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The Research of Emotional State Influence on Quality of a Brain-Computer Interface Usage

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Abstract

Nowadays due to the brain-computer interfaces it becomes possible to make a reasonable assumption about the cognitive activity of the user and to recognize certain mental commands, which is used for various purposes, including robotic devices control. In addition, modern brain-computer interfaces allow to monitor affective activity that contributes to real-time monitoring of the operator' emotions. In this paper the influence of affective activity on the quality of recognition of the cognitive commands is considered. For this purpose, methods of excitation of a certain emotional state are used. The result of the research is a methodology of improving the quality of recognition of mental commands by taking into account the emotional state of an operator during the command execution.

Keywords: brain-computer interface, affective computing, emotions detection, command recognition, control quality

1 Introduction

The brain-computer interface (BCI) is an interface which provides a direct transmission of information from the brain to a computing device. Any motion, perception or the inner thought causes interaction of neurons with a help of electric impulses. This interaction creates electromagnetic field which can be registered via electroencephalogram (EEG). The human brain constantly emits the electric impulses which are called the waves of brain activity (for example: alpha-, beta-, gamma-wave). The brain creates waves of one kind for the certain behavioral patterns. Several portable BCI were developed by different companies recently. Some of these BCI interfaces allow not only to receive data by EEG but also to receive data about emotional state of an operator, namely the type of wave of brain activity prevailing at the moment. In this paper the following hypothesis is explored: taking into consideration the emotional state of an operator while working with BCI it's possible to improve the recognition quality of cognitive activity and executing commands.

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2 Related works

Affective computing is relatively modern subfield in computer science that deals with human-computer interfaces that can sense or help to express emotions. There are several approaches to do so: good review of models, methods and applications of affect detection was given Calvo and D'Mello [1]. Another survey was given Kleinsmith and Bianchi-Berthouze [2] which is focused on affective body expression perception and recognition that currently is the one of most prominent ways to deal with emotion expression and analysis. But it is possible to obtain affective information not only from visual sources as body posture or facial expression. Physiological signals can be very useful sources for such kind of information, for example ECG are described by Agrafioti, et al. [3] and others, as blood pressure, temperature, electro dermal activity, etc, that are manifestations of emotions influence on autonomic nervous system are considered Wac and Tsiourti [4].

But the main neuroscience approach for emotions detections is based on several techniques of the brain-waves analysis obtained through EEG described by Calvo and D'Mello [1]. Several laboratories conduct researches in this field, so we can already observe some promising results. Some techniques of emotions detection and recognition from brain signals were described Petrantonakis and Hadjileontiadis [5] and Jenke, et al. [6].

It is possible to use common-of-the-shelf brain-computer interfaces to obtain information about operator' emotions considered Pichiliani, et al. [7]. In its turn, emotions can affect BCI performance, some of the evidence was shown Chepin, et al. [8]. However, it should be mentioned that the accuracy of these devices is less than expensive medical electroencephalograph's one (EEG - scanner). In this paper, we provide more rigorous research of how the basic emotional states, as engagement, excitements, frustration and meditation, can affect BCI performance.

3 Theory

The human brain generates waves of brain activity at any time. Some BCI allow to receive the numerical characteristic (as magnitude) of the alpha-, beta-, and gamma-waves emitted by the brain. The emotional state of an operator is a complex of numerical characteristics of these waves received via BCI. Such emotional states as Engagement, Excitement, Frustration, Meditation are observed in this paper. The detection of emotional state is produced in real time using BCI. To begin with we will develop the methodology of putting the person into the state in which one of the aforesaid states is prevailed.

3.1 The method of putting the person into the one prevailing emotional state

Originally the methodology of putting the person into the one prevailing emotional state was developed for several test subjects (people passing tests for the command's execution with help of BCI). Afterwards the general part of the methods allowed to put all the test subjects into a state of one emotion prevailing was selected.

Engagement methodology: concentration on a particular image. Engagement was observed during concentration on a certain image; also the significance of Engagement increased while making mental arithmetic (the test subject was asked to name the tenth Fibonacci number – the sequence where each subsequent number is equal to a sum of the two preceding ones). It should be mentioned that different test subjects had different peak values of Engagement while counting the tenth Fibonacci number (the first peak value 1.0; the second – 0.9) (Fig.1a).

