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A novel BCI based rehabilitation approach for aphasia rehabilitation

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Introduction: Current scientific opinion considers language as an interaction of ventral and dorsal systems mainly on the left hemisphere and stroke-induced language disorders (aphasia) as the results of a lesion of one of these systems or of disturbed interaction [1] between them. Word production, in particular, depends onto a rapid online interaction between top-down processing (i.e. the formulation of a conceptual representation into a linguistic and phonological form) and bottom-up processing (i.e. the adaptation of speech production based on sensory input) within the dual system [2]. Conventional speech therapy is based on an open loop process, where the interaction between top down and bottom up processing is mediated by an external person, the therapist. There is a moderate evidence of the efficacy of this therapeutic approach [3]. We propose a simple brain-computer interface (BCI)-supported auditory paradigm for the rehabilitation of speech production deficits in aphasia patients. A BCI system may be utilized for monitoring and exploiting relevant cognitive states in real-time, e.g. auditory attention [4]. This shall be achieved by closing the loop between top-down execution and bottom-up perception by positive reinforcement of the patient. The reinforcement, however, will be constraint to the detection of neuronal markers of auditory attention and acoustic processing. Both aspects are prerequisites for the use of such an auditory BCI, and we are aware, that these may be affected in aphasia patients. Therefore, the primary goal of this pilot study is to clarify, whether or not stroke patients produce reliable neuronal markers of auditory attention to word stimuli, and whether such EEG responses can be decoded by a BCI in single trial.

Material and Methods: In an offline study, word ERP responses were explored in twenty elderly healthy subjects (mean age 60.20±8.04 years, normal hearing, no history of neurological deficits) and in one aphasic stroke patient (60 years). He showed a chronic severe Broca's aphasia caused by a left fronto-temporal-parietal infarct. Subjects were seated in a ring of 6 loudspeakers (AMUSE paradigm, [3]). Explicit familiarization with the word paradigm was carried out prior to the EEG recoding. Stimuli consisted of 6 bisyllabic words. Within a trial, this set was repeated 15 times in pseudo-randomized order. Stimulus onset asynchrony (SOA) was switched between experimental blocks and lasted 250 ms or 350 ms. A total of 12 trials were recorded in each of the two offline EEG sessions (64 channel passive Ag/AgCl electrodes with nose reference) for each condition.

A*Results:* Offline analysis of data from the patient and both sessions revealed that the classification of target versus non-target words, using chronological 5-fold cross-validation with a shrinkage-regularized LDA, was 71.45% (SOA = 350 ms) and 63.67% (SOA = 250 ms). The average target and non-target ERP responses of the patient were clearly separable in both conditions (Figure 1A depicts results for SOA = 250 ms). Figure 1B shows the grand average (GA) ERPs of the age-matched controls at the same SOA. The GA classification accuracy for this group was 72.85% (SOA = 250 ms).

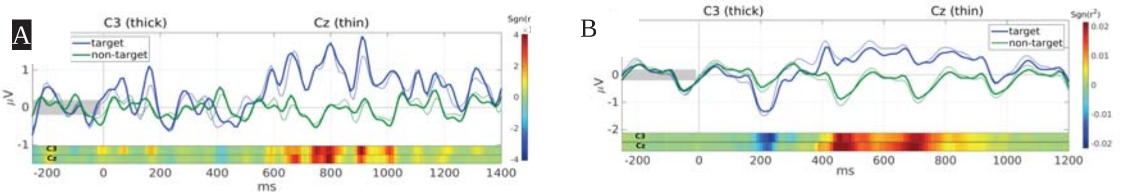

Figure 1: Comparison of average target (blue) and non-target (green) ERP responses at channels C3 and Cz upon bisyllabic word stimuli played at t=0 s and with an SOA of 250 ms. A grand average response of the aphasic patient: B: grand average responses of 20 controls. Colorbars visualize class-discriminant information as signed r² values over time.

Discussion & Significance: Although the stroke patient had severe language production deficits, he was able to perform the BCI paradigm. His target and non-target ERP responses were clearly separable, indicating that an online BCI training could be realizable for him. Based on these promising results, we are going to test other aphasia patients to further evaluate the feasibility of BCI-supported aphasia rehabilitation.

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