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Eye-to-Eye Contact: Controlling Robot Using P300 BCI

A. Kaplan[1], A. Kochetova[1], R. Draginsky[1]

[1]*Lomonosow Moscow State University Neurophysiology and Neuro-computer Interfaces Lab, Moscow, Russia*

Correspondence: A. Kaplan, Moscow State University, Faculty of Biology, Department of Human Physiology, Leninskie Gory 1/12, Moscow, Russian Federation. E-mail: akaplan@mail.ru

Abstract. A brain–computer interface (BCI) is a system for direct communication between brain and computer. The BCI developed in this work in principle is based on a protocol described by Farwell and Donchin in 1988 using P300 by spatially distributed target and nontarget visual stimuli. For BCI robot control in this work we used target and nontarget visual stimuli located at the same place but coded by different colors. As a place for stimulus representation we selected eyes of the controlling robot NAO. Each color is used as a target associated with a specific robot action. In a pilot study on 3 subjects we tested this eye-to-eye BCI loop and have got 87%, 84% and 91% effectiveness to control elementary actions of a robot.

Keywords: Brain–computer interface, colors perception, oddball paradigm, P300, brain-robot interface, NAO robot

1. Introduction

In the last decade BCI actuated devices developed in research laboratories throughout the world, searching an options for applications of this technology in medicine, brain-controlled virtual simulation environments, military [Wolpaw et al., 2002], in the game industry [Kaplan et al., 2012], and other human activities. More and more studies are done using BCI to control robots, robotic manipulators such as BCI-actuated robotic hands, robotic wheelchairs, prosthetic devices. Amongst the numerous BCI paradigms, those based on the P300 component in EEG are among the most successful and well studied [Guger et al., 2009]. Usually, in BCI, P300 ERPs are triggered using oddball procedures [Farwell and Donchin, 1988]. The 'oddball' paradigm relies on an infrequent but task-relevant stimulus being embedded in a series of frequent irrelevant stimuli. The sustained attention to the target stimuli is one of the main conditions for the effectiveness P300 based BCI. Numerous attempts have been made to try to improve on it, including using colors and shapes as the object features which would capture more attention [Takano et al., 2009; Ikegami et al., 2012]. Nevertheless, the effectiveness of BCI, especially when it's very important (like in medicine or military use), is still not high enough. Recently, a new approach to drawing the attention in the BCI appeared which is based on the use of natural stimulus to automatically capture the attention. For example, some studies used faces as a target [Kaufmann et al., 2012]. The best option here would be the placement of stimulus elements directly on the controlling device. In this paper we propose a system of BCI robot control, based on P300 waves, where the source of stimulus is placed directly in an eye of a robot. It is well known that eyes are the one of the most attractive elements of face. It is also best decision because the regular stimulus matrix for P300 triggering usually placed on a stand-alone computer screen that significantly restricts the use of the BCI technology. In this pilot study we test the hypothesis whether eyes located target/non-target sequences of visual stimulus would be effective for robot control.

2. Material and Methods

The pilot study involved three subjects. Data acquisition, stimuli presentation, online signal processing, and classification were done with an in-house Python program. EEG was recorded at 500 Hz sampling rate at Cz, Pz, PO7, PO8, O1, O2 against a reference at the right earlobe with ground electrode at Fpz. The main difference of our BCI from the standard P300 BCI is that instead of characters, such as letters or symbols spatially spread in the matrix, we used 3 (red, green, blue), or 5 (red, green, blue, yellow and purple) colors – flashing in same place - in the eyes of a humanoid robot NAO H25, made by Aldebaran Robotics, France. The robot eyes are circle and have a 0,76 inch in diameter and 3 inches between the eyes. All participants featured the same set of 3 or 5 colors. The duration of a single stimulus was 120 ms and the time between the onsets of subsequent stimulus, was 175 ms, as was optimized in our previous work [Ganin et al., 2012a]. Stimulus (3 or 5 colors) flashed randomly in the left or right eyes separately. Participants were instructed to sit at a distance of 35 inches from the robot and silently count the number of lighting of the target stimulus. The target stimulus each time was one of the backlight colors in the right or left eye. Five possible target stimuli were associated with five elementary robot commands: raise right/left hand, turn

right/left, one step forward. Thus, the target stimulus was presented randomly in one or the other eye with a probability of 1/3 or 1/5. Each target stimulus was repeated 10 times.

3. Results

Each subject had a training session in which the position (left or right eye) and the color of the target stimulus was indicated. The duration of the training was usually 3-5 minutes. After training, the subjects were asked to activate thru BCI a given sequence of actions to the robot, for example, turn to the right, raise the hand, make one step forward, turn to the left, etc. of 12 (for 3 colors) or 20 (for 5 colors) consecutive items. Each subject performed the task 7 times with a 3-4 minutes rest intervals. In total, he made 84 commands for 3 colors and for 5 colors 140 comands. For each subject we counted the number of correct decisions as % of a total number of attempts to control the actions of the robot. It was shown that all 3 well trained and highly motivated subjects were able to perform the robot control with the reliability 87%, 84% and 91% in the case of 3 colors flashing in one position (6 commands for both eyes) and 78%, 82% and 86% for 5 colors (10 commands for both eyes) respectively. We did not compare the effectiveness of different color features and colour sets because of insufficient statistics at the moment.

4. Discussion

The study was considered as a preliminary test of possible beneficial effects from the use of target feature of colored stimulus given to the subjects in one place – in the eyes of a robot in P300 BCI paradigm. Earlier [Treder et al., 2012] it was shown that the presentation of stimulus with different features in the same place on the screen allows to create an efficient path for the P300 BCI. In our paper we show that P300 BCI paradigm can work efficiently even if the stimulus differ only in color. Perhaps the effectiveness of such the design could be explained by the fact that the stimulus was presented in the robot eyes and such an efficiency is associated with the natural capture of the user's attention to the eyes of another person. This eye-to-eye P300 technique could be used to manipulate a different kind of humanoid robot with eyes highlighted in different colors. Our next study would explore the possibility of code modulation of P300 based on target color combinations or 2D-3D sets of color stimuli. Code modulation would significantly increase the number of commands to control the robot's actions in a human-robot communications technology, called "eye-to-eye" paradigm, which would be the base to the building of a “brain-robot interface” (BRI).

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