Excitement methodology: to cause excitement. Excitement was observed during a test subject was emotionally moved. The test subject was asked to remember the funny incident or he or she was told a

short comic story. If a test subject liked the story very much, the experiment went on – peaks of Excitement were observed almost continuously (fig. 1b, right).

Frustration methodology: to put the test subject into the state of anger, irritation. After the test subject remembered some unpleasant moments of his life, the significance's increasing of Frustration (fig. 1c) was observed. Though it was necessary to ensure that the test subject was not strongly enthralled by his memories, otherwise it led to Excitement significance's increase (fig. 2a).

Meditation methodology. The situation with Meditation is some more difficult since prevailing it the user must execute commands with a help of BCI, because of this the peak of Meditation does not reach the value 1.0 (fig. 1d). The first test subject was put into the state of a meditation by the relaxing music (fig. 1), but the melody's change caused the growth of Frustration and Excitement (fig. 2b). Later the test subject confessed that the melody was related with bad memories, that confirmed the case specified in the Frustration item. Another test subject was put into Meditation with a help of a deep inhale–exhale which brought him into relaxed state. Though such a methodology led to a frequent interruption of the experiment because the test subject got out of this state during executing some commands via BCI. Therefore the usage of the relaxing music which the test subject didn't listen earlier (to exclude memory's influence, connected with this music) was chosen as a resulting methodology.

The Common Methodology. The methodology of putting a test subject into a certain state was developed. The following actions were made above each test subject:

1. The test subject had to say what the Fibonacci numbers are (if there was no answer, the principle of their determination was explained to the test subject)
2. The test subject was asked to remember several funny incidents. The one which had the greatest influence on Excitement was determined.
3. The test subject was asked to remember several unpleasant situations. The one which had the greatest influence on Frustration was determined.
4. The test subject had to tell what music he listened to and what was his favorite band and song. The song which caused the greatest increase of Meditation and wasn't followed by the significant increase of other emotions was determined.

3.2 The division into positive and negative emotions

After the test subject has been tested, while being in the predominance of one of the emotions, we divide the emotions into positive and negative affecting performance of the command. Positively affecting emotions (hereinafter referred to as positive) are the types of human emotions, with the prevalence of which test quality is higher than when testing without considering emotions. Negatively affecting emotions (hereinafter referred to as negative) are the types of emotions, with the prevalence of which test quality was lower than when testing without considering emotions.

After that let's try to apply this division of emotions as input for the calculation of confidence to execute the command. However, in contrast with Chepin, et al. [8], we will consider the division into two kinds of emotions. Let's denote the sum of numeric characteristics of negative emotions - I_{neg}, the sum of positive - I_{pos}. We fix boundary confidence value to command execution during the training (minimum value $\frac{I_{pos}}{I_{pos}+I_{neg}}$). Further, during the test on command executing we consider the command to be executed if the current value $\frac{I_{pos}}{I_{pos}+I_{neg}}$ is more than min $\frac{I_{pos}}{I_{pos}+I_{neg}}$ value, obtained during the training (time t). Thus, the command will be executed, if condition is met:

$$\frac{I_{pos}}{I_{pos}+I_{neg}} \geq \min_t \frac{I_{pos}}{I_{pos}+I_{neg}} \quad (1)$$

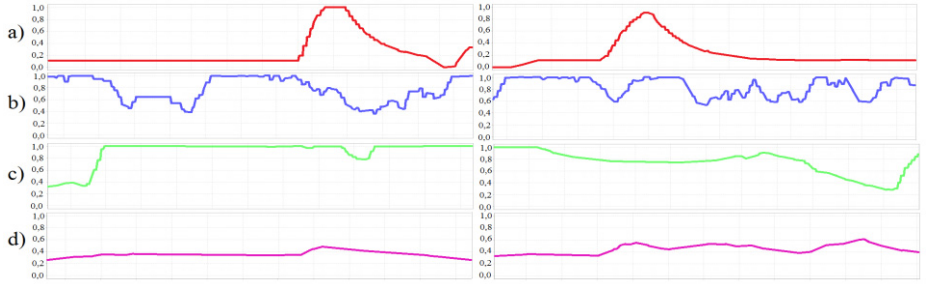

Figure 1: The peaks of values of emotions observed in the application of different methods for the two test subjects

