THE ETHICAL ASPECTS OF A "PSYCHOKINESIS MACHINE": AN EXPERIMENTAL SURVEY ON THE USE OF A BRAIN-MACHINE INTERFACE

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ABSTRACT

A brain-machine interface (BMI), one of the emerging cyborg devices, processes signals acquired from a human brain and translate them into a meaningful output in accordance with a given purpose such as operating a machine remotely. In this respect, a BMI system can function as a psychokinesis mechanism. This system can widely be utilised for various purposes including for enhancing healthy people's intellectual and/or physical abilities. However, ethical and social issues concerning such technology use have not been fully examined. This study aims at investigating these issues. To attain the aim, the authors constructed a simple experimental environment where a non-invasive wearable BMI device was put on the head of a healthy person as a subject of the experiment to operate a robotic arm remotely or without touching it. The interview surveys were conducted with subjects before, during, and after the experiments, to investigate their attitudes to BMI usage, feelings of robotic arm operation and ethical awareness of brain signal collection by the BMI device. The results of the surveys revealed their attitudes to and ethical concern about the BMI use and suggested research agenda for the future.

KEYWORDS: brain-machine interface, cyborg, privacy, responsibility.

1. INTRODUCTION

Owing to the development and increasing use of cyborg devices such as smart glasses, smart watches, powered exoskeletons and RFID chips in various fields including of medicine, education, commerce and sports, the cyborgisation of human beings is being accelerated. The cyborg devices can extend human intellectual and physical abilities, thus they are expected to assist those with congenital and/or acquired disabilities. Among them, a brain-machine interface (BMI), or a brain-computer interface (BCI), has recently attracted attention. Most BMI systems consist of four sequential components: signal acquisition, feature extraction, feature translation and classification output (Rupp et al., 2014). Based on these components, a BMI enables communication between a human brain and external devices through sending signals from the brain to devices and vice versa using dedicated hardware and software. According to the results of a survey conducted by Nijboer et al. (2013), people involved in BCIs tend to consider that BCI systems 'measure signals from the central nervous system and

"translate" those signals into output signals' (p.545). As their study suggests, BMI systems process signals acquired from a human brain and translate them into a meaningful output in accordance with given purposes such as remotely operating a machine or sending messages over a long distance. In this respect, a BMI system can function as a psychokinesis or telepathy machine.

Non-invasive wearable BMI devices have been used for medical or rehabilitation purposes. In this case, typically, patients' brain signals are collected by BMI hardware such as an electroencephalograph (EEG) and are processed by a dedicated BMI software application to operate devices remotely or in a non-contact manner just by setting their intention to do so. Thanks to such a BMI system, for example, those who could not move their bodies at will successfully worked as waiters in a coffee shop by remotely operating humanoid robots; during this process, the wearable BMI devices were non-invasively connected to their brains (Ory Labo). So far, BMI devices and systems have been proposed to be used for other purposes than medical one, such as for gaming (Nijholt et al, 2009; Nijholt , 2008) and marketing (Guger et al., 2014).

BMI use for a wider range of purposes may exert a substantial influence over individuals, organisations and society as a whole. However, ethical and social issues regarding the social penetration of BMI systems have not been fully discussed. The BMI research to date has tended to focus on the operability, functionality and/or usability of BMI devices or the effectiveness of the BMI system for medical treatment or rehabilitation. In addition, there are fundamental problems in predicting and evaluating the social risks or ethical issues relating to BMI usage, because such technology has not been used by healthy people in daily-life settings. Healthy people do not usually recognise the necessity for such technology, thus it is unlikely that the use of wearable or implantable BMI will be used by many of healthy people in the future. One way to investigate the ethical and social aspects of BMI usage in a wider context is to conduct an experimental survey of healthy people's using BMI devices.

To adopt this way, the authors constructed a simple experimental environment where a non-invasive wearable BMI device was used by a healthy person as a subject of the experiment. He/she was asked to operate a robotic arm connected to the BMI device, which was put on his/her head, without using any part of his/her body. Interviews with data subjects were conducted, before, during and after experiments, to examine their attitudes to BMI device usage, feelings of robotic arm operation and ethical awareness of brain signal collection by the BMI device. Interview questions were prepared based on the results of the authors' previous studies (Murata et al., 2019; Murata et al., 2018; Murata et al., 2017; Isobe, 2013).

