Effect of Short Term Meditation on Brain-Computer Interface Performance

Yin-Qing Tan, Lee-Fan Tan, Siew-Ying Mok, and Sing-Yau Goh
Faculty of Engineering and Science, Univerisiti Tunku Abdul Rahman, Kuala Lumpur, Malaysia
Email: {tanyq, tanlf, moksy, gohsy}@utar.edu.my

***Abstract*—Brain-Computer Interface (BCI) systems is a direct communication pathway between the brain and an external device. BCI systems enable patients with severe neuromuscular disorders to use their brain signal to communicate with others. BCI users need to maintain stable mental states to achieve a higher accuracy rate, while distraction and frustration will degrade the performance. Research had found that long-term mindfulness meditation practice can help increase regulate the mental state, and thus enhance the efficacy of BCI performance. A previous study showed that a 12-week mindfulness meditation practice programme improved BCI performance. However, long-term meditation course require extensive time and financial commitment. Thus the current study examines whether a short-term 4-week mindfulness meditation practice programme will promote a similar improvement in BCI performance. Undergraduate students were recruited for the study. BCI performance test been carry out before and after the intervention period to compare the changes. Preliminary results showed that all meditation subjects had improved their accuracy in BCI performance test after the 4-week meditation practice.**

***Index Terms*—brain-computer interface, mindfulness, meditation, attention, BCI performance**

I. Introduction

Brain-Computer Interface (BCI) defined as: "A communication system that does not depend on the brain's normal output pathway of peripheral nerves and muscles." [1] A BCI system allows patients with severe neuromuscular disorders such as stroke, amyotrophic lateral sclerosis (ALS) or spinal cord injury patients to regain control over their environment. Brain signals recorded from the scalp as electroencephalogram (EEG) or from within the brain (electrocorticogram, ECoG) were used as commands to communicate, to move or to control an external devices [2].

A complete BCI system includes two main parts: the system, to receive and analyze the signal, then produce a command to control the devices; and the user, who produces the brain signals to send to the system. Progress of BCI technologies mainly focus on these two parts, improvement of higher performance system, such as higher data acquisition rate or new signal processing techniques, and improvement of user training techniques to produce constant and more consistent brain signals. Previous studies showed that human factors, such as fatigue, frustration, concentration and other mental-state variations can affect the BCI performance [3].

A BCI user needs to learn how to control their mental states in order to achieve the goal. Dr. Kabat-Zinn, founder of Mindfulness-Based Stress Meditation defines mindfulness as "paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally" [4]. Mindfulness is a state of consciousness in which the practitioner maintains a single pointed awareness focused on mental, interoceptive and exteroceptive [5], so he is not easily distracted by external factors. Mindfulness meditation can help to improve cognition processes [6] and healthcare conditions [5].

Previous studies showed that mindfulness training such as meditation can enhance the efficacy of BCI control system [3], [7]. Tan *et al.* [8] showed that subjects that have undergone a total of 12 hours of mindfulness meditation over 12 weeks significantly improved their BCI performance compared to a no treatment control group.

However, one of the biggest challenges to meditators is the long-term commitment to continue the practices of meditation. Many people gave up mid-way in a meditation programme because of their inability to commit the time or financial expenses required for a long-term course.

Therefore, brief or short-term mindfulness meditation has been introduced to overcome this limitation. Researchers tried to study the effect of three to five days meditation courses and reported that short-term mindfulness meditation improved mood and cognition processes [9], and reduced pain rating and sensitivity [10], benefits that have previously been reported with long-term meditators.

The current study aims to examine the effect of short-term mindfulness meditation practices on BCI performance. The meditation programme follows the same syllabus used in our previous study [8]. The current programme is completed in a shorter period without reducing the total meditation practice hour. The meditation programme consists of 3 hours per session, one session per week for 4 weeks.

II. Methodology

Volunteer healthy university students that have normal or corrected-to-normal vision were recruited for the study.

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All subjects have been screen through a self-report questionnaire to make sure they did not have any previous experience in any format of BCI and meditation training.

This paper reports the results of 5 meditation students who had completed the test.

A. *Pre-test*

Each participant undergoes 2 tests, which are EEG scanning and BCI performance test. Before enrolment for the experiment, the researcher explains in detail the research procedure to each participant. The subjects will sign an informed consent form that they agree to join the project.

A Nicolet 64-channels EEG acquisition system was use to record the EEG signals with a 256 sampling rate, a built-in 0.1Hz-40Hz bandpass filter and a 50Hz notch filter.

Recording was carried out in an isolated room. Subjects sit comfortably in an armed chair. Instructions were given with a power point presentation from a laptop placed on the table in front of the part. Subjects performed three different mental tasks: imagined right hand movement, imagined left hand movement, and imagined both feet movement. Each set of instruction consists of 7 seconds of "Rest", 3 seconds of "Ready" and 5 seconds of motion imagery "Right", "Left" or "Foot". Each mental task was repeated sixty times. A 5 minutes resting period was given between two mental tasks. Subjects were advised to avoid eye blink and any other body movements during the mental task recording to minimize motion artifacts. The complete EEG scanning took about two hours.