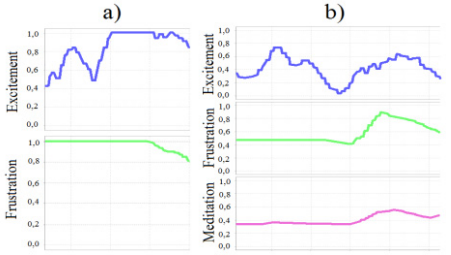

Figure 2: Special cases (a - frustration begins to cause the growth of Excitement b - meditation peak coincides with Frustration and Excitement peaks)

4 The experiment

At the beginning a person is tested for the command execution, as shown by Chepin, et al. [8]. Test for the command execution means a test in which a person must call a command for execution using the BCI, at a certain time. Testing quality is the ratio of right actions (call / do not call the command on performance) to the total number of human actions. Moments of time when a user will have to call / do not call the command for execution are determined by two kinds of images (Fig. 3). If the user sees an inanimate object, he should call the command for execution. If the user sees an animal he should not call the command for execution. The number of pictures shown in the tests was 50.

Figure 3: Two kinds of pictures. (Left) The kitten. If the user sees it, he should not execute the command. (Right) Motorcycle. If the user sees it, he should call the command to execute

Then, a research of the test quality is conducted, depending on the person's emotional state. For this purpose we influence on human so as to cause predominance of one of the emotions using the

method illustrated above. After a person' input into this state he or she needs to be tested for the command execution. To obtain significant results in the process of testing it is necessary to maintain the predominance of one emotion over the others. Thus, if a person in the process of testing will no longer be observed prevalence of emotions, a short break is made, during which the person is entered into a state of predominance of the initial emotion again. After this research, we have dependence of the test quality from kind of the prevailing human emotion.

5 Results and conclusion

Methods of human input into a certain state and testing of execution of the command by using the BCI, were carried out on several people. After the test, a table of dependence of recognition percent from test parameters (see Table 1) was made.

Predominant emotion	The proper recognized commands, %							
Engagement	46	58	68	48	48	62	64	60
Excitement	60	58	62	54	54	64	64	60
Frustration	30	42	42	38	40	42	36	48
Meditation	42	64	62	48	48	58	60	58
Excluding emotions	40	52	60	42	46	48	44	52

Table 1: Test with exclusion of emotions and with predominant emotion

Based on these results, we can conclude that positive emotions are Engagement, Excitement, and Meditation, as all test subjects with the predominance of one of these emotions have an increase of recognition quality (compared with testing excluding emotions). Negative emotion is Frustration, because all subjects with the predominance of this emotion had a decrease of recognition quality.

According to Shapiro and Wilk's W test for normality are described by Royston [9] it's possible to state about normal distribution of each group the correct command recognition depending on the predominant emotional state and excluding emotions. Consequently, we can apply the paired t-test in order to show the statistical significance of the influence of given emotional states on the quality of command execution using BCI , in comparison with the results obtained without putting the test subject into a state with a particular predominant emotion. The results of the calculations are shown in table 2, which suggest statistical significance of the influence of emotional state on the recognition quality of the commands.

No Emotion Detection vs	t-statistics	p-value
Engagement	-4.3799	0.003235
Excitement	-4.8878	0.001778
Frustration	5.0834	0.001426
Meditation	-3.7804	0.006888

Table 2: Paired t-test results

After such separation, the user was asked to take a test given his general emotional state. The test result is presented in table 3. The result of calculation is based on t-test suggest statistical significance of the recognition quality of the commands improvement.

Thus, it was shown that the prevalence of a particular type of emotion affects the quality of command recognition. It should be noted that a disadvantage of some methods of putting the person in a particular state is that they have only a brief exposure. However, in the case of the technique for Meditation state a lasting effect on the person was given.

Parameters	The proper recognized commands, %							
With exclusion of emotions	40	52	60	42	46	48	44	52
With usage of command confidence	48	64	64	44	48	60	56	62

Table 3: Tests with exclusion of emotions and with usage of command confidence

Despite the fact that the considered methods lead to the predominance of the emotion desired in the research, they have a different effect on each individual. Such a conclusion can be drawn by analyzing table 1. In the same procedure, each person had different influence of emotions on execution of the command (for the test subject 1 (1st column) component Excitement produced the best effect, for the test subject 3 (third column) - Engagement). Also, at application of methods, each test subject was observed different value of maximum magnitude of emotion. In the future we plan to take into account all these factors, and to conduct a more large-scale testing using abovementioned and other methods of putting the person into a state of predominance of a particular emotional state.

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