2. ETHICAL QUESTIONS ON THE USE OF BMI

While most of existing studies on BMIs have focused on their clinical or rehabilitation use, some researchers have discussed the ethical issues surrounding BMI use (e.g. Kansaku, 2013; Schermer, 2009). They conducted questionnaire and interview surveys concerning ethical evaluation on the development and use of BMIs, most respondents to which were medical or rehabilitation professionals and patients using BMI devices (e.g. Gilbert, 2019; Nijboer et al., 2013; Isobe, 2013). However, only a few surveys of healthy people, who are neither experts nor professionals in relevant fields, concerning their attitudes to BMI usage have been conducted. Given that BMIs will soon be used in society for a broader range of purposes, the ethical issues and social risks caused by its usage should be examined in a proactive manner taking socio-cultural and economic contexts around BMIs into account. To conduct this examination, the following questions, for example, may be raised.

- If a BMI system malfunctions contrary to its users' intentions, who is responsible for the malfunction? How can we decide who are responsible people or organisations?

- Should users' brain signals collected by BMI systems be protected as sensitive personal information?
- Is it socially or legally acceptable that brain signals obtained from individuals while their using BMI systems are utilised for not-initially-intended purposes? For example, is it acceptable that a BMI system is used as a lie detector, and, if that's the case, under what conditions?
- What benefits and risks do exist when BMI are used in a specific context?

In the near future, it is expected that implantable BMIs or BMI brain chips will become available. In that case, people may be required to decide whether they implant the chip in their brains, evaluating risks and benefits associated with the implantation and continuous use of the chip. In this regard, the following questions are also raised.

- Under what conditions is the implantation of a BMI chip into the brain – a very complex and not-well-known organ, which deeply relates to human dignity – justified?
- Should an equal opportunity in BMI chip implantation be guaranteed for all? Should the disabled be prioritised? Is the difference of opportunity between the rich and the poor acceptable?
- Should the autonomy of an individual's decision to become a cyborg using an implantable BMI be respected? Is it acceptable that an individual is forced to implant a BMI chip to play his/her social or professional role?
- How is an individual's self-recognition and self-identity transformed when an implantable BMI device is embedded in his/her brain? Should the mental transformation be cured, and how?

These ethical and social questions regarding the use of BMI chips should proactively be addressed to predict and avoid any subsequent and future risk. Based on the interests and concerns described thus far, this study attempts to examine how individuals feel about their enhanced abilities acquired by using a non-invasive BMI device in an experimental laboratory setting, as the first step toward responding the interests and concerns.

3. OVERVIEW OF THE BMI EXPERIMENT AND THE INTERVIEW SURVEY

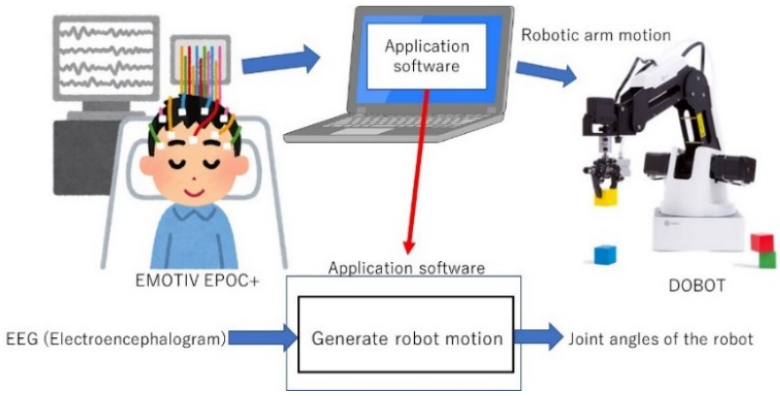
3.1. Outline of the experiment and the interview

An experimental environment was designed and set up to allow subjects of the experiment to control a robotic arm using only their brain signals. As shown in Figure 1, a non-invasive wearable BMI/EEG device (EMOTIV EPOC+), a robotic arm (DOBOT) and the dedicated application software were located in an experimental laboratory.

