THE SURGEON 8 (2010) 267–269

available at www.sciencedirect.com

The Surgeon, Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland

www.thesurgeon.net

Matter for Debate

Brain-machine interface: The challenge of neuroethics

Andreas K. Demetriades [a,*], *Christina K. Demetriades* [a], *Colin Watts* [b], *Keyoumars Ashkan* [a]

[a] *Department of Neurosurgery, King's College Hospital, London SE5 9RS, UK*
[b] *Academic Neurosurgery Unit, Addenbrooke's Hospital, Cambridge CB2 2QQ, UK*

ARTICLE INFO

Article history:
Received 29 March 2010
Accepted 21 May 2010

Keywords:
Brain-machine interface (BMI)
Neuroethics
Robotics
Brain stimulation
Philosophy

ABSTRACT

The burning question surrounding the use of Brain-Machine Interface (BMI) devices is not merely whether they should be used, but how widely they should be used, especially in view of some ethical implications that arise concerning the social and legal aspects of human life. As technology advances, it can be exploited to affect the quality of life. Since the effects of BMIs can be both positive and negative, it is imperative to address the issue of the ethics surrounding them. This paper presents the ways in which BMIs can be used and focuses on the ethical concerns to which neuroscience is thus exposed. The argument put forward supports the use of BMIs solely for purposes of medical treatment, and invites the legal framing of this.

Introduction

A brain-machine interface (BMI) is the direct communication between a brain and an external device, which involves the use of transducing or stimulating electrodes. A BMI may take the form of a brain-computer interface, a direct neural interface, a brain-machine application, or a deep brain stimulating electrode. The morphology is not fixed, much like its use. In practice, experiments about BMIs started towards the end of the 20th Century and have aimed to restore eyesight, hearing, mobility, to treat Parkinson's disease and epilepsy or to relieve pain. On the theory level, BMIs started to concern academics after the turn of the millennium; hence the debate surrounding BMIs is still rather young.

The burning question surrounding the use of BMIs is not merely *whether they should* be used, but *how widely* they should be used, especially in view of some ethical implications that arise concerning the social, as well as legal, aspects of human life. In other words, if BMIs are to be used, should there be placed a limit to the extent and to the way in which they are used?

As technology advances, it can be further exploited through medicine so that it can affect the quality of human life. Since the effects of BMIs can be both positive and negative, it is imperative to address the issue of the ethics surrounding BMIs.

In what follows, the discussion presents the ways in which BMIs can be used and focuses on the ethical concerns to which neuroscience is thus exposed. The argument put forward supports the use of BMIs solely for purposes of medical treatment, and invites the legal framing of this.

* *Corresponding author*. Tel.: +44 (0)2032999000x5155.
E-mail address: andreas.demetriades@gmail.com (A.K. Demetriades).
1479-666X/$ – see front matter
doi:10.1016/j.surge.2010.05.006

How do BMIs work?

There are invasive, partially-invasive and non-invasive BMIs.

Invasive BMIs are implanted directly into the brain during neurosurgery. These are the most effective, as the electrode-brain interface is the closest. Yet, at the least, they tend to cause scar-tissue formation, as the body reacts to a foreign body in the brain, which in turn weaken the signals significantly, and at the worst they may lead to direct neural damage. Invasive BMIs have been used to treat Parkinson's disease, non-congenital (i.e. acquired) blindness, as well as paralysis. Recent experiments have demonstrated that communication is possible with people who are completely paralysed and who cannot use their body parts independently (e.g. Amyotrophic Lateral Sclerosis patients). BMIs focusing on motor neuroprosthetics seek to restore movement or provide a device that will assist paralysed individuals, such as interfaces with computers or robotic arms.[4,6,7]

Partially-invasive BMIs are implanted inside the skull or the spine but outside the Central Nervous System. These are less effective than invasive BMIs, but have the benefit of a lower risk of tissue damage. Electrocorticography (ECoG) is a method that has been used in the investigation of patients suffering from severe epilepsy, where the ECoG implant proved to be easy to control, requires minimal training on the patient, and keeps a satisfactory level of signals. Spinal cord stimulation used to treat intractable pain also involves the insertion of electrodes extradurally over the spinal cord and is another example of a partially-invasive BMI.

Non-invasive BMIs have been used to power muscle implants and restore partial movement. They are easily used, but produce poor signal resolution, as the skull dampens the signals and therefore interferes with the electromagnetic waves created by the neurons. Electroencephalography (EEG) is the most studied potential non-invasive BMI and has been used to enable epileptic patients to prevent impending epileptic fits by control over a computer cursor, as well as to allow paralysed patients to communicate through a computer.

