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Attentional processes during P3-based Brain Computer Interface task in amyotrophic lateral sclerosis patients

A. Riccio[1], F. Schettini[1,2], L. Simione[3], A. Pizzimenti[4], M. Inghilleri[4], M. Olivetti[5], D.Mattia[1], F. Cincotti[1,2]

[1] Fondazione Santa Lucia, IRCS, Rome, Italy; [2]DIAG, Sapienza University of Rome , Italy; [3]Institute of Cognitive Sciences and Technologies, CNR, Rome, Italy.; [4]Department of Neurology and Psychiatry, Sapienza University of Rome, Italy; [5]Dep of Psychology, Sapienza University of Rome, Italy

*Via Ardeatina, 306 I-00179 Rome, Italy. E-mail: a.riccio@hsantalucia.it

Introduction: To be available for a wide range of end-users a brain-computer interface (BCI) should be flexible and adaptable to end-users' cognitive strengths and weaknesses. People's cognitive abilities change according to the disease they are affected by, and people suffering from the same disease could have different cognitive capacities. We aimed at investigating how the amyotrophic lateral sclerosis (ALS) disease, and two different cognitive attentional aspects [1] influenced the usage of a P3-based BCI.

Material, Methods and Results: Thirteen participants with ALS diagnosis and 13 healthy participants, matched for age and years of education, participated in the study. Both groups performed a P3-based BCI task (P3-speller [2]) and were screened for attention substrates by means of a rapid serial visual presentation task (RSVP; [3]).
Aims of the statistical analysis are listed in the following. *i)* First, to investigate ALS influence on BCI usage, by comparing the two groups in terms of BCI performance (ITR scores), amplitude and latency of N2 and P3 ERPs. Furthermore we calculated the influence on ITR scores, of the coefficient of determination R-square estimated within N2 wave interval (N2-Rsquare) and within P3 wave interval (P3-Rsquare). We assumed that the two variables mostly reflected the contribution of N2 wave and of P3 wave respectively, on performance in BCI control. *ii*) The second aim was to investigate whether attentive subprocesses measured with the RSVP (T1%= index of participants' temporal attentional filtering capacity; T2%=index of the capacity to adequately update the attentive filter) were predictors of the BCI control (ITR). *iii*) Third aim was to compare the two groups in terms of T1% and T2%.
Results showed that i) ALS had an influence on BCI usage: participants with ALS had lower ITR scores ($p<.05$) and longer P3 latency ($p<.05$) in comparison to healthy participants; no differences between the two groups were found in N2 and P3 wave amplitudes and in N2 wave latency; in participants with ALS, N2-Rsquare -but not P3-Rsquare- was significantly predictive of ITR scores with a Beta of 0.59 ($p<.05$). *ii*) T1% -but not T2%- was a predictor of ITR scores ($p<.05$) and P3 wave amplitude ($p<.05$) and *iii*) T1% was compromised in participants with ALS ($p=.01$).

Discussion: Results showed that ALS affected the capacity to accomplish the P3-speller task (ITR scores) and the latency of the P3 wave. We speculate that the disease affects attention modulation, when perception (reflected by N2 wave) was complete, by delaying the storing of the target in working memory and the context update processing stage (reflected by P3 wave latency). ALS also influenced another temporal aspect of selective attention i.e. the capacity to temporally filter a target stimulus within a stream of stimuli (T1%), which was related to BCI control (T1% correlate with ITR). Moreover N2-Rsquare significantly predicted BCI performance: we therefore identify the temporal aspects of attentional processing as a limitation for successful interaction between people with ALS and BCI. Conversely N2 modulation (which was not influenced by the disease) could be further exploited for classification, thus improving BCI control.

Significance: Our data partly clarify cognitive features influencing P3-based BCI control in people with ALS. The temporal aspect of the stimulus processing is a crucial point to be taken into account when developing BCI devices which should be specifically designed considering the cognitive characteristics of end-users.

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