Motion-based ERP spellers in a covert attention paradigm

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Overview: There is evidence that visual brain–computer interfaces (BCIs) using overt attention depend on eye movements, which limits their clinical applicability [1]. Besides, usual intensification types can be discomforting for the user. As a solution to these shortcomings, three spellers based on motion Visual Evoked Potentials (mVEPs) were developed and evaluated in this online study. mVEPs have favorable characteristics, i.e., low contrast and luminance requirements, low variability, high amplitudes and localized spatial distribution but are only recently employed as BCI input signal [2].

Methods: Eleven participants operated three mVEP spellers: Overt Motion Speller (OMS) (similar to [2]), Covert Motion Speller (CMS) and Motion Center Speller (MCS). They differed in attention modes: overt (OMS) and covert (CMS, MCS), and locus of motion stimulation: foveal (OMS, MCS) and peripheral (CMS). MVEPs were generated either by small moving bars (OMS, CMS) or a central moving grid-pattern (MCS), and all spellers adopted a vocabulary of 30 symbols.

Results: All participants successfully operated the spellers. Online spelling accuracies amounted to 97.5% for the Overt Motion Speller, 71.7% in the Covert Motion Speller, and the Motion Center Speller reached 92.4%. Spelling speed reached 2 characters/min. Classification in the OMS was mainly based on N200, in the CMS on P300, and the MCS exploited both components.

Conclusion: The motion-induced N2 component is not discriminative when the stimulus is presented in the visual periphery. However, a novel gaze-independent speller using stimulation at a central location is able to exploit both N2 and P3 components during classification.

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From visual to tactile speller

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For patients suffering from locked-in syndrome, brain–computer interfaces (BCIs) constitute a way of communicating with the environment. One well-known BCI for communication is the visual speller. However, in some patients the visual modality deteriorates with disease progression. For patients whose vision impairments become too severe to use the visual speller, a solution might be to switch to a BCI that is not dependent on eye gaze. One possibility is a speller based on somatosensory stimulation. Previous studies have shown that brain responses to tactile stimuli on the waist [1] and steady-state somatosensory stimuli on the fingertips [2] can be used to control BCIs. In a pilot study, we stimulated the fingertips of healthy participants with short mechanical taps while measuring EEG activity. The subjects were instructed to focus attention on one of the fingers by silently counting the number of taps on that finger. An increased amplitude of the P300 ERP component was found in response to stimuli on the attended finger versus stimuli on any unattended finger. This is consistent with previous findings in visual [3] and tactile [1] BCI experiments.

On the single trial level, classification rates of around 60% were reached. Information transfer rates were around 7 bits/min on average, with our best subject reaching bit rates up to 27 bits/min. Encouraged by these results, we further developed the tactile speller and evaluated its offline and online performance. Comparisons were made to the visual speller operated in both overt and covert attention conditions, taking into account classification performance as well as underlying electrophysiological responses. We assess the practical value of the tactile speller and discuss the attentional processes that may underlie its use.

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Natural stimuli for auditory BCI

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With brain–computer interfaces (BCI), one can establish a communication pathway which solely relies on neural activity. Since visual BCI paradigms might not be suitable for users with vision impairments (e.g. patients suffering from neurodegenerative diseases) [1], auditory speller paradigms have recently been investigated [2,3]. For any kind of BCI paradigm based on event-related potentials (ERPs), the choice of stimuli is crucial. In the PASS2D paradigm described in [2], nine auditory stimuli with varying pitch and direction were presented in random order with the task to count a target stimulus. It was found that concentrating on one out of the nine tones is possible, but very demanding: two out of twelve subjects could not distinguish the stimuli at all and for three other subjects, the experiments could not be finished, possibly due to fatigue. In the present offline study, the use of phonemes instead of tones as auditory stimuli was investigated to reduce the workload and to improve applicability of the PASS2D paradigm. Short phonemes, such as ‘ta’, ‘to’ or ‘it’ were recorded from three speakers, resulting in nine different spoken stimuli (125 ms each). These stimuli were used to drive a 9-class BCI in close analogy to [2]. In contrast to a BCI based on tones [2,3], all participants ($N=5$) judged the phonemes as pleasant stimuli, that were easy to concentrate on. Although natural stimuli possess a diffuse temporal structure, the observed ERPs (N200 and P300 component) were very similar to those ERPs evoked by tones. Classification performance was almost equal for both types of stimuli. It can be concluded that natural stimuli can be used for driving a BCI. Phonemes stand out as a particularly suited type of stimulus for auditory ERP paradigms, due to their short duration and close relation to speech.

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