At the beginning of an experiment, the EEG device was put on a subject's head, which enabled to measure his/her brain signals. He/she was then invited to join the training process, where his/her brain signal data were collected and recorded by the EEG system. Brain signal data in two kinds of mental states – a 'relaxed state' and an 'in-operation state' – were collected. To acquire the data of a subject in the in-operation state of mind, he/she was required to imagine that he/she was pushing a small box displayed on the computer screen toward the back. The two kinds of data – the relax state data and

the in-operation state data – acquired in the training process were transmitted to and stored in the application software system installed in a personal computer, to which the EEC device is connected.

Figure 1. The experimental environment.



After completing the training process, a subject was asked to maintain his/her relax state of mind for a while, and then to intentionally move to the in-operation state with imagining he/she was pushing the robotic arm toward the back. When his/her brain signal patterns acquired at this time was similar to the in-operation state ones stored in the software system to a satisfactory extent, a robotic arm turned toward the back. During the experiment, a subject was required to conduct this several times. In addition, the experiment was designed so that a subject once experienced a preprogrammed robotic arm movement towards the near side when he/she asked to move to the in-operation state. This is intended for letting a subject experience malfunction of the BMI system.

Before, during and after the experiment, a subject was asked to grant semi-structured interviews prepared for it. Some interview questions were responded in written form at a later date. The interview sheet was designed so as to examine subjects' attitudes to and recognitions of their experience with the BMI system during the experiments, based on previous studies (e.g. Gilbert et al., 2019; Nijboer et al., 2013; Tamburrini, 2014; Isobe, 2013; Fukushi & Sakura, 2007). The interview questions pertained to: (a) privacy and personal data protection, (b) human autonomy and dignity, (c) identity development and personal transformation, (d) the acceptance of body extension in an individual and organisational context, (e) the workplace cyborgisation and (f) social responsibility and informed consent. The interview sheet was designed so that a subject could consider the benefits and risks associated with implantable BMI devices, though a non-invasive device was used in the experiment.

3.2. Survey participants

The surveys of five healthy undergraduate students, who majored in commercial science, were conducted in February 2020 at Meiji University, Tokyo. Their attributes, knowledge about a BMI, and expectation and anxiety about the experiments are shown in Table 1. Most subjects had known little about a BMI and all of them had positive feelings about the experiment rather than negative.

Each subject was informed of the purposes and methodology of this study and the contact information for enquiry in advance the experiment. In particular, based on the ethical policy adopted in this research, he/she was clearly notified that he/she had total say over whether to participate in this survey or not, and the experiment would never put him/her in a disadvantageous position. The

expected risks entailed in the experiment and the measures to prevent them were also explained. After offering the full explanations about the study, each subject was required to sign a consent form when they determined to participate in the experiment and the interviews.

Table 1. Experimental subjects (n = 5).

ID	Age	Gender	Have you ever heard about a BMI or are you familiar with a BMI?	Expectation/anxiety about the experiment (Weak 0 – Strong 7)
1	21	Female	I have heard only a little about it before in class.	5/1
2	22	Male	No, not at all.	6/1
3	21	Male	No. I have no idea what I'll do during the experiment.	5/3
4	21	Male	Yes. I have seen people with disabilities who operated a robotic arm on a TV programme.	6/3
5	21	Male	No, I have never heard about BMI, although I have heard about brain tech.	7/1

4. THE RESULTS OF INTERVIEW SURVEY

4.1. The feelings about the operability of the BMI system

The observed ease or difficulty in operating the robotic arm and the speed of operation varied among subjects. During the experiment, they were asked how they felt about the operation of the robotic arm using a BMI device. Their responses are summarised in Table 2.

Table 2. Feelings about the operation of the robotic arm using a BMI.

