Optimized Stimulus Design for a Spatial Auditory BCI based on ERP

Late ALS stages result in unreliable eye control and increased secondary vision problems. In order to provide a remedy for these patients, a new spatial auditory BCI design was recently introduced [1] which is based on ERP components. As ERP effects are known to be susceptible to changes of the experimental design, this offline study explores the influence of the variables loudness, stimulus duration and inter stimulus onset (ISO) to optimize them under real-world conditions for an online study with patients.

Methods

Given written consent, healthy subjects were seated in the center of a ring of 6 speakers. During a sequence of 60 or 66 tones from different directions, a subject's task was to count the 10 (11) target tones (defined by direction and pitch) and ignore the non-target tones. EEG was recorded via 64 electrodes in an office room. A sequence realized either one out of seven loudness levels, from very quiet but above hearing threshold (52 dB) to loud (74.5 dB), during 1000ms ISO (block 1) or 300ms ISO (block 2), or one out of six stimulus durations (5ms to 300ms), again in two ISO steps.

At the time of submission, seven subjects were recorded with varying duration and six for varying loudness. The design was pseudo-randomized in the levels of the respective variable and 6 target directions. Changes in the ISO were applied blockwise during 2 blocks of at least 5000 tones each. It was ensured that successive stimulations from the same direction were separated by at least two stimuli from a different direction. To analyze the EEG data, a band pass filter in the range of [0.2Hz, 40Hz] was applied and outliers were removed (based on a fixed variance criterion). Then time windows (-50ms to 800ms around single stimuli) were cut out and baselined in the 50ms pre-stimulus interval. Binary target/non-target classification of single stimuli was performed with regularized FDA. Classification errors were estimated based on cross validation.

Results

The described experimental procedure resulted in the desired enhanced ERP effects for target stimuli. Depending on the subject, an attention-modulated enhancement of early negative component around 140ms could be observed in addition to or instead of an enhanced P3 component.

While individuals had preferences for low-to-medium loudness levels, grand-average analysis of classification errors did not reveal an optimal loudness for neither 1000ms nor 300ms ISO. However, results show increased inter-subject variance for higher loudness levels.

Individual preferences for stimulation duration were not so clear, but the grand average classification error suggested the use of approximately 40ms duration within the used setup for both ISO settings.

Discussion and Conclusions

The relatively slow setup of 1000ms or 300ms ISO (compared to [1]) reflects the necessities posed by the work with patients. Previously reported systematic increase in ERP amplitudes upon louder stimuli [2] could not be verified for the special case of the new spatial auditory BCI paradigm, such that the amplitude can be chosen according to the liking of the subject. Individual low classification rates for loud stimuli might be caused by irritations due to stronger sound reflections in the room. The clear optimum for...
medium-length stimuli is stable over ISO conditions and a useful starting point for individual optimization.

References
