

総 説

The ethical and philosophical issues concerning the clinical
application of brain-machine interface technology:
from the perspective of rehabilitation medicine

ブレインマシンインターフェイス技術の臨床応用における
倫理的、哲学的問題について
ーリハビリテーション医療の視点からー

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抄 録

本論文の目的は、リハビリテーション医療におけるブレインマシンインターフェイス技術の適用に関する倫理的、哲学的問題について考察することである。今回は特に以下の3点について議論する。1. ブレインマシンインターフェイス技術の医療への応用に対する条件について、2. ニューロ・エンハンスメント（神経増強技術）における倫理的、哲学的問題について、3. ブレインマシンインターフェイス技術が個人のアイデンティティを変容させてしまうことへの危惧について。

ブレインマシンインターフェイス技術により生じる身体の変容は、自分自身の身体に対する私たち認識を覆す可能性を秘めている。もし私たちの社会がBMI技術を受け入れるのであれば、既存の人間観、すなわち自由で自律的な近代的自我としての人間観の変容も受け入れるという心の準備が必要であろう。医療の歴史が人類の文化の歴史と同じくらい長いという事実を考えれば、本論で提起された諸問題は、歴史的、文化的、そして社会的文脈のなかで、それぞれの国による継続的な検討が必要であると考ええる。

Abstract

Purpose : This study examines the ethical and philosophical issues concerning the introduction of BMI technology in rehabilitation medicine. In particular, the following three points are discussed. 1. Conditions for application of BMI technology to medical treatment. 2. Ethical and philosophical issues of “Neuro-enhancement”. 3. A fear of BMI technology changing one’s identity. Conclusion: Bodily transformation because of BMI technology will disrupt our understanding of the body as one’s own. If our society accepts BMI technology, we need to be prepared to accept the changing view of what a human being is (i.e., the change of the modern self as a free and autonomous agent). Considering the fact that the history of medical care is as long as the history of human culture, this paper raised various issues that require further examination in the historical, cultural, and social contexts in each country.

キーワード：ブレインマシンインターフェイス技術、倫理的、哲学的問題、リハビリテーション医療、ニューロ・エンハンスメント

Key words : BMI technology, the ethical and philosophical issues, rehabilitation medicine, Neuro-enhancement.

Introduction

The brain-machine interface (BMI) or brain-computer interface (BCI) that utilizes both neuroscience and information communications technology is now being used in the medical field. Hammad et al¹⁾ previously showed that a BCI “aims to restore functional movements in subjects with neuromuscular disorders by interpreting neural signals recorded from the brain and translating the inferred information into control signals for external devices such as a prosthetic limb or to guide electrical stimulation of the patient’s own limbs.” Daly et al²⁾ mentions that “BCI technology might also restore more effective motor control to people after stroke or other traumatic brain disorders by helping to guide activity-dependent brain plasticity by use of EEG brain signals to indicate to the patient the current state of brain activity.” This technology may prove to be a useful rehabilitation tool for patients with severe disabilities, and the number of studies on this has increased.³⁻⁷⁾ At the same time, some ethical and philosophical issues concerning a direct connection between the brain and machines have been raised.⁸⁻⁹⁾ For example, there is the risk of invasion to the brain, whether to permit the use of medical technology for enhancing a condition beyond the normal condition, the invasion of privacy due to mind-reading and the potential for the collapse of the general concept of an individual that is autonomous and self-determined. These issues highlight the importance of examining the influence of BMI technology on human society. More specifically, it is vitally important to consider beforehand the potential of BMI technology to impose an undesired influence on humans. Based on the above, this study examines the ethical and philosophical issues concerning the introduction of BMI technology in rehabilitation medicine. In particular, the following three points are discussed.

1. Conditions for application of BMI technology to medical treatment.
2. Ethical and philosophical issues of “Neuro-enhancement”.
3. A fear of BMI technology changing one’s identity.

