Meditation: A Performance Booster for BCI Applications

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Abstract

A key factor that a typical Brain-Computer Interface (BCI) demands of operators is concentration of mind. A focused mind is more effective in controlling a BCI. One way to improve mental concentration is meditation. Past studies have demonstrated the positive effect of long-term meditation (month-long to year-long) on BCI performance. In this study, we examined the impact of short-term meditation (10-15 minutes long). We explored two guided meditation techniques of mindfulness: 1) open monitoring, and 2) mindful breathing. A brain-controlled toy helicopter was used as a testbed. Five participants volunteered in the experiment in which they were exposed to an emotional stressor of a violent video gameplay followed by operating the helicopter through mental concentration. A brief meditation intervention was introduced between the video gameplay and the BCI task. The results reveal that, in comparison to the control trial, participants were able to lift the helicopter for longer time durations after meditation. Furthermore, this performance improvement was significantly greater than the participants achieved by sitting idle.

Author Keywords

Meditation, EEG, brain-computer interface.

Figure 1: The graph illustrates flying time per minute for all the participants (S1-S5) and for all the trials (Ctr - Control trial, M1 - Open monitoring meditation, M2 - Mindful breathing meditation, AvgR - Average of two relaxation sessions). The red markers indicate the population mean.

Trial	Ctr	M1	M2
M1	0.021	-	-
M2	0.017	0.187	-
AvgR	0.011	0.081	0.410

Table 1: P-values for paired t-tests comparing the mean flying time per minute for each of the six distinct pairs of treatments. $n = 5$ for all the tests. Statistical significances at 95% and 90% confidence intervals are highlighted in the green color and in the yellow color, respectively.

ACM Classification Keywords

H5.2. Information interfaces and presentation: User Interfaces – Interaction styles, Theory and methods; H.1.2 [Models and Principles] User/Machine Systems: Human factors.

Introduction

Brain-computer interface (BCI) technology has been adopted for a multitude of real-world applications, ranging from medical applications such as neuronal rehabilitation to entertainment applications such as *brainball* game, and from security applications to educational applications. These applications primarily seek one of two modes of BCI operations: 1) controlling and communicating with a machine and 2) monitoring an individual's emotional, cognitive or affective state [1]. This paper focuses on the first mode in which concentration of mind is of utmost importance for better control of a BCI. It has already been demonstrated that a focused mind increases cognitive performance [10]. Furthermore, past research has documented the importance of meditation for improved control of a BCI. Specifically, Eskandar and Erfanian reported that a year-long meditation practice can improve the performance of BCI operators [4]. Tan et al. conducted a 12-week mindfulness meditation training and reported that the training enhanced operator performance of BCI system controls [13]. In another study, the same group experimented with a 4-week mindfulness training and demonstrated the promising potential of mindfulness meditation in boosting BCI performance [12][14]. All these studies examined the impact of long-term meditation practice (month-long to year-long). In contrast, we explored the impact of brief meditation on the users with no prior meditation experience. We hypothesized that

- 1) a brief meditation intervention (of 10-15 minutes) after an emotional stressor improves the recovery of BCI performance; and
- 2) this performance improvement is greater than one would achieve after sitting idle for relaxation.

Experimental Design

A total of 5 volunteers (1 female and 4 males) participated in the experiment. Their ages ranged from 20 to 30 years. None of them suffered from any mental disorders, heart disease, or took medicine that might have affected their physiological and cognitive responses. Also, none had any prior meditation experience nor had any experience with operating a BCI. Each received a \$50 gift card for participating in the experiment.

The study was carried out per an approved protocol from the university's Institutional Review Board. The experiment consisted of 5 one-hour long trials, which included a control trial and 4 experimental trials. The experimental trials consisted of 2 guided meditation trials (open monitoring meditation and mindful breathing meditation), and 2 relaxation trials. The number of trials and the number of participants were optimized considering the following two practical trade-offs: data sufficiency to conclude the pilot study and funds to conduct the study. To eliminate experimental bias, the Latin square approach was used to randomize the trials.

The control trial began with the study participants playing a violent video game (Survival Horror Video Game) on an Xbox 360 for 15 minutes followed by operating a brain-controlled helicopter (Puzzlebox Orbit from NeuroSky) for 5 minutes. The purpose of the

Figure 2: The graphs illustrate mean HR per activity (VG - Video gameplay, M - Meditation, R - Relaxation, and BCI Task - BCI gameplay) of all the participants for each trial. The red markers indicate the population mean.

violent game was to induce mild emotional stress in the participants. The stressor acted as a normalizing factor for the study participants who might have carried different mental states before each visit. Besides, previous studies reported that emotionally stressed participants experience physiological arousal and tend to be less focused [8]. Thus, the stressor created a suitable experimental environment to test our hypotheses. To measure physiological arousal, we used the participants' heart rate (HR), which was captured via an Empatica E4 sensor [11].

The *Puzzlebox* Orbit is an educational toy helicopter, operated via an EEG headset [9]. The Orbit wirelessly communicates with the headset and adjusts its altitude based on the strength of the operator's mental concentration. The Orbit operator is required to lift the helicopter through focused concentration. The participants in our study were instructed to keep the Orbit flying as long as possible. Two GoPro video cameras were used to record the participants' BCI performance and the camera recordings were later used to derive a BCI performance indicator.

