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Practicing fast-decision BCI using a "goalkeeper" paradigm

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Introduction

Brain-computer interfacing (BCI) aims at providing paralyzed patients with a communication device that obviates the need of using the usual motor pathways. A large number of BCI systems is based on motor imagery for encoding the user's intention. Motor imagery typically leads to event-related desynchronization (ERD) of the 10 Hz mu-rhythm in the motor cortex associated to the respective limb. This EEG phenomenon can be used for feedback control for most subjects by a classifier that was individually trained on the subject's EEG [1,2]. We introduce the goalkeeper paradigm that aims at improving online BCI performance by subject training under time pressure conditions.

Methods

Multi-channel EEG of eight BCI-experienced subjects was acquired while they were playing three runs (100 trials each) of a BCI-controlled computer game that imitated the task of a goalkeeper during a penalty kick. During a trial, a ball was moving from the top of the screen towards one of its bottom corners. Using two different types of motor imagery (chosen from left hand, right hand and foot) the subjects had to control the horizontal movements of a bar at the bottom of the screen to catch the ball. Consistent with the goalkeeper metaphor, the bar could only be moved once (like a jump) into one or the other corner. The speed of the ball increased linearly from trial to trial and over the three runs. Subjects had to catch the ball within 2500 ms (at the beginning of run 1) to 1250 ms (at the end of run 3). Late arrival in a correct corner or arrival in a wrong corner were interpreted as misses. To achieve a constant goalkeeping performance, the subjects were thus required to generate faster and/or stronger ERD responses in the later runs to steer the bar quickly into the correct corner. In an offline analysis, the goalkeeping per-

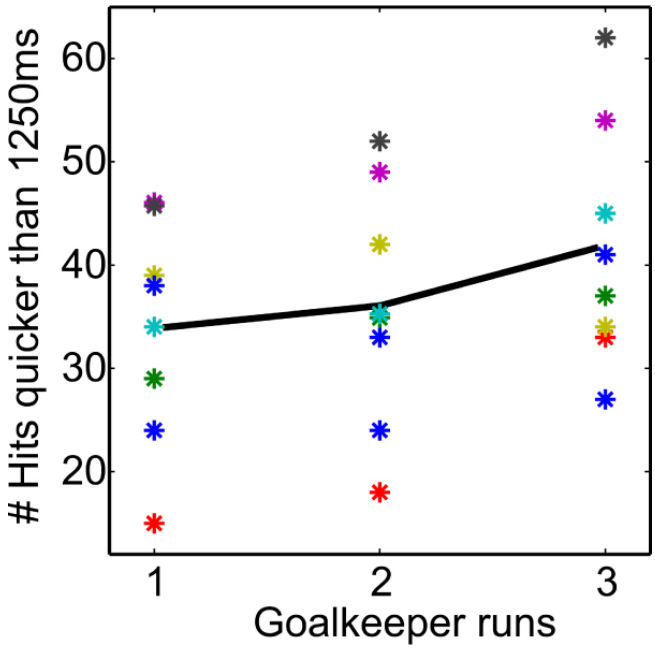

Figure 1
Reaction time improvement for 8 subjects.

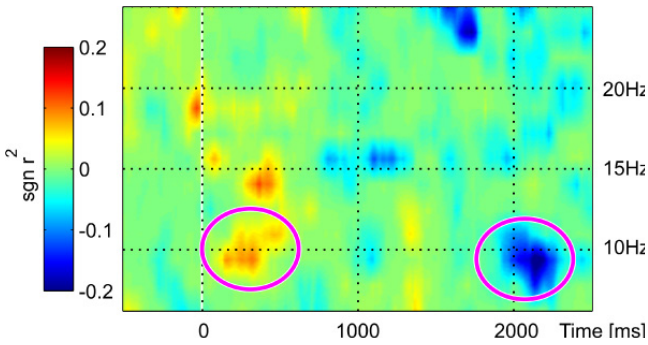

Figure 2
Earlier ERD and earlier ERS around 10 Hz for quicker trials in run 3.

formance, the reaction times (defined as the time needed to reach the correct corner) and EEG features were analyzed in relation to the block design of the experiment.

Results

The goalkeeper paradigm effectively increased time pressure over the 3 runs. Performance was measured in terms of balls caught within the first 1250 ms. Seven out of eight subjects managed to respond with increased performance from run 1 to 3 (average of 33.8 balls caught in run 1 to 41.6 in run 3, see Figure 1).

A close analysis of time-frequency EEG features between successful trials of run 1 and 3 revealed different subject strategies, e.g. earlier ERD or stronger ERD in the alpha band under time pressure. As a side effect, the training introduced for some subjects an additional ERD in the beta band (which had not been used for feedback). Earlier re-synchronization (ERS) could be observed for some subjects in run 3, where trials were shorter (Figure 2).

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