The goal of this paper is not to provide answers but to raise our intelligence by examining complex issues.

1. Conditions for application of BMI technology to medical treatment

It is necessary to weigh the benefits and risks of introducing a new technology in clinical situations. Clinical trials that measure effects are necessary to demonstrate the benefits of short-term and future uses of BMI technology. However, it is difficult to judge objectively the benefits and risks of BMI technology because this technology aims to treat the brain, which is directly linked to the human mind. Furthermore, in clinical trials of applying BMI technology in rehabilitation medicine, the level of patients’ cooperation may affect the treatment outcome. In fact, many studies have shown that improvement of motor function is influenced by the degree of concentration on the therapy by the patient or the level of motor imagery.¹⁰⁻¹²⁾ However, Mulder¹³⁾ reported that the effects of motor imagery differ according to not only individual ability to mentally simulate the action, but also the cooperation and concentration of the learner. More generally, biomedical research related to physiological reactions caused by the intake of drugs excludes the subjectivity of the patient from the experiment. The determination that a new medicine is more effective than a conventional medicine is validated according to the hypothetical model, and high reliability is determined by double-blind randomized controlled trials. On the other hand, when measuring the

effect of applying BMI technology for the treatment of stroke, it is necessary to clarify the process of neuronal network reconstruction caused by conscious body movement. Moreover, it may be necessary to verify whether the therapy can cause favorable changes in the connections of neurons and synapses, in the quantity of the neurotransmitters, and in the properties of receptors. Accordingly, so long as the treatment outcome is influenced by the level of patients' cooperation, it is difficult to determine the scientific validity for BMI technology in rehabilitation medicine.*¹

Some reports show that electrical potentials such as the mu rhythm¹⁴⁾ or P300¹⁵⁾ that are detected from the scalp or cortical surface can be used in rehabilitation medicine. It is well known that the mu rhythm is suppressed when one performs or visualizes performing a motor action. Dobkin¹⁶⁾ pointed out that "therapists could use the change in the mu rhythm to get immediate feedback about whether a subject is optimally prepared to make a movement and has focused his motor attention." Even if this feedback may enhance the presynaptic drive to a cell population and network that patients use to plan the trajectory of the foot for walking, which in turn may increase motor output and improve the timing and completeness of movements¹⁶⁾, the effect may depend on the patient's motor attention. Consequently, compared with the method for determining the effect of a new medicine, it is very difficult to verify the treatment outcome reflected in the patient's mental condition.*¹ In this situation, should patients choose the invasive BMI technique over other therapy?

Standard clinical treatments do not provide any guarantees for identical outcomes because physical or mental conditions differ between individual patients. There is no indication that invasive treatments of the brain, such as the BMI technique, would be any different. Furthermore, evidence obtained by medical workers or researchers is required to apply BMI technology to standard treatment in rehabilitation medicine.*² Here, it should be noted that advanced technology always introduces uncertainty, and

BMI technology should be considered from the perspective of not only scientific validity but also from an ethical or moral standpoint.

2. Ethical and philosophical issues of "Neuro-enhancement"

'Beyond Therapy : Biotechnology and the Pursuit of Happiness' by The President's Council on Bioethics was published in 2003.¹⁷⁾ This report defines therapy as bringing a condition back to normal, and "beyond therapy" as enhancing a condition beyond normal. However, the realm of biotechnological beyond therapy is a hard-to-define gray zone where ethical judgments are difficult. Chaotic discussions have focused on having better children, superior performance, ageless bodies, and happier souls. The report says that the vast majority of council members feel that beyond therapy should be approached cautiously and that some believe this type of therapy should be regulated. Some people are trying to use genetic manipulation, nanotechnology, and robotics to improve humans after birth, and they insist that society should not be limiting the pursuit of happiness via the use of transhumanist technology. The technology itself is said to be 'value-neutral' because the value judgment of it being right or wrong depends on the social context. Generally, scientists tend to seek the highest degree of technological development. Therefore, the technological developments that sufficiently enhance functions may spread throughout society. Many ethical issues have to be solved if someone motivated by desires for sensual pleasures makes use of biotechnology. An individual could also attempt to gain superior strength or performance, like the 'Hulk' . However, from a moral perspective, if they have a greater ability to do heavy work compared to others, they will never be highly appreciated. Moreover, it is expected that this technology would not become commonplace in society. Taking this into consideration, if the use of biotechnology or BMI technology is regulated, it will be necessary to adjust the regulations based on the intended target of the therapy. Nevertheless, the differences between

