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Applying Brain-Computer Interfaces outside the lab – Piloting a plane with active BCI

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Abstract

The precursor study presented here describes one further step towards investigating active BCIs in realistic scenarios. We invited six trained pilots to control horizontal flight in a flight simulator via an active BCI. Performance was tracked via standard BCI measures and performance in operational flight tasks. Results indicate that standard BCI setups can indeed be used in realistic scenarios outside of the laboratory.

1 Introduction

Previous work has investigated active BCIs [6] based on motor imagery in lab studies (see [1] for example). As BCIs are intended to be applied in real world scenarios the question arises whether the methodology developed in recent years is also reliably working in more complex and less controlled environments. From a human factors perspective it is of interest whether users can use a BCI while interacting with a technical system in a realistic setting [5]. In the precursor experiment we are presenting here we addressed these questions by investigating motor imagery-based BCI control in a flight simulator. Experienced pilots controlled a plane in the horizontal axis while performing operational flight tasks.

2 Setup

Six pilots with different levels of experience were invited to participate in our experiment. In each run the participants occupied the left seat in a flight simulator. The simulated outside world view was projected on a cylindrical 180° screen round the fixed-base cockpit. The instruments provided to the subjects comprised classical (backup) instruments (airspeed indicator, attitude indicator, altimeter and magnetic compass) as well as a research display, which showed attitude, airspeed, altitude, vertical speed, flight path angle, heading, turn rate, a brain signal feedback with a delay of 1 second and task specific elements. Two types of flight control were investigated. Control type A enabled the pilot to change the rate of turn directly (direct mapping). Control type B provided a turn rate only if the BCI input exceeded a threshold, and automatically returned to straight flight otherwise.

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3 Experiment

3.1 Calibration

Before online flight control each participant generated calibration data. Based on data from these trials a BCI classifier was trained for each participant individually. Each trial had a sequence of fixation, command and relax states. This sequence was communicated by objects displayed in the center of the screen. Fixation was indicated by a cross displayed for 1 second. It was then replaced by a letter randomly drawn from the set {L,R,F}, which was displayed for 4 seconds. Participants were advised to consistently imagine a specific movement with their left hand (L), their right hand (R) or their foot (F), respectively. Each calibration session had 120 trials (40 trials per class) in total, subdivided by breaks of 60 seconds after 40 trials.

3.2 Application

The resulting BCI was then applied to lateral control in simulator scenarios. Altitude and throttle were controlled automatically by the simulator. As all pilots were familiar with the controls and displays of the simulator, tasks were communicated through the displays. Either a marker on the Horizontal Situation Indicator (HSI), indicating a specific angle to take (heading bug), or the alignment of the main axis of the plane (lubber line) with a course select pointer on the HSI (localizer) was used for this purpose. Participants were advised about the tasks by the experimenter before the application experiment began. The application had three stages. Participants flew all stages with both controls (as described in section 2). The order of control types was permuted over participants.

Turns. The task was to follow steps of the heading bug on the HSI, i.e. to acquire and hold a given heading. The pilot was advised to always choose the shortest turn to acquire the next heading and, if possible, to turn with standard rate of turn ($3°/s$). The sequence of steps has been selected to be random appearing with an equal number of left and right turns.

Tracking. In the tracking task, pilots were instructed to follow the heading bug on the HSI. This time, however, the heading bug oscillates about the initial heading. The forcing function of this tracking task was composed of 10 different sine waves, so that it was randomly appearing.

Approach with offset localizer and visual landing. The task was to first intercept the offset localizer, and then track it [3]. As there were no outside visual references in this stage, it was not apparent to the pilot that the localizer was offset. When the aircraft descended below 500ft above ground level, the runway became visible. The pilot now ignored his navigation instruments and continued the approach only by outside visual references. Since the first part of the approach was offset, the pilot was forced to conduct a sidestep maneuver. After that, he tracked the runway centerline. The simulation ended just before touchdown.

4 Analyses

BCILAB [2] was used to calibrate classifiers for all pairwise comparisons of classes. Features were extracted with standard parameters for Common Spatial Patterns [4] on time windows between 1 and 3 seconds after task onset. The classifier with best cross-validation estimates was then used in online application. Flight performance was tracked by diagrams indicating the deviation of the optimal target heading.

