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Research Article

OVERLOOKED FACTORS AFFECTING THE PERFORMANCE OF THE BRAIN COMPUTER INTERFACE (BCI)

Venkata Aditya Chintala[1] and Nayonika Basu[2]

[1]Computer Science Department, SRM University 2013-2017
[2]Information Technology Department, SRM University 2013-2017

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ABSTRACT

The surge in development of brain-computer interface (BCI) devices is highly focused on the algorithms, mechanics, and neurophysics of their production (Lebedev and Nicolelis, 2006; Lebedev *et al*., 2011; Opris, 2013). We propose the capitalizing on research findings which affect the performance of the Brain Computer Interface from the perspective of the subject. In this study, different factors along with the extent to which they affect the performance of the Brain Computer Interface were assessed. The challenges of BCI illiteracy or BCI inefficiency demands the need to consider all the factors comprehensively in order to decrease the failure rates. Additionally, it has been suggested that BCI inefficiency can be reduced by addressing flaws in human training approaches, which have been largely neglected (Lotte *et al*., 2013). Therefore, all the factors affecting the performance of the BCI should be taken into picture. This study reports the findings of numerous studies along with the factors which affect the performance of the Brain Computer Interface.

INTRODUCTION

Brain-Computer Interfaces (BCIs) is a means of communication that takes brain signals as input, analyses them, and translates them into commands that are relayed to output devices to carry out desired actions. BCIs never follow fixed orthodox neuromuscular output pathways. The aim of BCI is to replace or restore useful function to the people disabled by neuromuscular disorders such as Amyotrophic Lateral Sclerosis (ALS), cerebral palsy, stroke, or spinal cord injury.

There are several factors which affect the functioning, efficiency and performance of a normal BCI. They include meditation, mental state, motivation, music intervention, psychological effects and social factors. Meditation is the art of concentration which improves the cognitive responses and helps in regulating the emotions, thereby strengthening the positive benefits of the BCI. Music greatly improves one's focus on minute details-the feature which greatly impacts the results of BCI since it involves attending to the right stimuli at the right time. The level of one's mental state stability affects the proper usage of the device since the presence of high amounts of frustration and fatigue could lead to producing incorrect results. Psychological factors such as high confidence and better mood results in efficient performance of the BCI. Strong, intense emotional states and depression hamper the performance of BCI. Social interaction consists of emotional responses that have powerful rewarding qualities, which in turn affects the performance of the Brain Computer Interface (BCI).

Factors

Meditation

Meditation is the practice of concentrated focus upon a sound, object, visualization, the breath, movement, or attention itself in order to increase awareness of the present moment, reduce stress, promote relaxation, and enhance personal and spiritual growth.

While undergoing meditation, there were significant changes occurring in the brain which in turn directly impacted cognitive responses such as attention regulation, body awareness and emotional regulation.

In one particular study (Eskandari, 2008), meditation practice was used to enhance the controllability of the mind during the performance of a mental task in a BCI system. The mental states to be discriminated are the imaginative hand movement and the idle state. The experiment was conducted on two groups namely meditation group and control group. The experiment concluded that the average accuracy of the control group was 70.28% whereas the average accuracy of the meditation group was 88.73%. An accuracy as high as 98% was reached in the meditation group.

**Corresponding author: Venkata Aditya Chintala*
Computer Science Department, SRM University 2013-2017

In another study (Dienez, 2014), meditation was claimed to increase metacognitive regulation. The study was conducted for 12 weeks, the number of participants on which the study was conducted was 76. The participants were divided into 3 groups namely meditation training group, music intervention group and control group. After the analysis, the study states that the mindfulness meditation training group achieved a much higher BCI accuracy compared to both the music training and no-treatment control groups after the intervention, indicating the positive effects of meditation on the performance of BCI.

Therefore, based on the evidence gathered from the above findings, meditation can be regarded as a significant factor which improves the accuracy and performance of the Brain Computer Interface.

Mental State

In this study (Myrden A, 2015), the investigation on the effects of three mental states—fatigue, frustration and attention on BCI performance was done. Twelve participants were trained to use a BCI based on the performance of user-specific mental tasks. The participants completed three testing sessions after the training, in which they used the BCI to play a maze navigation game while reporting their perceived levels of fatigue, frustration and attention.

The analysis conducted during the experiment revealed that there exists a significant relationship between frustration and BCI performance, while the relationship reached significance between fatigue and BCI performance. When fatigue was low, the performance was 7% lower than average. When frustration was moderate, there was 7% higher performance in BCI than the average. Finally, a visual analysis showed the sensitivity of underlying distributions to changes in the mental state. Looking at them collectively, these results indicate that mental state is closely related to the performance of the Brain Computer Interface.

Therefore, it can be concluded from the evidence cited in the above study that the performance of Brain Computer Interface is closely related to the mental state of the participant.

Music Intervention

In an independent study (Jansari, 2009), the effect of two forms of mental training were studied, mindfulness meditation and learning to play a musical instrument. Learning to play any musical equipment such as a classical guitar can be regarded as a practice of attention where very often the beginners are required to focus their attention on the movements of their fingers. This study, after the analysis conducted, stated that there was significant improvement in the performance who were asked to learn to play the guitar but not as much as the meditation group.

Another study (Dienez, 2013) explored whether mindfulness meditation training can improve the performance of BCI users. In the experiment, they introduced a music training condition. The study found that there was significant increase in the performance of both meditation group and music intervention group. The study found that the level of performance of BCI in the music training group was less than that of the meditation group. It can never-the-less be concluded that there was an improvement of performance of the music training group.

