Platform for analyzing multi-tasking capabilities during BCI operation

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Abstract

Operating brain-actuated devices requires split attention between the interaction of the device with its environment and the Brain-Computer Interface (BCI) feedback. In case of screen-based applications it is possible to merge BCI feedback and application, but not in case of controlling devices, like wheelchairs or exoskeletons. Recently we demonstrated that BCI feedback could be provided via tactile stimulation and no performance difference between tactile and visual BCI feedback could be found. In this work we want to present a platform for characterizing these multi-tasking capabilities during BCI operation. Thereby, the subjects will have to perform a visual engaging and complex task in a game like setup while interacting with the BCI in a coordinated multi-tasking manner.

1 Introduction

Controlling a brain-actuated device like a wheelchair requires the participant to look at and to split his attention between the interaction of the device with its environment and the status information of the Brain-Computer Interface (BCI). Such parallel visual tasks are partly contradictory, with the goal of achieving a good and natural device control. Recently we demonstrated that it is possible to free the visual channel from one of these tasks, by providing feedback for a motor imagery based BCI via a spatially continuous tactile stimulation [1]. Thereby, we could demonstrate that the participants were able to perceive this type of tactile feedback well and no statistical degradation in the online BCI performance could be identified between visual and tactile feedback conditions. Nevertheless, an open issue is to demonstrate that the freed visual channel can now be fully devoted to the device while controlling the BCI.

In this work we want to present a platform for analyzing these multi-tasking capabilities during BCI operation. Thereby, the subjects will have to perform a visual engaging and complex task in a game like setup while interacting with the BCI in a coordinated multi-tasking manner with the presented stimuli. This platform is giving us the possibility to evaluate different parameters in a reproducible design, which would not be possible with a brain-actuated device.

2 Methods

The goal of this work is the evaluation of multi-tasking capabilities while exploiting visual and tactile BCI feedback. Therefore, the participant will have to perform 2 tasks in parallel.

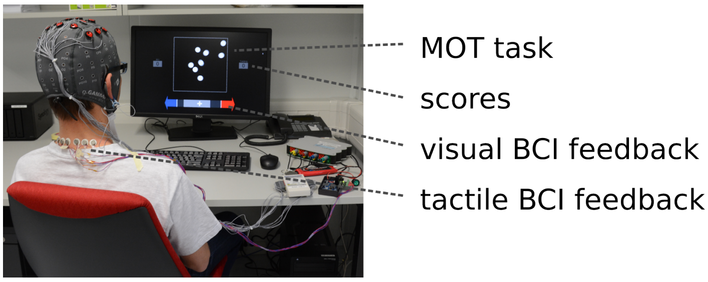

Figure 1: Experimental setup including the multi-object tracking game and the BCI feedback. Visual and tactile BCI feedbacks are used alternately.

The first task is the use of a 2-class BCI, which allows the delivery of a right or left BCI command via the imagination of hand movements (MI). E.g. the imagination of a left hand movement moves the BCI feedback to the left and the imagination of a right hand movement to the right. The instructions when to move the BCI feedback and in which direction (cue) is embedded in the parallel task described below.

The second task is to track several ball like objects on the screen (multi-object tracking game [3], see Figure 2). At the beginning of each trial one, two or three targets out of 10 possible balls are highlighted and the participant is instructed to keep track of them. Furthermore, only the target(s) is/are slightly moving twice for 1 second either to the left or right, to indicate the target direction (the BCI cue for the motor imagery) for this run.

After that, all targets are starting to move around in a physical realistic way. They can bounce at the wall or at each other, but are never occluded. After approximately 10 seconds half of the balls are highlighted (changing the color) for 4 seconds. The participants should perform a BCI command during the time (while still keeping track of the targets). If one of the tracked targets is highlighted, the participant should perform the BCI command, which was indicated by the cue during the first 2 seconds of the trial. If the tracked target is not highlighted the opposite BCI command should be applied. After these 4 seconds all balls return to white. After another random period of around 10 seconds again half of the balls are highlighted and the same actions as mentioned above have to be performed, dependent if one of the targets is highlighted or not.

The trial finishes after around 30 seconds and all balls stop moving. They are immediately numbered and the participant has to mark the one(s), s/he thinks are the targets. Furthermore, they can report at which time the lost (if at all) one of the targets, and/or delivered a wrong BCI command. After that the users receives feedback about his/her tracking performance. Finally a new trial with new targets and BCI cue direction is starting.

The visualization contains two parts (see Figure 1). The balls are displayed in the top center part of the screen. But also information about the current state of the 2-class BCI is presented to the participant, which gives information of how much the BCI thinks that the participant is applying e.g. the imagination of a left or right hand movement. Two different feedback conditions are performed: This feedback is either displayed as a visual bar on the bottom part of the screen (as used in normal BCI runs). Or in the second conditions this BCI feedback is presented via 6 tactile stimulators on the neck (see Figure 1), whereby different stimulators are activated to present the information similar to the position of the bar before. In this condition no visual BCI feedback is shown, but the tracking task is performed in the same visual manner.