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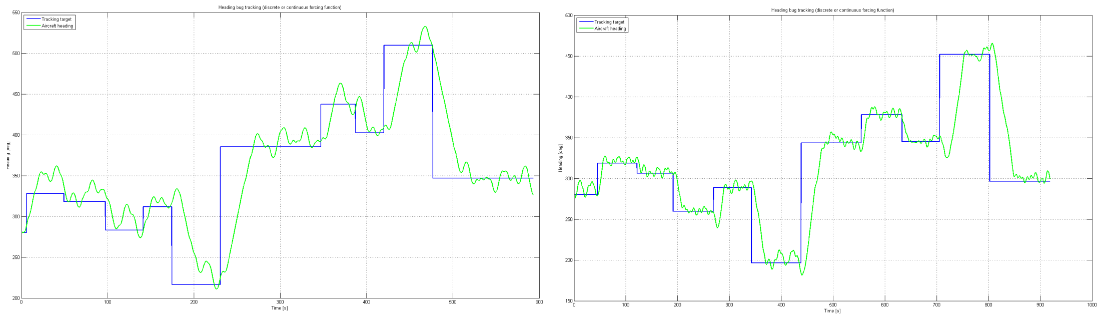

Figure 1: Examplary flight diagram for control type A (left) and control type B (right) during turns. The blue line indicates the optimal target heading, the green line the actual flown target heading. X-Axis is in seconds, Y axis is heading in degree.

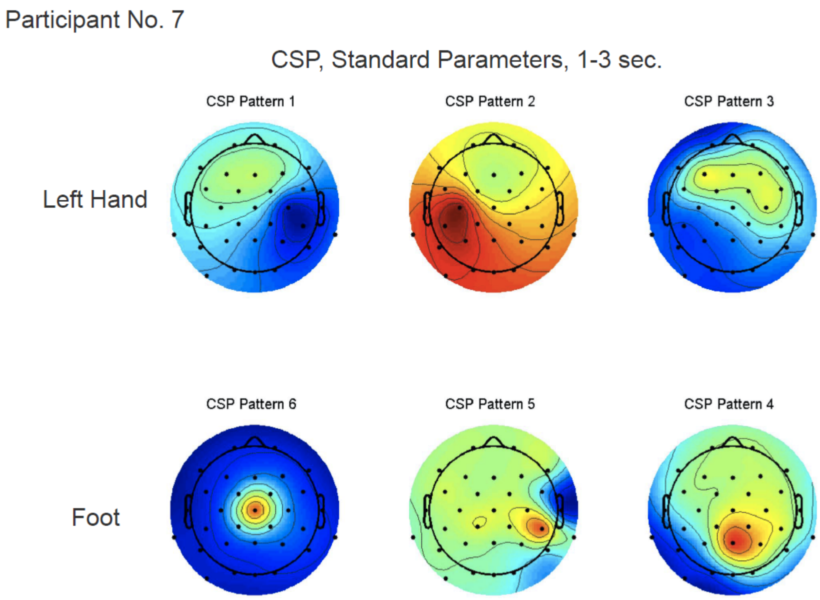

Figure 2: Common Spatial Patterns selected for Participant 6. Discriminating between classes 'left hand' (upper row) and 'foot' (lower row). Pattern 1 focuses on the right motor cortex, while pattern 2 aims at the left motor cortex inversely weighted and pattern clearly weights the central motor cortex.

5 Results

Table 1 shows cross-validation estimates of the chosen classifiers (left column), while figure 2 shows the chosen CSPs for the best performing participant (no. 6). Online flight performance is shown exemplarily for participant no. 6 in the 'turns' condition for control type A and control type B (figure 1). Participants were asked whether they felt having control. Participants with high classification accuracies stated to have control while participants with low accuracies did not (see table 1, right column).

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	CV acc.	Participant reported having control?
Participant No. 1	98	yes
Participant No. 2	58	no
Participant No. 3	51	no
Participant No. 4	64	no
Participant No. 5	89	yes
Participant No. 6	95	yes

Table 1: Best classification accuracy from pairwise comparisons of the classes via cross validation.

6 Discussion and Outlook

The results of this precursor study indicate that a one-dimensional control via active BCIs is applicable in real world applications. Interestingly the group of participants was divided in two subgroups. One group had almost perfect control while the other had no control at all. In future studies we will investigate whether this is a stable effect and whether the participants show a similar result in standardized lab-studies. As the aircraft's flight dynamics have an impact on control as well, we will also investigate further improvements of the flight controller.

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