therapy and enhancement seem to have been blurred. To clarify the difference between the two, it is essential to answer questions such as 'What is the desirable normal condition?' or 'Is the deviation from a healthy or normal condition simply because of a disease?' If stroke patients are given functions superior to those of healthy elderly individuals of the same age by BMI technology, should it be considered beyond therapy?

Jotterand⁹⁾ indicated that "the question I address is not whether attaching artificial limbs or enhancing particular traits or capacities would dehumanize or undignify persons but whether nonbiological entities introduced into or attached to the human body contribute to the "augmentation" of human dignity." Whether or not we can use BMI technology depends on the augmentation of human dignity, and discussions about human dignity and posthuman dignity are essential.^{*3} When examining the issue of enhancement or neuroethics, an important consideration is that there is no simple solution to this complex problem. Considering that health and disease are socially constructed concepts, the concepts of normal and abnormal are also similarly constructed. Thus, the individual desire to become stronger and faster reflects a sense of values and the state of society. Notably, a society's values become a kind of pressure, and there is the risk that an individual's freedom to choose a therapy becomes restricted. That is to say, in a society in which it is common to use BMI technology for treatments, people may be unable to choose an alternative therapy. Moreover, the problem of enhancement by BMI technology can include enhancing a function that is desirable, as well as excluding an undesirable function, such as treatment to remove a specific state of mind by electric stimulation of the brain. If BMI technology eventually becomes mainstream, is it an oversimplification that a single misstep could give rise to eugenics? Thus, in the case where BMI technology is applied, it is necessary to obtain a social agreement about 'What is normal?' or 'What is an acceptable range of therapeutic applications?'

3. A fear of BMI technology changing one's identity

BMI technology that assists with defects in motor function is used as an example in this section to consider identity crises and human nature. These technologies are broadly classified into two types: invasive and noninvasive. The invasive type includes implanting multiple electrodes in the brain, and the noninvasive type involves detecting a weak biosignal from the surface of the skin. The extracted signals are electrically connected to the joint and limbs via a machine to provide aid for easily moving the hands or feet. These technologies are expected to function as an effective treatment in clinical applications, and when established, could lead to serious ethical issues, such as the uncertainty of body ownership; in other words, the collapse of the sense that the body is one's own. Humans grow emotionally or mature through physical states or experiences throughout their lifetime. The body is a place where one's emotions exist; the human body can even be said to be the organ of emotion. Moreover, we not only have explicit knowledge, such as verbalized information, but embodied knowledge, such as a way of moving the body based on the internalization of physical experiences.^{*4} A lack of embodied knowledge means that a smooth daily life or social life is difficult because there is a close relationship between mind and body. Accordingly, the sense of body is an important requirement for developing rich emotions and acquiring embodied knowledge. Our anthropocentric view of the world may be greatly influenced by bodily changes induced by cyborgization that changes our emotions or personality.