Should BMIs be used in medicine?

The benefits of using BMIs, whether invasive, partially- or non-invasive, can grant medicine a leap forward. Through BMIs, neuroscience has made considerable progress in treating a number of diseases and conditions that continue to trouble humanity today. Cochlear implants have been used to treat patients whose auditory nerve is damaged; retinal implants have been used to treat acquired blindness; BMI-based motor prostheses have been used in patients with epilepsy or paralysis, through the control of an artificial limb; deep brain stimulation has been used to treat patients with Parkinson's disease who have motor complications secondary to medication and spinal cord stimulation is used for treatment of intractable pain.[3]

One must not eliminate, however, the adverse side effects that have been observed during BMI experimentation, such as neuronal damage during electrode insertion or scar-tissue formation in the brain with the application of invasive BMIs, and the potential for nervous system and psychiatric disorders. In Parkinson's disease, for example, stimulation at certain targets has been thought to increase the risk of suicide.[11] On the other hand, careful analysis has shown that the suicide may be more related to unrecognised active psychiatric disease or postoperative management rather than the effect of the stimulation itself. Partially-invasive BMIs can be used more safely, since these do not cause direct tissue damage to the central nervous system. At any rate, science could never progress without experimentation, and this inevitably sometimes entails unwanted adverse side effects. In medicine, the extent to which experimentation can proceed while producing adverse side effects surely must be controlled. This, in turn, amounts to the (currently lacking) *limits* that must be legally cemented regarding the use of BMIs.

How should BMIs be used?

In other words, the use of BMIs must be legally framed. At this point, we must turn our attention to the fact that BMIs can be used either for *medical treatment*, which has hitherto been discussed, or for *enhancement* of a "normal" ability or condition.

Regarding medical treatment, no legislation is in place to safeguard the informed consent of the patients before a BMI is used in their therapy, nor is there a guarantee for the protection of their personal data during the use of a BMI. There lacks a protocol to guide the application of BMIs in humans, even in animals (not forgetting animal rights). These are serious ethical concerns and could have severe social implications if not dealt with adequately.

Steps have been made so that BMIs be used not just for therapy, but also for human enhancement. A strong case is the United States military, which has begun to explore the possibility of using BMIs to enhance troop performance, as well as a possible development by adversaries.[10] The *abuse* of BMIs would potentially trigger an indefinite series of BMI exploitations by various parties in order to serve purposes that are in essence *unethical*. One might argue that using BMIs for military troop enhancement is unethical because it would make a war unjust. What war is just? Whether a war is just or unjust, ethical or unethical, does not concern us here. What should, however, be held in clear view is that *antagonism* is embedded in human behaviour, especially seen in the struggle for power and domination that has characterised the human species ever since recorded history can help us remember. Given the opportunity to use BMIs freely, the antagonistic human will most probably *abuse* it to serve purposes that in the long run could threaten his own species.

Another view is that it is unethical to use BMIs for the enhancement of troop performance because this means disrespecting the limits of nature; that "playing God" will eventually backfire, is an argument often used against the *abuse* of genetic engineering, otherwise considered a great scientific advancement, because the extent of the adverse side effects could be very distressing and is, in fact, *unknown*.

BMI experimentation has revealed the ability to modify behaviour, such as in the case of depression or Tourette's

syndrome.[1,8] On another occasion, a neurochip has been designed to function as an artificial hippocampus –hippocampus being the area of the brain designed to encode experiences for storage as long-term memories elsewhere in the brain.[9] With sufficient progress in this area, it is ethically disputable that BMIs should be used for anything other than therapy –and that with the appropriate legal framework in place.

In other words: There are some issues where there is, or should be, no room for risk-taking. Such are those where the risk of losing *what makes us human* is prominent –such as genetic engineering, or – in neuroengineering – the use of BMIs for anything but therapy. BMIs promise an ability to progressively control the human body in terms of mobility, eyesight, hearing, even behaviour. Human antagonism, coupled with an unrestrained use of BMIs, could incur consequences that could prove critical for the stability of the human society and, ultimately, for the human species as a whole. Compared with other methods used to enhance the human body and brain, such as gene manipulation and pharmacological manipulation (doping), the potential dangers associated with BMI-related enhancement are still complicated and unclear.[4,12] The extent to which the use of BMIs, especially for purposes other than medical therapy, could in the long run harm instead of benefit human life is *unknown* and the risk of discovering this when it is too late, is too great to take.