Like the control trial, the experimental trials also featured these two activities (video gameplay and BCI operation), but the activities were separated by a brief meditation or relaxation session. Two guided mindfulness-meditation techniques, open monitoring (M1) and mindful breathing (M2), were employed in the experiment - one technique per trial. Numerous studies have documented the positive effect of mindfulness meditation on human wellbeing [3][6][7][15]. The open monitoring technique that we used in the experiment was based on Jon Kabat-Zinn's oneness meditation technique for stress reduction [7]. This

meditation technique is rooted in the Buddhist practice of mindfulness [3]. The meditation instructions were delivered by audio, guiding the participants to passively observe their breathing, body sensation, surrounding sounds, and thoughts and emotions, without reacting or intentionally following any one train of thought [2]. This session was 15 minutes long. The second meditation trial (M2) focused on rhythmic breathing [5]. The participants were instructed by audio to inhale and exhale in a rhythmic manner, bringing attention to the natural sensation of breath, especially to those areas associated with the process of breathing, and observing breathing patterns without the intention of altering them. This session was 10 minutes long. During each meditation session, the participants were instructed to sit in a chair with eyes closed and back straight.

During the two relaxation trials, the participants were instructed to sit back and relax for 15 minutes. They were asked not to talk, eat, or drink. The purpose of these trials was to find out if sitting idle results in the same outcomes as the meditation techniques.

Data Analysis

In total we collected 50 BCI operation videos (2 videos per participant x 5 trials x 5 participants) and 25 HR signals (1 HR signal per participant x 5 trials x 5 participants). From the collected data, we derived a BCI performance indicator and a physiological indicator. In particular, *flying time per minute* was computed and used as the performance indicator. It describes the average amount of time per minute that the helicopter stayed in the air. It correlates with the strength of mental concentration. The physiological indicator was derived from the HR data. Specifically, for each control

Control Trial		
Exp. Phases	VG	M/R
BCI Task	0.235	-
Open Monitoring Trial (M1)		
M	0.007	-
BCI Task	0.067	0.009
Mindful Breathing Trial (M2)		
M	0.033	-
BCI Task	0.4797	0.037
Mean of Relaxation Trials		
R	0.242	-
BCI Task	0.072	0.421

Table 2: P-values for paired t-tests comparing the mean HR data for every activity (VG - Video gameplay, M/R - Meditation or relaxation, and BCI task - BCI gameplay) in each trial. $n = 5$ for all the tests. Statistical significances at 95% and 90% confidence intervals are highlighted in the green color and in the yellow color, respectively.

trial, we computed 2 mean HR values (one for video gameplay, and the other for BCI operation). Similarly, for each experimental trial, we computed 3 mean HR values (the third one for the meditation/relaxation period). This indicator was used to determine which intervention (meditation or relaxation) was better in calming the physiological arousal due to the stressor.

Experimental Results

Figure 1 illustrates the average number of seconds per minute that each participant managed to keep the helicopter in the air. We performed a paired t-test to compare each of the six distinct pairs of treatments. The p-values for these tests are reported in **Table 1**. The results reveal that, in comparison to the control trial, all three experimental treatments (M1, M2, and R) yielded significantly greater flying time per minute ($p < 0.05$). The results support the conclusion that any form of resting after being exposed to the emotional stressor improves BCI performance. Furthermore, the performance improvement after open monitoring meditation (M1) was greater than that after relaxation ($p < 0.1$), indicating that open monitoring is more effective in improving BCI performance than relaxation.

Figure 2 illustrates the mean HR per activity of all the participants for each trial. Their paired t-test results are given in **Table 2**. The most interesting finding to observe in the results is the effectiveness of meditation in calming the physiological arousal. The heart rate was reduced significantly after open monitoring meditation ($p < 0.05$). The same is true for the mindful breathing trial ($p < 0.05$). Thus, both meditation techniques had the intended effect on the participants. Furthermore, simply sitting idle for relaxation was not as effective as meditation - the mean HR between the video gameplay

and the relaxation phase is statistically insignificant ($p = 0.242$). The elevated HR during the BCI task can be attributed to task engagement.

Conclusion

This pilot experiment examined the impact of brief meditation on an operator's BCI performance after being exposed to a mild emotional stressor. The study results suggest that brief meditation has a direct measureable effect on controlling BCIs. In particular, open monitoring meditation is more effective in improving BCI performance than simply sitting idle. It is worth noting that the study participants had no prior meditation experience, suggesting that even novices can benefit from a short-term guided meditation. It will be interesting to see if these findings can be extended to other BCI applications. For instance, can brief meditation make BCI interactions more effective for people who rely on BCI for everyday communication? If the performance improvement is observed across multiple applications, should brief meditation be recommended before a BCI interaction?

Although the results are promising, their power is limited because the study featured a small sample ($n=5$ participants). Given that some effects are noteworthy, we plan on collecting more data in the near future.

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