Here, we consider the reaching motion exercise of amputees by a robotic arm using BMI technology as an example. First, a brain signal related to the reaching motion must be converted to a mechanical signal by a machine, and an amputee must perceive the motor information feedback from the robotic arm. This feedback information must be converted to vital signs. It is necessary to understand how this kind of interaction between the human body and a robotic arm is comprehended, as it is completely different

from a normal biological phenomenon. Thus, when the amputees lift something with the robotic arm, they will probably feel a new mental representation. Amputees are then forced to change their body image. A constructed social relationship through embodied interaction by humans is also expected to change similarly. When amputees become able to control the robotic arm the same way as their own body due to advances in technology, there could be philosophical issues such as ‘Who am I?’ or ‘What is my body?’ Even Descartes, well known for his concept of methodological doubt, i.e., a method of doubting everything that exists for the pursuit of truth, never doubted that the body is one’s own. However, bodily transformation because of BMI technology will disrupt our understanding of the body as one’s own. These points indicate blurring of the boundary between nonbiological artifacts and humans.

The Japan Science and Technology Agency has succeeded in moving a humanoid robot via data that is detected from cortical brain activity in a monkey and transmitted through an internet interface between the U.S.A. and Japan in real time¹⁸⁾. This monkey essentially has another body at the remote location. In other words, the individual is separated, thus, jeopardizing the sense of identity. An identity crisis arises in organ transplant patients, who, as recipients, are given an organ from a donor; BMI technology may also lead to the same problem.^{*5} The success of this experiment¹⁸⁾ means the conventional concept of human embodiment, that one brain controls one body, begins to weaken. Thus, our understanding of the individuality of human beings is not absolute. The externalization of brain function based on a direct connection between the brain and a machine raises abstruse philosophical issues, such as ‘What defines a human being?’ or ‘What defines the human brain activity of the identical personality?’ If our society accepts BMI technology, we need to be prepared to accept the changing view of what a human being is (i.e., the change of the modern self as a free and autonomous agent).

Conclusion

Ethical and philosophical issues from three perspectives were discussed in light of the future prevalence of BMI technology in rehabilitation medicine. When discussing these issues, both the benefits and risks of BMI technology should be considered. Because the discourse itself about the risks of BMI technology acts as a social pressure, there is a possibility of undermining the benefits to patients who need this technology. Paraphrasing Baron¹⁹⁾, technological achievement is not a great invention in itself; its importance depends on what it means for humans and how it will alleviate sickness-related pain. Therefore, we have to consider the social and cultural perspective of happiness for all humankind in technological development.^{*6} In a report on introducing a caregiver robot into nursing care institutions, nearly 40% of respondents replied that ‘facility users and their families are eager for manual care and they will not accept care by machine.’²⁰⁾ Although it will be appreciated, new technology will not immediately be fully accepted by the social community. Current problems include how to introduce BMI technology into daily life and whether it will be naturally accepted by many people. Considering the fact that the history of medical care is as long as the history of human culture, this paper raised various issues that require further examination in historical, cultural, and social contexts in each country.^{*7}

Notes

***1 :** As pointed out earlier, the main aim of rehabilitation medicine is to restore physical abilities lost to injury or disease in order to function in a normal or near-normal way. Therefore, it is difficult to evaluate quantitatively the efficacy of rehabilitation treatment. Moreover, cognitive ability or motor attention influences the therapeutic effect. However, the advent of positron emission tomography, functional magnetic resonance imaging, and transcranial magnetic stimulation as noninvasive evaluation methods through the development of medical electronics enabled observation of cerebral

nerve activity that was once difficult to detect. I hope that progressive use of these devices contributes to assessment of the treatment effect of rehabilitation medicine in the future.

*2 : Clinical practice guidelines for the use of BMI technology will likely be prepared through the accumulation of case reports. To accomplish this, healthcare practitioners need to report what was diagnosed, the clinical manifestation, any medical treatment, the treatment period and clinical outcomes. A report on a person's mental and psychological status is especially important. When a change in human nature is suspected of resulting from treatment utilizing BMI technology, it is necessary to re-examine the validity of this treatment method.