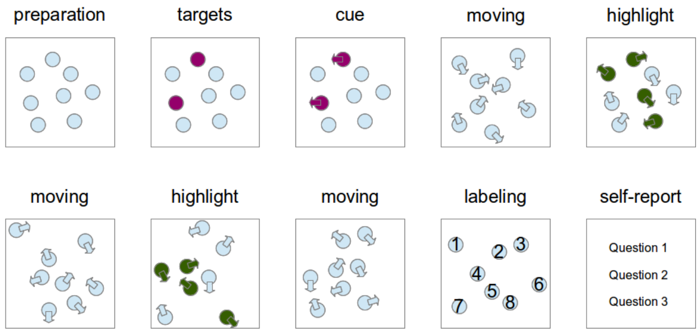

Figure 2: Time-line of the experimental protocol.

The experiment contains 10 trials in a series (called run), after that a short break is given. In total 2–4 runs are played with each of the 2 conditions and with different levels of difficulties.

2.1 Applied BCI setup

The brain activity was acquired via 16 EEG channels placed over the sensori-motor cortex (Fz, FC3, FC1, FCz, FC2, FC4, C3, C1, Cz, C2, C4, CP3, CP1, CPz, CP2 and CP4 with reference on the right ear and ground on AFz). The EEG was recorded with a g.USBamp (g.tec medical engineering, Austria) at f_s=512 Hz, band-pass filtered 0.5–100 Hz and notch filter set to 50 Hz. From the Laplacian filtered EEG, the power spectral density (4–48 Hz) was calculated. Canonical variate analysis was used to select subject-specific features, which were classified with a Gaussian classifier. Decisions with low confidence on the probability distribution were filtered out and evidence was accumulated over time. More information about our BCI is given in [2].

In online experiments the output of the BCI is translated in a movement of the feedback, which informs the subjects about their current brain status. In the case of visual feedback, the horizontal bar moves on a screen. In the case of tactile feedback, the motors vibrate accordingly.

3 Results

Three experienced BCI participants (between 27 and 40 years, all male, all participated already in study [1]), performed the first tests with the goal of tracking 1 or 2 balls out of 10 with either visual or tactile feedback (conditions are called v1, v2, t1 or t2). As performance measures we define the tracking score (TS) as the percentage of correctly tracked balls, the BCI true positive rate (TP) as the percentage of correct BCI commands delivered in the highlighting period (maximum 1 command possible per period) and the BCI false positive rate (FP) as the ratio between BCI commands delivered in the free moving period (intentional non-control, where no commands should have been delivered) compared to the number of highlighting periods.

Exemplary for one subject the detailed results are: TS varied between 100 % in t1, 75 % in v1, 55 % in t2 and 40 % in v2, with a TP of 73 % in t1, 75 % in v1, 65 % in t2 and 50 % in v2, and with a FP of 40 % in t1, 55 % in v1, 15 % in t2 and 70 % in v2. The other subjects showed similar behaviors, but with different performance levels (e.g. TP of 30 %). Overall in all subject, the TS was reduced in the visual conditions compared to the tactile ones, and further reduced if the number of targets was increased. The TP ratio was stable over the two feedback types, but seems to be reduced if more targets have to be tracked.

Participants reported that especially an existing bias in the BCI classifier, was dragging too much attention away from the search task, since the subject had to fight all the time against the misclassification. Otherwise if the tracking task was performed with higher priority the number of FP or wrong commands increased. Furthermore, the BCI decision thresholds and the duration of the highlighting period have to be mutual adjusted, so that there is more and longer chance to deliver correct commands. Currently some correct commands have been delivered shortly after the end of the highlighting period (which would be FP) since it took longer to identify the correct command side and then bring the BCI feedback towards it.

Nevertheless, we realized that the original goal of tracking 3 balls out of 10, while delivering BCI commands in (randomized) defined orders is very challenging and mostly too complex. Subjects even reported that they forgot the target class (cue) within one run, since the workload was too high, which of course is contra productive to the goal of the game.

Therefore, we are currently modifying our setup according to following parameters:

1. Keeping the BCI target class (which has to be delivered if a tracked ball is highlighted) predefined for the whole run or even session and not changing it every trial. This will not have any effect on the balance of BCI commands to be delivered, since anyway just half of the time the tracked balls are highlighted.

2. Characterization of the maximum possible balls to be tracked and the maximum speed of the balls, without BCI control but while delivering faked BCI commands. The idea thereby is, that the subject is experiencing the same BCI feedback characteristics (as it would be during brain control), but the subjects are not delivering mental commands. Instead they are sending the commands via the keyboard (to have a 100 % success rate), which are then influencing the BCI feedback towards the left or right side.

4 Discussion and Future Work

The presented platform is giving us the possibility to evaluate different multi-tasking parameters. The strong link between the challenging visual multi-object tracking task and BCI feedback in coordination with the presented stimuli is a perfect simulation environment of a real brain-actuated device.

Unfortunately, the initial experiments were too challenging and complex, so that modifications and a deeper characterization of the game parameters are necessary. Furthermore, an unbiased classifier should be applied and an additional standard BCI online recording before and after the experiment should be performed. Based on the outcome of the characterization, we will modify the tracking time and paradigm, the number of balls and the used speed, so that there is a chance to succeed in the task during easier levels, while it will be very challenging at higher levels, and then re-do the experiments.

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