EEG signals from nine electrodes located around motor cortex (AC3, ACz, AC4, C3, Cz, C4, PC3, PCz, PC4 as shown in Fig. 1) were extracted for offline signal processing. The combination of two bipolar channels and two out of three mental tasks that gave the highest accuracy in the cross validation analysis was selected to be used in the following BCI test.

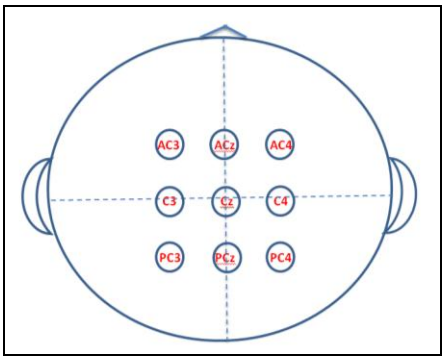

Figure 1. 9 electrode positions use to find the best bipolar channel.

The BCI performance test started with a training phase. During this training phase, the participant was requested to perform the two imagery tasks that have been selected, repeated sixty times for each task. Then continue to the testing phase.

Fig. 2 shows a graphical user interface (GUI) for the testing phase.

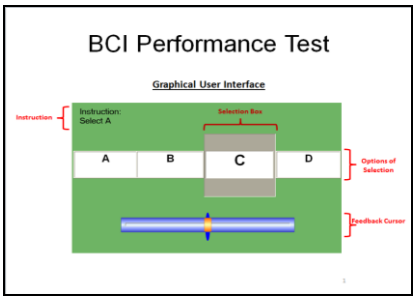

Figure 2. GUI for BCI test.

Four alphabets "A", "B", "C", and "D" automatically scrolls across the center of the screen. An instruction is shown on the upper left corner of the screen, subjects are requested to do the selection with the two mental tasks selected (representing 'YES' and 'NO') according to the instruction given. A feedback cursor displayed to show to the user how well their brain signals has been recognized by the system.

After each selection, the screen is changed to a "RESET" page. If subjects do a correct selection, the test proceeds to the second selection after reset. Otherwise, it returns to the previous selection.

After completing four selections, subjects are given a 30 seconds resting period. They must make sure that no selection is made during this period. Then the programme proceeds to next selection. Each BCI performance test consists of 12 alphabet selections, 12 RESET sessions and 3 resting sections, as show Fig. 3.

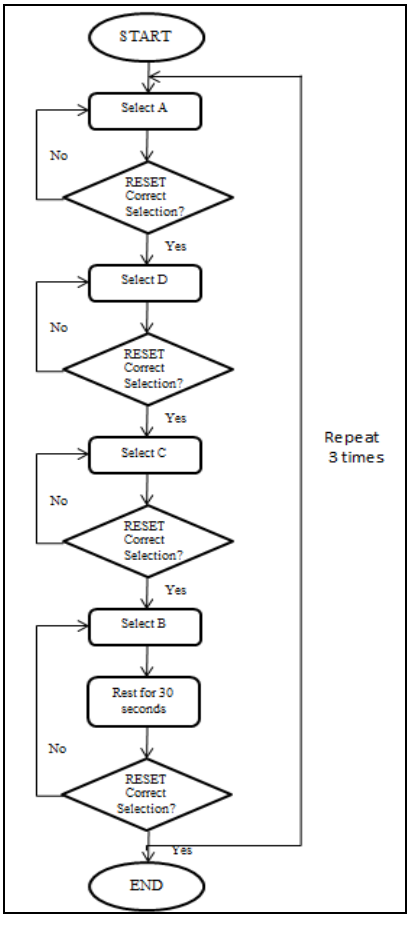

Figure 3. Flow chart for BCI performance test.

The optimum time to complete the whole test is 7 minutes. Each participant is given 30 minutes to complete as many selections as possible. The four types of classification from the BCI test were True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN), as shown in Table I.

TABLE I. CLASSIFICATION OF BCI PERFORMANCE TEST

Response	Instruction	
	Select	Not select
Select	TP	FP
Not select	FN	TN

The BCI performance is measured by the percentage of accuracy, which is defined as:

$$(TP+TN) / (TP+TN+FP+FN) \times 100\%$$

B. Intervention

Upon completion of pre-test, subjects were randomly assigned to two groups: a meditation group and a no-treatment control group.

The mindfulness meditation (MM) programme was conducted in English by an experienced instructor. The classes were conducted 3 hours per session, one session per week for 4 continuous weeks.

The classes were held in a spacious meeting room, every Wednesday; from 5pm until 8pm. Subjects were required to fulfill 100% attendance to the classes.

