

[v]It is important to recognize that whatever impacts an individual can and does also impact society, and vice versa. The division we offer here, however, should be understood as a way to categorize relevant ethical issues, and not as a stronger claim about the relation between individuals and society.

or behaviors, among other outcomes, can have a range of effects, whether intended or unintended, positive or negative. While the technology under consideration in this article is still very new, and while there remain high levels of uncertainty regarding implications and impacts, an ethics-by-design approach requires that consideration is nevertheless already given to these potential outcomes. Accordingly, the ethics guidelines suggest that:

> A high ethical benchmark needs to be applied to cases in which an enhancement affects emotions and affect, cognition and other mental capacities. It needs to be taken into account that these capacities are interrelated, and that they are related to a person's values, beliefs, judgments, and personality, so that changing one element will also affect some or all of the others.
>
> (Erden and Brey, [4], 47)

For all these reasons, the third individual impact to consider here concerns well-being. Neural prostheses offer substantial scope for irreversible changes and impacts, including secondary outcomes like scar tissue. More broadly, we need to take into account contemporary or future legal implications regarding the ownership of human enhancement technologies. For instance, licensing of software, or hardware that could become indivisible from the user, and how rights and responsibilities (including for data management or updates to hardware and software) may change in the short, medium, and long term. This should incorporate the assessment of risks from unwarranted interference by external parties, ensuring that such risks are minimal, and ensuring that there is informed consent for all remote access to an enhancement. This guideline on well-being is therefore pertinent for this technology:

> The well-being of the recipient of an enhancement should be paramount. Enhancements, especially those that are irreversible, should provide a clear benefit to the individual's life, with a likelihood that their overall well-being is increased not just in the short term, but over their lifespan. This includes being clear about if a treatment is irreversible and why, and what potential there is for an alternative, reversible enhancement that would serve the same or similar purpose. It also requires a careful weighing of potential benefits and harms to the recipient over an extended period of time, taking into account the unique characteristics and circumstances of the recipient, their own perspectives and wishes, as well as any potential changes in their circumstances and life choices over time.
>
> (Erden and Brey, [4], 46)

As we noted above, human enhancement technologies impact not only individuals; there are also broader societal implications to consider. For instance, it needs to be recognized that while human enhancement could diminish existing inequalities, it could also cause new inequalities by providing individuals and groups with superior abilities not possessed by others. It may also exacerbate existing social inequalities as well as engender new ones by creating new social identities and challenging or reifying existing conceptions of identity, including what is considered "normal" or typical, unusual or deviant. It may put pressure on unenhanced persons to enhance themselves. The neural prosthesis we consider in this article offers scope to challenge expectations of health as it relates especially to diseases associated with memory loss caused by aging. Related to this, it is worth noting that health already divides along socio-economic lines, whereby those with higher socio-economic status or backgrounds typically also have greater access to better health provision, plus the means (time, resources) to engage in preventative measures that include healthier food, exercise, and so on.[29] Memory is a valuable attribute, and it is clear that difficulties with memory can substantially impact a person's life and capacities. Thus this ethics guideline proposes that human enhancements should:

> Take into account where the abilities bestowed by the enhancement are among those abilities considered most important for having success in life, such as intelligence, memory, self-confidence, strength, dexterity, and endurance, among other qualities. In the case where such enhancements are made available, then they should be made accessible to all people equally.
>
> (Erden and Brey, [4], 49)

There are other societal issues to consider. For instance, human enhancement could have serious implications also for the institution of medicine and other social institutions; for families, communities, and other social groups; and for society as a whole. Therefore, social responsibility should be paramount in research, development, and deployment of human enhancement. For instance, the technology we discuss here has commercial, as well as military, potential, as demonstrated by the substantial DARPA investment in its development.[30,31] Given this, our next relevant ethics guideline suggests:

> The commercial market for human enhancement should be regulated so as to ensure that the interests of recipients, as well as those of society are paramount. Products should meet the requirements set out in these guidelines, relevant product safety guidelines, and GDPR, and it should be assessed per product category whether commercial advertising should be allowed, and if so, what restrictions it is subjected to. Advertising should not lead consumers to believe that certain enhancements are necessary for their well-being and success or for them to fit into society, or that not acquiring the enhancement causes them to be deficient.
> (Erden and Brey, [4], 50)

The potential for enhancements to be used to gain social or employment advantage, or toward other success such as in sports, has already been well explored.[29] The risk that enhancement potential could become commonplace, or even required, is one that was of great concern to the stakeholders we consulted.[4] In terms of memory, it is easy to see why an educational institute or an employer might value students or employees who can more regularly or reliably recall information, and so the following ethics guideline seeks to prevent this becoming an expectation:

> Human enhancements that are internal to the body or are irreversible should not be specifically developed to be applied in the workplace or in education. This includes by normalizing human enhancement for employment prospects, career progression and development, or education, and thus creating undesirable social pressure for it to be used. There should not be work requirements or educational requirements that directly refer to, or indirectly rely on, the presence of human enhancement.
> (Erden and Brey, [4], 50)

## 3 | CONCLUSION

The above six ethics guidelines for human enhancement offer insight into the full instrument. In the extended report[4] the full list of guidelines is presented, and we offer more detail on their potential, including scope for further case-by-case ethical analysis and application. In this article, we have focused on the enhancement potential of one specific neurotechnology, but there are many other cognitive enhancements worthy of consideration. These include pharmaceutical interventions, plus a whole host of neurostimulation, and neuromodulatory techniques (cf. Ref. [29]). With a greater range of technologies and interventions, we also have a greater range of enhancement potential, including to a person's moods, cognition, and behavior. The guidelines can be easily applied to any enhancement technologies and beyond, including artificial organs more generally.

Some limitations of guidelines generally have already been identified in Jensen,[29] and in Erden and Brey,[4] yet guidelines provide a useful framing mechanism to evaluate neurotechnologies like the hippocampal neural prosthesis for ethical and social impacts. Our ethics guidelines are intended to help fill current regulatory gaps as they exist for technology with enhancement potential. We think our guidelines can be useful for researchers, developers, and (para)medical practitioners that work in areas in which human enhancement could be an objective or unintended consequence.

There are many further relevant questions to consider, such as the role of funding bodies, and regarding distinctions between public, private, and military funding. While the guidelines we offer encompass values such as well-being, autonomy, informed consent, equality, justice, and (moral and social) responsibility, they offer scope for further development and expansion into new topics and areas, not least for future applications. In these ways, we seek to balance technological optimism with caution for technologies like the hippocampal cognitive prosthesis that can profoundly impact not only the memory of the individual but also what we expect from individuals as they live and work, develop and age. We can neither take for granted what an enhancement represents nor the benefits it can bring, even while we remain hopeful about the technological solutions that can help us to live authentic and meaningful lives.

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