Assessment of the P300 Evoked Potential Latency Stability During C(o)vert Attention BCI

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Abstract. Recently several researchers proposed different P300-based Brain Computer Interfaces which can be controlled even with impaired eye movements (covert attention). However, in all the comparative studies, authors detected lower accuracy for the covert attention modality with respect to the overt one. This study aims to investigate if this decrement correlates with lower stability of the P300 potential evoked during the task. We evaluated the latency jitter of the P300 potential peak evoked by two BCI spellers exploiting overt and covert attention. We found that the P300 latency jitter is significantly higher and accuracy is significantly lower for the covert-attention BCI speller. Considering these results we can conclude that the reduced performance of BCIs based on covert attention could be only partially explained by the absence of discriminant short-latency Visual Evoked Potentials (VEP).

Keywords: Brain Computer-Interface, P300, Latency jitter, C(O)vert attention, Wavelet analysis, NASA-TLX

1. Introduction

The Farwell and Donchin's P300 Speller interface is one of the most widely used BCI paradigm for text writing. Recently, some authors showed that the P300 Speller recognition accuracy significantly decreases when the eyes movements are impaired [Brunner et al., 2010]. User interfaces specifically designed to be operated in absence of eyes movements have been recently reported [Treder et al., 2010; Liu et al., 2010; Aloise et al., 2012]. In all the comparative studies, authors have shown a decrease in system performance using interfaces in covert attention condition with respect to the overt attention one, and they related the overt task based spelling success mainly on the Visual Evoked Potential (VEPs) measured at occipital and parieto-occipital sites [Treder et al., 2010; Aloise et al., 2012]. Also, [Thompson et al., 2013] demonstrated that accuracy achieved with P300 Speller, was strongly correlated with the P300 latency jitter. This study aims to investigate whether the decrease in system performance is fully explained by the absence of VEPs, or if it correlates with a lower stability of the P300 evoked potential elicited in covert attention condition with respect to overt attention one.

2. Material and Methods

Nine healthy female subjects were involved in this study (mean age 27 ± 5). Scalp EEG signals were recorded (g.USBamp, gTec, Austria, 256 Hz) from 8 positions (Fz, Cz, Pz, Oz, P3, P4, PO7 and PO8, referenced to the right earlobe and grounded to the left mastoid). The stimulation interfaces consisted in: i) the P300 Speller, a 6 by 6 matrix containing 36 alphanumeric characters; ii) the GeoSpell interface, in which characters are organized in 12 hexagonal groups of 6 characters each [Aloise et al., 2012]. Each subject performed 4 recording sessions in different days. A session consisted of 6 runs of 6 trials. Each trial (consisting of 8 stimulation sequences) corresponded to the selection of a single character displayed on the interface. Each stimulus was intensified for 125 ms, with an Inter Stimulus Interval (ISI) of 125 ms. At the end of each half-session (3 runs using P300 Speller or GeoSpell), subjects were required to perform the NASA-TLX (Task Load Index [Hart et al., 1988]) workload assessment, in order to evaluate the workload perceived by the subject using the two interfaces. For each participant, BCI performances were assessed offline, according to the number of stimulation sequences averaged during each trial. We used a Stepwise Linear Discriminant Analysis (SWLDA) to select the most relevant features that allowed to discriminate Target stimuli from Non-Target ones. In particular we performed a 3 fold cross-validation exploring all the possible combinations of training (2 runs) and testing (1 run) data set for each session and interface. The maximum Written Symbol Rate (WSR, symbols/minute [Liu et al., 2010]) was calculated for each iteration as a function of the number of stimuli repetitions in the trial. Furthermore, we excluded the contribution of the VEPs in the performance evaluation in order to take into account only the P300 ERP. Only for the P300 Speller interface, we evaluated performances taking into account both VEPs and no-VEPs contribution. In this way, the EEG signal was reorganized in overlapping 600 ms long epochs starting 200 ms (0 ms for the P300 Speller with the VEPs contribution) after the onset of each stimulus. Also, we evaluated the latency of the P300 evoked potential for each trial, in order to estimate the latency jitter for each interface. In this regard, we applied a method based on the Continuos Wavelet

Transform (CWT) and the estimation of the empirical Cumulative Distribution Function (CDF), in order to enhance the signal (P300) to noise (spontaneous EEG) ratio [Hu et al., 2010]. At this point, we first estimated the inverse CWT for each trial, and we detected the latency of the P300 potential as the highest peak of the signal into the epoch. Therefore, we assessed the distribution of the P300 latency for each subject, for a total of 72 trials (4 sessions, 3 runs, 6 trials) for each interface. We evaluated the jitter of the latency subtracting the 3rd and the 1st quartile of the distribution.

3. Results

Results showed a significant decrease in the jitter of the P300 latencies during the P300 Speller task ($p < .05$), with respect to the GeoSpell interface. Furthermore, performance achieved with P300 Speller in terms of WSR, were significantly higher ($p < .05$) with respect to the GeoSpell interface. Finally, NASA-TLX results showed a lower (but not significant) workload perceived by the subjects using P300 Speller with GeoSpell.

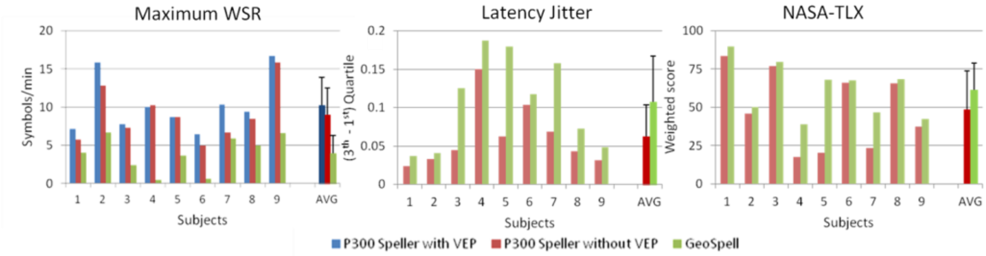

Figure 1. *Maximum value of WSR, P300 latency jitter over exemplary channel (Cz) and weighted NASA-TLX score (mean and standard deviation) over all subjects for each interface.*

4. Discussion

The aim of this study was to investigate whether the decrease in system performance using GeoSpell interface in covert attention condition could be related to a low stability of the P300 potential evoked during the task. We evaluated the P300 latency jitter and performances of nine healthy subjects during the two tasks, excluding the VEPs contribution during the feature extraction stage. The results showed an increase in the P300 latency jitter, consistent with performance evaluation. Preliminary findings indicated that even in the absence of VEPs, the P300 Speller interface used in overt attention modality reaches greater accuracy with respect to the GeoSpell one used in covert attention. Furthermore, both the accuracy and the latency jitter significantly change comparing overt and covert tasks. This result could indicate that the low stability of the P300 evoked potential during the covert task would be one of the causes of the significant decrement of the system performances. Further investigations will address the neurophysiological causes of the high jitter detected during the covert task. A possible hypothesis is that the covert attention modality induces a higher variability of the time needed for the perception and categorization processes of the stimuli. Also, a method to estimate the P300 latency for single epochs could be used to decrease the P300 latency jitter online, improving the system performances.

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