Subjects were first introduced to some basic concepts of being non-judgmental in mindfulness meditation. The class starts with basic sitting meditation, subjects start to focus on breathing, with eyes closed, and be aware of the thoughts. The basic procedure is: if you notice that your mind has wandered, focus back to your breath and start observing the thoughts again. Body scan is practiced after that.

The second class comes with increased awareness of body sensations, thoughts and emotions. Subjects are taught to observe not only their internal stimuli, but also how their body and mind response with environment. Different meditation poses such as walking, sitting, lying down meditation are introduced: subjects learn how to practice MM in their life, even when they are eating, speaking or relaxing.

Non-judgmental training is the core of following class, focus, observe and accept what is happening, be aware of present state, responding to it but not reacting to it. This is important when handling stress. Subjects learn how to accept and response to the pressure but keep their mental state stable.

During the last class, MM is conducted with distraction, subjects are told to practice MM while the instructor tries to create some noise and movement, to distract the subjects. Subjects should notice the distraction, but react non-judgmentally to it and keep mindfulness.

Discussion and experience sharing session are also carried out during the last two classes.

Subjects in the control group continued their normal daily life and were advised not to involve in any meditation-related activity during the intervention period.

C. Post-test

After four weeks intervention, all participants from the meditation group and the control group go through the same EEG scans and BCI performance test as at pre-test.

The accuracy of the BCI performance of each individual before and after intervention was compared to examine the effect of meditation.

III. RESULT & DISCUSSION

The preliminary results of two female and three male Chinese students, age range between 19-21 years old are reported here. The subjects were enrolled at the beginning of semester, and the tests were completed at the end of semester.

Accuracy of BCI performance test before and after the intervention for each subjects are shown in Fig. 4.

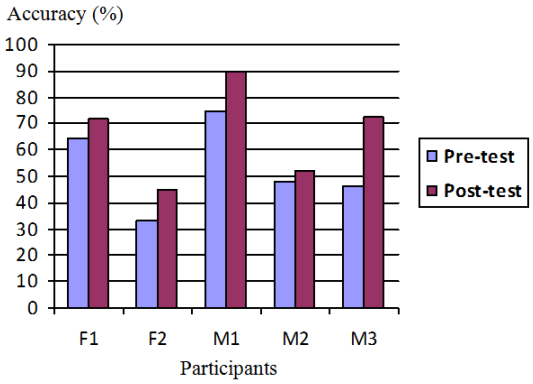

Figure 4. Preliminary result for meditation subjects.

After practicing mindfulness meditation for 4 weeks, subjects able to show improvement for BCI performance test.

Specifically, participant M1 was the best performer in both pre- and post-test. He achieved almost 90% accuracy in post-test. Participant F2 had the lowest accuracy, with less than 50% in both pre- and post-test. Participant M3 shows highest improvement rate, from 46.52% in pre-test increase to 72.33% in post-test. During post-test BCI, he managed to complete the 12 selections within 970 seconds, compare to pre-test BCI, he only can do 7 selections within 30 minutes.

Overall results revealed that all subjects improved their BCI performance after the 4-week mindfulness meditation practice programme. Improvement ranges from 4.44% to 25.81%.

However, the current findings only apply to undergraduate student in this institute with narrow age range, it cannot generalize to other age group and society.

This is a continuing project, more subjects will be recruited to enlarge the database. Further statistical test will be carried out for more detail data analysis.

IV. CONCLUSION

The preliminary results of an on-going study showed that meditation subjects improved their BCI performance. Further research will reveal whether this improvement is significant compared to a control group.

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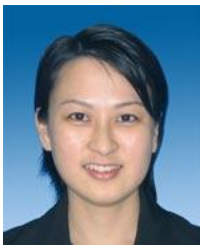
Yin Qing Tan obtained her bachelor of engineering degree in Biomedical Engineering from Universiti Malaya in 2005. She is now pursuing her Master degree in Universiti Tunku Abdul Rahman Malaysia. Currently she is a tutor and researcher in the Department of Mechatronics and Biomedical Engineering, Faculty of Engineering and Science. Her main research interests include brain-computer interface and mental training.



Lee Fan Tan obtained her bachelor of engineering degree in Biomedical Engineering from Universiti Malaya in 2005. She is now pursuing her PhD in Universiti Tunku Abdul Rahman Malaysia. Her current research focus in the effect of mental training on the performance of brain-computer interface users.

Siew Ying Mok is an Assistant Professor in the Department of Mechatronics and Biomedical Engineering, Universiti Tunku Abdul Rahman. She obtained her PhD in Biomedical Engineering in year 2012. Her research interest is in experimental neuroscience, particularly the electro-physiological study of neuronal activities.

Sing Yau Goh is a Professor in the Department of Mechanical Engineering at the Tunku Abdul Rahman University, Kuala Lumpur, Malaysia. He obtained his PhD (1971) in mechanical engineering from Imperial College London but later developed an interest in biomedical engineering, in particular, brain-computer interface and experimental and computational neuroscience.