Q: Did you have a sense that you operated the robotic arm during the experiment?	
1	The robotic arm actually turned when just casting my eyes. I had little sense of my operating it. I felt that the robotic arm autonomously turned when something came into my field of vision during the time of my intensively imagining that I was pushing the robotic arm.
2	Toward the end of the experiment, I felt that my operation of the robotic arm became easier, although this feeling was not necessarily solid. In the beginning, the image of pressing the robotic arm in my mind was weak. The best tip I can give other participants is that the robotic arm turns when you become calm and empty your mind.
3	I had the sense that I was actually pushing the robotic arm. However, when my will to push became weaker accidentally, the robotic arm moved, so I felt frustrated. This robotic arm move was observed between my attempts to say 'move!' in my head. So, there was definitely a time lag between my attempt and the movement of the robotic arm.
4	From the third or fourth attempt, I gained the sense that I was actually operating the robotic arm. I tried to see the scene of the robotic arm's move in my mind, which I saw at the first or second attempt. When I recalled the scene with the sound at that time, the robotic arm actually started to move. In the beginning, I vaguely imagined the move of the arm. Through repeated attempts, I became able to visualise the specific image of how I operate the robotic arm.
5	I did not have the sense that I operated the robotic arm at all. The robotic arm moved at an unexpected time. This is strange. Actually, the robotic arm moved at the moment when I thought it would not move and my mental concentration became weak. It might move with a delay. Maybe, the robotic arm moves when I don't have a strong intention to push it toward the back. Intuitively, the robotic arm likes a perverse person, because it moves against other's will.

The interviews after the experiment provided the authors with interesting findings: after multiple operations, Subjects 1, 2 and 3 felt that their physical states related to robotic arm movement.

Subject 1: 'I don't know why the arm turned. The key to understand this may be my experience during the experiment that the arm didn't move unless I didn't make a motion of pushing something with my hands. If I had a lever or the like to operate the arm, I would have had a different feeling. But, in this experiment setting (where she could not operate the robotic arm physically), I still want to operate the arm with making that motion. I can't operate without doing so. Maybe, this is because I am a dancer.'

Subject 2: 'The robotic arm did not turn when I kept my eyes open. It moved immediately as I closed my eyes. This may be a just coincidence, but it's a fact that my attempts to push the arm in my head with closing my eyes worked.'

Subject 3: 'I think I could easily make the robotic arm in motion when my body wasn't tensed up or was rather relaxed. It became easier for me to operate it in the latter half of the experiment in which I took myself less seriously.'

4.2. Subjects' recognition of the intended malfunction of the BMI system

When the robotic arm moved in an unexpected way, how did they recognise this? Subjects' feelings about such a move, which were talked about during the experiment, are summarised in Table 3. All subjects considered that the movement of the arm, which pretended the malfunction of the BMI system, was their faults or due to their failure.

Table 3. Feelings about unexpected moves of the robotic arm.

Q: Why do you consider the robotic arm moved in an unexpected way?	
1	It's due to my changing the position of my hands. I didn't do anything else in particular. I think that when it moved toward the near side, so did my hands.
2	I highly concentrated my mind on pushing the arm, after attempting to pull it lightly in my head. I can guess this caused its strange movement. But, I cannot understand why. I don't think the robot made a mistake. I'm a little bit confused.
3	Maybe because I attempted to move the arm anyway – not to push it toward the back – in my head, the arm moved toward the near side. In the beginning of the experiment, I understood that the robotic arm could turn to any direction, and this was embedded in my memory. So, I might unconsciously consider that 'to move the arm' is to it anyway, and because of this, the arm turned toward the near side. My unconscious mind was read by the system, and consequently the arms turned toward the back and near side. I don't think that the robot was out of order, but something was wrong with my attempt in my head. I don't feel that there was some coding error.
4	I consciously stopped my attempt to move the robotic arm in my head – actually, I considered nothing then – but, the arm moved toward the different direction. My mental operation didn't work well. I had several successful attempts, but the last one took a little time and maybe I became impatient or a little bit upset. I told myself 'relax, relax', but then the arm moved. I didn't think anything in particular. Perhaps my impatience resulted in such a strange movement.
5	If several kinds of movements of the robotic arm were preprogrammed, it would move in accordance with the programs. But, I don't have any evidence about this, and I think I'm completely wrong. If my brain signal patterns were steady, the machine arm would not malfunctioned at all. I think that my brain signal patterns were somewhat unstable, so my attempt to move the arm in my head was misinterpreted, leading to the strange move of the arm.