*3 : It is difficult to establish a common definition of "human dignity" because of the differences in thoughts and religions between periods and regions. However, any consideration of human dignity must consider the following points. From a moral perspective regarding human dignity, the externalization of brain function based on a direct connection between the brain and a machine should not be done. However, what are the moral obligations if a patient's pain can be relieved by BMI technology? Thus, we cannot simply say that use of BMI technology is still immoral. The alleviation of a patient's pain by BMI technology would be vital in maintaining human dignity. This is a difficult problem that cannot be solved immediately. For details, see Jotterand's report.⁹⁾

*4 : The body is a very important medium through which to recognize the external world. According to M. Merleau-Ponty's phenomenological thought on body²¹⁾, the human body functions as a medium in which one takes recognition of the actual world by the reciprocity between body and the environment. For example, it's not that children know the concept 'chair' by learning the linguistic definition of a 'chair', it's just that they already knew about it through the physical act of 'sitting in the chair'. Therefore, the transformed body will almost certainly recognize the external world differently.

*5 : Recipients of organs transplanted from donors have suffered from identity crises, such as not being able to "feel" their own organ and having their identity jeopardized. Through experiences of heart transplantation, French philosopher Jean-Luc Nancy²²⁾ came to feel, "In me there is the intruder, and I become foreign to myself", and he philosophized about what the subject is. BMI technology is none other than the intervention by 'what others call scientific technology' to the brain as an important organ of human intelligence or memory. Therefore, the possibility that BMI technology will lead to an identity crisis cannot be ruled out. Considering the sense of 'I' being nothing but 'I' supported by my memory, rewriting this memory by BMI technology could cause serious issues, such as "Who is the subject?" We must be prepared to deal with the issues surrounding technological intervention in the brain.

*6 : Does BMI technology contribute to human happiness or well-being? Deep brain stimulation is currently being explored as a treatment for psychiatric disorders, such as major depression. If this treatment using electrical impulses can make patients happier, we wonder if this truly contributes to well-being. In a thought experiment known as the Experience Machine (a machine for realizing experience as desired), Robert Nozick²³⁾ says well-being is not only constituted by mental states but also by living in contact with reality. According to Nozick, people would not want to obtain happy feelings using the Experience Machine, they would want to make decisions about their life in the real world. From this perspective, if self-identity changes depending on the BMI technology, complex issues such as 'What part of me is making the decisions?' or 'Does achieving well-being mean changing my identity?' may arise. For more information, see Schermer's report.⁸⁾

*7 : We must consider peaceful uses of BMI technology. Particularly, BMI technology shall not be used for war or crime, nor shall it be used for mindreading or mind control. Countermeasures to prevent misuse of BMI technology will be

needed. Three fundamental rules concerning the development and use of nuclear power will probably be a good reference for establishing these countermeasures. However, because brain function has not been studied sufficiently, formulation of a code of ethics and code of conduct will be difficult. Nuclear weapons may bring about the annihilation of man. On the other hand, BMI technology may dehumanize people. We expect discussion to proceed with due consideration toward differences between nuclear power and BMI technology.