Therefore, based on the above given studies it can be concluded that music intervention has an influence over the performance of the Brain Computer Interface.

Effect of Motivation

A study was done to examine the effect of motivation as a possible psychologically influencing variable on the amplitude, performance and speed of the Brain Computer Interface (F Nijboer, 2010). In this study, participants were instructed to copy spell a sentence by attending to cells of a randomly flashing 7 * 7 matrix. BCI performance was defined as the overall percentage of correctly selected characters. They were divided into 2 groups, the motivation group and the control group. The participants in the motivation group were extrinsically motivated by giving monetary benefit. The study found that the performance(P300 based BCI) was higher in the motivation group as compared to the control group and the speed(EMR type BCI) was higher in the motivation group as compared to the control group.

Another study investigated the effects of motivation on Brain-Computer Interface performance in amyotrophic lateral sclerosis (Birbaumer, 2010). The factors which positively related to BCI performance were motivational factors, specifically challenge and mastery confidence, while incompetence fear was negatively related with performance. The study concluded that motivational factors may be related to BCI performance in individual subjects and suggested that motivational factors and well-being should be assessed in standard Brain Computer Interface protocols.

It can be concluded from these studies that Motivation can be regarded as one of the significant factors which influences the performance and speed of the Brain Computer Interface.

Psychological Effects

Psychological effects include well-being measured as Quality of Life (QoL), depression, and current mood on Brain Computer Interface performance on various participants.

In one particular study (By Nijboer *et al*. 2008a) better mood and mastery confidence were related to better better performance of the BCI(better SMR-regulation), whereas higher ratings of incompetence fear were related to higher inefficiency (worse SMR-regulation) in the performance of the BCI. The authors suggested that when performance is high from the beginning of the training, the incompetence fear in further sessions or loss of interest may hamper performance and further learning. However, when performance is low at initial training, moderate incompetence fear might boost performance. The authors concluded that mastery confidence and mood (psychological effects) are some of the factors that impact the performance of the Brain Computer Interface.

In another study (N Birbaumer, 2010), it was told that both negative and positive emotional states may impair performance. For example, in that particular study, word recall was impaired among individuals when pleasant and unpleasant emotional states were induced (Seibert and Ellis, 1991). Likewise, symptoms of depression may impair learning and

lead to deficits in attention and executive control. Therefore, they speculated that intense emotional states and depression hamper BCI performance.

Therefore, it is quite evident from the above citations that physiological factors greatly affect the performance of the Brain Computer Interface.

Social Factors

Learning in a social context is very much effective then in non-social instruction. Numerous neurophysiological studies have shown that social interaction actually alters physiology, including changes in neuroplasticity and arousal. More importantly, social interaction consists of emotional responses that have powerful rewarding qualities and get reciprocal action. It has been suggested that Brain Computer Interface inefficiency can be reduced by addressing flaws in human training approaches, which have been largely neglected (Lotte *et al*., 2013). Therefore, the social cues and contexts a patient has when BCIs are integrated and employed should not be overlooked for their potential to improve effectiveness.

Social Cues and contexts

Social contexts include participating in exchanges between individuals along with observing, and responding to cues integral to social behaviour. The emotional responses of self and others are also social cues. The mere presentation of cues which are specific to social interaction, such as language or images of the same species, is enough to cause neurophysiological changes in brain and behaviour. This special effectiveness of social stimuli was recently shown when superimposing familiar face images onto the spell checker of a Brain Computer Interface, where the performance increased the accuracy and speed in healthy individuals(Kaufmann *et al*., 2011) and patients (Kaufmann *et al*., 2013).

Social Learning

The social environment can be said to be the richest environment for learning the most complex cognitive skills, pointing out the importance of training methods. The use of Social reinforcements has been noted to be very much useful to improve Brain Computer Interface integration (reviewed in Lotte *et al*., 2013). This suggests that engaging a person who communicates during feedback along with the computer display could facilitate acceptance and speed of acquisition of the participant during training.

Brain to Brain coupling

Complex joint behaviour such as communication and social coordination depend on synchronous interactions. Inter-personal entrainment of behaviour between people occurs when engaged in some sort of rhythmic behaviour, for example finger-tapping (Konvalinka *et al*., 2010) or chair rocking (Richardson *et al*., 2007) which results in unintentional coordination. Inducing synchronous activity where there is brain to brain coupling, which might increase the efficiency of partnership engaged with the usage of the Brain Computer Interface. Intriguing results with a multiuser BCI video game based on motor imagery showed improved utility, effectiveness, and engagement (Bonnet *et al*., 2013), suggesting methods using interacting brains would help reduce BCI illiteracy and would increase the efficiency of the performance of the Brain Computer Interface.

Therefore, these studies have shown that social factors which include but are not limited to Social cues and context, Learning Socially and Brain-to-Brain coupling play a significant role which ultimately affects the efficiency and performance of the Brain Computer Interface. Some of the other social factors which could be taken into account are cognitive function, social intelligence and brain-to-brain transfer. Therefore, social factors can be considered as a factor which affects the performance and efficiency of the Brain Computer Interface.

CONCLUSION

The challenges being faced for BCI illiteracy, or the inefficiency of the BCI can only be addressed by taking all the factors into consideration and by not overlooking any of the factors which are involved. All the factors we've included are shown from the perspective of the person using the Brain Computer interface. We suggest that the inefficiency of Brain Computer Interface can be reduced by addressing flaws in human training approaches. Taking these factors into consideration which influence the performance and efficiency of the Brain Computer Interface. We'd like to suggest that these factors should be taken into consideration while designing or employing a Brain Computer Interface so as to increase the overall effectiveness of the Brain Computer Interface.

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