4.3. The recognitions of enhanced abilities enabled by the BMI system

Subjects' recognition of their abilities enhanced by the BMI system, which was questioned about after the experiments, were mixed, as shown in Table 4.

Table 4. The recognition of enhanced ability.

Q: Do you think your ability was enhanced by using the robotic arm?	
1	I don't think my ability was enhanced, at least in the sense that the arm was not part of my body. It was, I felt, rather like my buddy or a replacement of my hand outside my body. If the arm showed its functions better than my hand's, I would feel my ability was enhanced. But, as long as the arm is outside my body, all I can do is that I operate it as intended. (How would you feel, if there were many robotic arms at home and they performed household chores instead of you?) In that case, also, my ability would not be enhanced, but I could just control the convenient tools.
2	I don't think so, because I couldn't really imagine the robotic arm's move, though it moved. If I get used to operate it, or if it has similar traits and appearance to a human arm and has fingers to pick something up, I might think so. In that case, I might be able to feel it was my own arm. In reality, my physical ability was decreased, because I did not move the arm with my body.
3	I had a sense that my ability was enhanced a little. I'll become better at operating the robotic arm, if I train myself a bit more. If we have robots at home and workplace which can be controlled by our mind, our capability will surely be increased. In addition, the environment surrounding robots plays a key role. If such robots become available to anyone, human beings will evolve to a new level. We'll be able to do what we can't do now.
4	The experiment brought a brand-new experience to me. I felt my ability was improved, and I was enhanced. If I can operate the robotic arm as if it were one of my limbs, I'll surely feel that I become more able. I cannot imagine any opposite situation.
5	My ability was expanded, but not strengthened. Thanks to the robotic arm, my arm's reach was expanded, but this is not the improvement of my ability. The arm is just a tool. If my ability to use this tool is better than others', then my ability is improved. But, if I rely on it too much, my ability will be weakened because I'll less engage in physical work.

4.4. The attitudes to the application of BMI technology

After the experiment, each subject was asked to answer the questions about possible application of BMI technology in daily life and the risks entailed in it. The results are shown in Table 5. While almost all of subjects considered the technology as the useful devices for their daily life, some of them mentioned the risks caused by malfunction of a BMI system.

Table 5. Attitudes to the application of BMI technology in daily life.

Q: In your daily life, for what kind of work or activity do you want BMI technology to be applied? Is there any risk or problem such application would entail?	
1	Simple tasks like housework.
2	I'd like to become able to remotely turn on and off an air conditioner and other appliances using a BMI. But, I'm concerned about malfunction of the system and brain damage it would give.
3	I hope smart home environment will be created. In a business setting, I want to finish simple, miscellaneous tasks (such as responses to emails) before commuting to work using a BMI . But, any trouble caused by the malfunction of the technology is problematic.
4	I would like to use a BMI to regulate my life such as maintaining good sleep habits. I'm afraid hacking into or malfunction of such a BMI system would bring serious danger such as an individual user's falling asleep suddenly during the day.
5	Mail order of daily necessities and social networking service handling. Problems are malfunction of the BMI system, and so on.

After the experiment, they were asked to give written responses to the question about expected application fields of BMI technology, and the following fields were mentioned: construction industry, disaster support, medical field including disability aid, physical labour support, advanced intellectual

activity support and entertainment including games. In addition, when subjects were asked about the situations in which an implantable BMI are used, almost all of respondents expressed their concern about malfunction of it. For example, Subject 4 and 5 pointed out the risky phenomenon regarding implantable BMI use as well as the benefit of it as follows.

> Subject 4: 'This should never be used with a war objective. I'm worried about the advent of pain-insensitive or excessively fearless soldiers by using this brain chip. In addition, the use of this implantable chip could bring about a socio-economic gap between the haves and have-nots. This can't function as a scholarship, though a brain chip to enhance an implantee's learning capability sounds a good idea.'
>
> Subject 5: 'I don't like to be implanted it, even if I can't deny the implantation. If it can be implanted and removed at will, it may be acceptable. I never want to be implanted it for safety reasons and given the risk of brain damage. If its use becomes widespread in society, I may want to use it. If I can't live without it, then I will use.'