References

- 1) Hammad SH, Farina D, Kamavuako EN, Jensen W: Identification of a self-paced hitting task in freely moving rats based on adaptive spike detection from multi-unit M1 cortical signals. *Front Neuroeng.* 2013 Nov 15 ; 6 : 11. doi : 10.3389/fneng. 2013. 00011. eCollection 2013. PMID : 24298254 [PubMed] PMCID : PMC3828672
- 2) Daly JJ, Wolpaw JR: Brain-computer interfaces in neurological rehabilitation. *Lancet Neurol.* 2008, 7 : 1032-1043.
- 3) Schwartz AB, Cui XT, Weber DJ, Moran DW : Brain-controlled interfaces: movement restoration with neural prosthetics. *Neuron.* 2006, 52 : 205-220.
- 4) Hochberg LR, Serruya MD, Friehs GM, Mukand JA, Saleh M, Caplan AH, Branner A, Chen D, Penn RD, Donoghue JP: Neuronal ensemble control of prosthetic devices by a human with tetraplegia. *Nature.* 2006, 442 : 164-171.
- 5) Velliste M, Perel S, Spalding MC, Whitford AS, Schwartz AB : Cortical control of a prosthetic arm for self-feeding. *Nature.* 2008, 453 : 1098-1101.
- 6) Mayaud L, Congedo M, Van Laghenhove A, Orlikowski D, Figère M, Azabou E, Cheliout-Heraut F : A comparison of recording modalities of P300 event-related potentials (ERP) for brain-computer interface (BCI) paradigm. *Neurophysiol Clin.* 2013, 43(4) : 217-27.
- 7) Rea M, Rana M, Lugato N, Terekhin P, Gizzi L, Brötz D, Fallgatter A, Birbaumer N, Sitaram R, Caria A : Lower Limb Movement Preparation in Chronic Stroke : A Pilot Study Toward an fNIRS-BCI for Gait Rehabilitation. *Neurorehabil Neural Repair.* 2014 Jan 30. [Epub ahead of print] PMID : 24482298 [PubMed - as supplied by publisher]
- 8) Schermer M : Health, happiness and human enhancement-dealing with unexpected effects of deep brain stimulation. *Neuroethics.* 2013, 6 : 435-445.
- 9) Jotterand F: Human dignity and transhumanism: do anthro-technological devices have moral status? *Am J Bioeth.* 2010, 10(7) : 45-52.
- 10) Page SJ, Levine P, Sisto S, Johnston MV : A randomized efficacy and feasibility study of imagery in acute stroke. *Clin Rehabil.* 2001, 15(3) : 233-40.
- 11) Crosbie JH, McDonough SM, Gilmore DH, Wiggam MI: The adjunctive role of mental practice in the rehabilitation of the upper limb after hemiplegic stroke : a pilot study. *Clin Rehabil.* 2004, 18(1) : 60-8.
- 12) Dunskey A, Dickstein R, Marcovitz E, Levy S, Deutsch JE: Home-based motor imagery training for gait rehabilitation of people with chronic poststroke hemiparesis. *Arch Phys Med Rehabil.* 2008, 89(8) : 1580-8.
- 13) Mulder T: Motor imagery and action observation : cognitive tools for rehabilitation. *J Neural Transm.* 2007, 114(10) : 1265-78.
- 14) Wolpaw JR, McFarland DJ : Control of a two-dimensional movement signal by a noninvasive brain-computer interface in humans. *Proc Natl Acad Sci U S A.* 2004, 101(51) : 17849-54.
- 15) Sellers EW, Donchin E: A P300-based brain-computer interface: initial tests by ALS patients. *Clin Neurophysiol.* 2006, 117(3) : 538-48.
- 16) Dobkin BH: Brain-computer interface technology as a tool to augment plasticity and outcomes for neurological rehabilitation. *J Physiol.* 2007, 15: 637-42.
- 17) Kass LR: Beyond Therapy: Biotechnology and the Pursuit of Happiness, New York, Harper

Perennial, 2003.

- 18) JST Press Release [Internet]. World's First Bipedal Locomotion with a Humanoid Robot Controlled by Cortical Ensemble Activity with a Real-time Network Brain Interface. [cited 2013 Oct 20];
Available from : http://www.jst.go.jp/pr/info/info461/index_e.html
- 19) Baron R : An introduction to medical phenomenology : I can't hear you while I'm listening. *Annals of Internal Medicine*. 1985, 163 : 606-611.
- 20) Ministry of Health, Labour and Welfare, The Association for Technical Aids [Internet]. [cited 2013 Oct 25];
Available from: <http://www.techno-aids.or.jp/robo2012.05.28.pdf> (In Japanese).
- 21) Merleau-Ponty M : *Phenomenology of perception* (C.Smith, Trans), London, Routledge, 1962.
- 22) Jean-Luc Nancy : *L'Intrus* (S.Hanson, Trans), *The New Centennial Review*. 2002, 2(3) : 1-14.
- 23) Nozick R: *Anarchy, State, and Utopia*, Basic Books, 1977.