Furthermore, the uncontrolled use of BMIs threatens not only the 'unwritten' social norms, but also the 'written' laws in criminal justice. *Mens rea* is a criminal law concept requiring proof that the mental state of the accused was such that s/he committed the crime purposely, knowingly, recklessly or negligently. If BMIs promise to control higher mental functions such as attention, memory, choice, even consciousness, then the accused in court could easily escape conviction simply by appealing to the causality of the brain. In other words, the accused will claim that the brain is a causal machine and that s/he had neither a choice about the matter, hence nor any responsibility of her or his criminal actions.[2,5]

Yet it is *the legal system* that should contain the use of BMIs for therapeutic purposes. A legal framework must be put in place so as to control the extent to which adverse side effects in BMI-treated patients are acceptable; to safeguard patients' right to be informed and to protect their personal data; to protect the rights of the animals used in experimentation; to prevent the (ab)use of BMIs for purposes of enhancement, potentially leading to consequences that carry the risk of destroying much of what currently holds the human society and characterises the human species; and to pre-empt the possibility of a mockery of the criminal justice system. The concerns surrounding these issues make the use of BMIs the greatest ethical challenge that neuroscience faces today.

Further philosophical considerations

The general debate around BMIs raises questions about the ethical implications that arise, as well as about how neuroscience could threaten what makes us human. Considering the promises that BMIs hold, from controlling thoughts and desires, to voluntary mobility, one can't help asking "how robotic can we be before we stop being human?" If volition, in its widest sense of wanting or choosing to act or behave in a certain way, can be controlled by machines, then causality leaves little room for free will.

Ethically, this leads us to the imperative conclusion that the use of BMIs should urgently be legally contained, so as to avoid the risk of discovering precisely where the limits of humanity lie – viz. so as to avoid the incurrence of irreversible consequences, destructive for the human social and legal arrangement and for the course of the human species as a whole.

On a deeper philosophical level, by "robotising" human volition or behaviour, real-life BMIs inevitably renew the philosophical internalist–externalist argument, suggesting evidence of the existence of the external world (the world surrounding oneself) and thus challenging the classic Cartesian argument that holds possible only the knowledge that *I* exist, but not that the world around me does, too.

Just as ethics holds the social role of guiding legislation, so neuroethics holds the role of guiding legislation regarding neuroscience. An attempt has been made in this paper to argue for the use of BMIs for medical treatment but not for enhancement, and for legally securing that this is done in the most socially sensible way possible.

REFERENCES

1. Ackermans L, Temel Y, Visser-Vandewalle V. Deep brain stimulation in Tourette's syndrome. *Neurotherapeutics* 2008;**5**(2):339–44.
2. Churchland P. *Brain-based values*. American Scientist, http://www.americanscientist.org/bookshelf/pub/brain-based-values; 2005.
3. Clausen J. Man, machine and in between. *Nature* 2009;**457**(7233):1080–1.
4. Fukushi T, Sakura O, Koizumi H. Ethical considerations of neuroscience research: the perspectives on neuroethics in Japan. *Neurosci Res* 2007;**57**:10–6.
5. Gazzaniga M. *The ethical brain*. Dana Press; 2005.
6. Haida M, Shinohara Y, Ito Y, Yamamoto T, Kawaguchi F, Koizumi H. Brain function of an ALS patient in complete locked-in state by using optical topography. In: Koizumi H, editor. *The frontier of mind-brain science and its practical applications (II)*. Tokyo: Hitachi Ltd; 2000. p. 95–7.
7. Hochberg L, Serruya M, Friehs G, Mukand J, Saleh M, Caplan A, et al. Neuronal ensemble control of prosthetic devices by a human with tetraplegia. *Nature* 2006;**442**(7099):164–71.
8. Lozano AM, Mayberg HS, Giacobbe P, Hamani C, Craddock RC, Kennedy SH. Subcallosal cingulate gyrus deep brain stimulation for treatment-resistant depression. *Biol Psychiatry* 2008;**64**(6):461–7.
9. Sandhana L. Chips coming to a brain near you. Wired.com, http://www.wired.com/medtech/health/news/2004/10/65422; 2004.
10. Shachtman N. Top Pentagon scientists fear brain-modified foes. Wired.com, http://blog.wired.com/defense/2008/06/jason-warns-of.html; 2008.
11. Soulas T, Gurruchaga JM, Palfi S, Cesaro P, Nguyen JP, Fénelon G. Attempted and completed suicides after subthalamic nucleus stimulation for Parkinson's disease. *J Neurol Neurosurg Psychiatry* 2008;**79**(8):952–4.
12. Talwar SK, Xu S, Hawley ES, Weiss SA, Moxon KA, Chapin JK. Rat navigation guided by remote control. *Nature* 2002;**417**(6884):37–8.