4.5. The attitudes to personal data collections by a BMI device

Other questions asked after the experiment pertained to subjects' awareness of data collection by the BMI system. The answers to the questions are shown in Tables 6 and 7. As described in Table 7, a subject expressed his concern about misuse of those data, whereas other subjects thought that brain signal data were not sensitive.

Table 6. Attitudes to EEG data collection.

Q: How did you feel about the EEG's collecting data of you?	
1	No problem at all.
2	It was a little uncomfortable, because I had never put something like that (the EEG) on my head. I am interested in it, but I know nothing about any technological feature of it.
3	I don't feel any aversion. I think it is because I am ignorant about the technology. I wonder what can be found from my brain signal, and I think no one wants to look into my heart. There may be no relationship between one's thought and brain signal. It's no problem for me that my brain signals are read and used.
4	It's not uncomfortable for me at all. I don't want my mental states to be grasped as an image, but because I don't think the brain signal does not convey details of that image, it is OK. On the other hand, it's not pleased for me that my mental states are grasped in detail by others.
5	I don't recognise any risk. I hate to think that my thinking patterns are read by someone else. But, I don't feel bad about someone else's acquiring my detailed brain signals.

Table 7. Attitude to brain signal data collected by the EEG.

Q: Do you think that brain signal data the EEG collects need to be protected carefully as sensitive personal data? What do you think if your brain signal data are utilised for lie detection?	
1	It's not too bad for me that the brain signal data are used to read my emotions or for lie detection. I believe my brain signals represent what I think more accurately than my recognition of it. But, I don't feel that the data are my personal information.
2	From such data, I can learn about my own physical condition that others can't see. It is okay that I look at the data. Whether other people can see the data or not is decided on a case-by-case basis. If specialists look at my data, they will find out everything about me. But, anyone other than them can't do this, so the data are not sensitive. If I am an employee and my condition was evaluated by my employer based on my brain signals, they demonstrate my true condition. I can use the data to explain my condition rationally. In the case of a lie detector, the brain signals do not express everything. It is only one of many things that can be used to decide whether I'm a liar or not. Brain signal data are not sensitive from my personal viewpoint.

3	I agree that a certain protection is needed. Perhaps it is the same as when it comes to marketing. As long as my personal information is provided to researchers of brain signal, I hope my data is managed properly. It's a little bit sensitive, isn't it? A lie can be detected by how nervous you are – this is rather sensitive. But, compared with other kind of personal information, I don't think brain signals are sensitive.
4	I think brain signal data should be managed properly, because not all of us feel good about arbitrary usage of the data. If a lie is detected using the data in real time, such data usage will pose a problem for ordinary human communication. I think brain signal data is particularly important personal information, more than other kinds of one. If my brain signal data are handed to others and used to evaluate me, this is really terrible.
5	I think emotions are personal information that can't be hidden. Because I don't trust machines, I pay no mind to whether machines handle my information or not. Information gained from machine processing is not necessarily correct, and we can treat it as merely one of many. I would provide information if its price is appropriate. I think brain signal data are not sensitive because the information is constantly changing.

4.6. The recognitions of legal regulations for BMI usage

Finally, the question concerning respondents' recognition of the necessity of legal regulations for BMI use was asked. The outcomes are shown in Table 8. Except Subject 1, all subjects recognised the necessity of legal restriction on BMI usage.

Table 8. The necessity of legal restriction on BMI usage.

