

Towards an EEG-based Covert Attention Brain-Computer Interface (BCI) Training Procedure for Soccer Goalkeepers

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Introduction:

Current sport-training procedures mostly focus on physiology and biomechanics. We hypothesise that training athletes' cognitive abilities could contribute to further improve their performance. BCIs allow for the design of ElectroEncephaloGraphy (EEG)-based cognitive enhancement training procedures as long as EEG-correlates (**C1**) specific to the target cognitive ability, (**C2**) measurable on a single-trial basis and (**C3**) related to athletes' expertise or performance can be identified.

We present preliminary results on the possibility of using BCIs for a cognitive enhancement training procedure aiming to increase soccer goalkeepers' performance through the improvement of their Covert Visuo-Spatial Attention (CVSA) abilities. Indeed, it is essential for these athletes to have high CVSA abilities, i.e., to be able to covertly commit attention to an object located in their peripheral vision field [1]. CVSA has been shown to elicit α -synchronisation over parieto-occipital areas ipsilateral to the attended vision hemi-field [2]. This α -synchronisation reflects an inhibitory process aiming to allocate more resources to the target location. The suitability of this pattern for controlling BCI-based applications [3] and for rehabilitation [4] has been investigated. Here, we aim to assess whether this pattern meets the conditions C1-3 and is thereby suitable for a BCI training dedicated to goalkeepers' cognitive enhancement.

Material, Methods and Results:

17 experienced soccer goalkeepers took part in a 2-session study. Each session included 4 runs of 32 trials. Goalkeepers had to look at a central cross and, based on the cue, covertly attend one of the 4 targets located at each corner of the screen (Figure 1A). 500-2000ms after the cue, a '+' or 'x' sign was displayed on the target for 200ms. Participants had to indicate which sign they perceived. Goalkeepers' expertise was set according to the level at which they evolve in the French championship. Their performance was assessed through a multiple-object tracking task completed at both the beginning and end of each session. Data were spatially filtered using a small Laplacian. The Power-Spectral Density (PSD) was computed within 1s sliding windows (62.5ms steps). For each subject, we computed the Individual Alpha Peak (IAP) and extracted the α -power band accordingly (IAP \pm 2Hz). Finally, we identified two Regions of Interest (RoI): Left (P7-P1, PO7, PO3, O1), Right (P8-P2, PO8, PO4, O2); and computed the Lateralization Index (LI) as: [α -power_{Left} - α -power_{Right}]. Main results:

C1: Consistently with the literature, grand-average analyses revealed that the LI was positive/negative when the target was located on the left/right vision hemi-field, respectively (Figure 1B). A main effect of the target location on the LI was revealed [$F(1,16)=11.21$, $p<.0001$].

C2: A Quadratic Discriminant Analysis classifier was trained using as features the amplitude and latency of the LI during the last 500ms of the trial. Average classification accuracy (n-fold cross-validation) was around chance level (Figure 1C). A second classifier was thus trained based on the most discriminant PSD features. It gave significantly higher performances ($p<.05$).

C3: We investigated the relationship between goalkeepers' expertise, CVSA performance and the amplitude and latency of the LI. The different correlation analyses (corrected for multiple comparisons) revealed no significant results, which might be due to the small sample size.

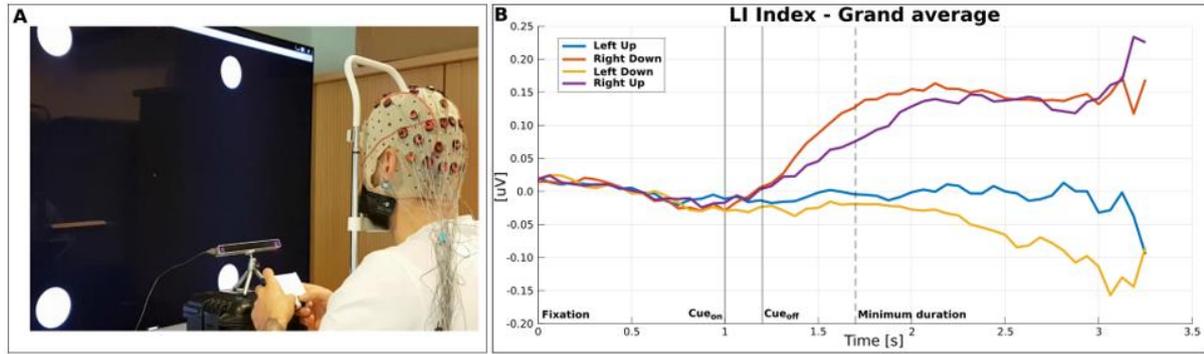


Figure 1. [A] Participant performing the CVSA task. [B] Average evolution of LI during the trial for each target location. Vertical plain lines represent the timelapse during which the cue was displayed, the dotted vertical line indicates the moment when the sign appeared for the shortest trials.

Discussion:

Although LI is a main EEG correlate of CVSA, it is seemingly not robust enough to be exploited at single-trial level. Conversely, subject-specific PSD features (α -band, parieto-occipital channels) seem to be good candidate for online CVSA BCI. This is in line with the strategy currently adopted in motor-imagery based BCIs, where specific channels/frequencies are selected for each subject. These results pave the way for a BCI training procedure dedicated to goalkeepers' cognitive enhancement.

Significance:

While BCIs are promising for cognitive enhancement, they are still scarcely explored for improving athletes' performance. Because cognitive abilities greatly influence sport performance, this approach could have a huge impact in sport sciences.

References:

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