Q: Do you think legal restrictions on BMI devices usage is necessary?	
1	I don't think it should be regulated by law. In a company, better standards or rules can be set up. The rules don't need to contain a punitive clause. It's a company's job to set their own standard as to how to deal with the information they collect. They can certainly decide on it, because this relates to their productivity.
2	I think it is necessary. Training for using BMI devices in accordance with the regulation is absolutely necessary. If this is conducted well, we don't need to worry about any problematic use of them. If the devices are connected to appliances at home to control them, any malfunction of them can be prevented. If the devices are used for military purposes, their users have to be trained harder. It is necessary to establish a clear criterion in your mind of acceptable usage of the devices. I can't think of any justifiable reason for using them at work. It is better that the users have the right to claim information disclosure on the devices.
3	Regulations are necessary. Even if risks are explained, some people would be suspicious about it. (In terms of using the brain signal to manage employees) While this may be rational, I personally and instinctively feel uncomfortable about this. In this regard, I feel regulation may be necessary. (If a person works with such BMI devices, how do you think?) I would be envious of him/her. But, if it comes to a member of my family or someone close to me, I would be worried about whether they would be harmed by the device use.
4	Regulations are necessary. Such a device can be used by criminals to commit violence, murders and abduction. We need to know how to use it, and to have an established way to stop its functioning by the police. I agree that the police can use it, but obviously this is not the case when it comes to miscarriages of justice and crime committed by the police.
5	Some crisis awareness is necessary. I don't know what to think about the risks. Because the risks are invisible, we should be more cautious. There is a possibility that some people would face an irrational situation in which a decision is made based on brain signals, such as in an analysis of emotions. This is meaningful information for those in a customer-facing industry. Standardising human feeling leads to impoverishment, but it cannot deal with diversity of humanity.

5. DISCUSSIONS

Through the experiments and subsequent interview and questionnaire surveys regarding BMI devices and systems, the authors gained the following findings and insights.

- Operability of BMI: There was a wide range of variations in subjects' recognition of the operability of the BMI system. This may have depended on the accuracy of the BMI devices; therefore, improvements in experimental devices such as changes in default settings used by experimental systems should be reconsidered. On the other hand, the subjects seemed to develop original ideas regarding how the robotic arm could be moved by their brain signals; they subsequently attempted to explain their own interpretation, and some of them subjectively experienced physical synchronisation of their body move with the robotic arm's one. Similarities between the methods, which may be found with repetition of the experiments among the subjects, could be useful for understanding the deep relationships between physical movement and brain function and/or to examine how human recognitions and feelings are strongly related to physical body movements.
- Recognition of responsibilities to operate a BMI device: When the robotic arm moved in an unintended way, the common responses by all subjects was to assume that it was their faults or due to their failure to emit correct brain signals. These results may have been caused by the authors' explanation or by the experimental environment; therefore, there is a need to re-examine the experimental situation. Alternately, their attitudes may imply that the users of information systems or cyborg devices tend to have higher recipiency or to feel a responsibility for the misconduct. Furthermore, it may be difficult to consider various possibilities and reasons around the malfunction of the system when the default settings are given and explained.
- Self-enhancement, enhanced abilities: While the subjects recorded various opinions and feelings about their enhanced abilities enabled by BMI devices, there is the possibility that their feelings and awareness of the BMI devices may change when the experiments are repeated and they become able to operate the robotic arm more effectively. Therefore, it is necessary to evaluate their own awareness of their enhanced ability and self-consciousness with BMI devices in continuous manner.
- Risk awareness on development and usage of BMI: Throughout this study, it seems from the data that the subjects expressed their recognition regarding the use of BMI more concretely than they would have done if they had merely completed a questionnaire or interview survey without the experiment. In this regard, the experiment itself had an educational effect in terms of information ethics to analyse the social influence of emerging technologies, such as cyborg technologies. While the subjects were aware of the risks caused by malfunction or unintended movements of BMI devices and the necessity of regulations, they also had unarticulated anxiety about them. Furthermore, the invasion of privacy issues related to the collection of brain signal data and its analysis may have been difficult for the subjects to imagine. Then, it may be required that the interview sheets and question items should be revised to be easier to respond for the subjects.

6. CONCLUSIONS

As a first step in examining the ethical aspects of BMI usage, this exploratory survey conducted qualitative investigations of BMI usage of five data subjects. Through the investigations, subjects' personal experience of BMI usage and their expectations and ethical concerns about using BMI devices were investigated. While the number of subjects was small, these outcomes provided valuable insights for the development of more appropriate experimental environments and questionnaire sheets.

As these results and subject responses imply, the development and application of BMI devices face plenty of operational challenges and controversial ethical issues; the acceptance of body extension, awareness on protection of brain signal data, the necessity to restriction. Moreover, considering all subjects in this study are university students who have represented their opinions and feelings to a certain degree, if the experiment for the professionals and researchers conducted, they may emit more specific opinions on the survey. With many kinds of research, future challenges and ethical issues regarding BMI technologies should be addressed in an ongoing manner.

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