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Effects of Stimuli Relevance on Auditory BCI

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Introduction: Individuals with locked-in syndrome (LIS) typically lose the ability to reliably direct their eyes, in addition to other motor skills, forcing a reliance on covert attention when using many well-established visual processing based EEG-brain computer interfaces. In contrast, auditory processing remains largely unaffected in many cases of severe paralysis (progressed ALS and upper spinal cord injury patients) leaving an opportunity for BCI control via auditory evoked neurological responses [1 2]. At present, most auditory brain-computer interfaces (aBCI) employ sounds designed to optimally stimulate the auditory system (e.g., pure tones) and require a visual interface. Some recent efforts have focused on speech and environmental stimuli, though few studies have eliminated visual support in the aBCI paradigm [3 4]. In this study, we employ speech stimuli and investigate two characteristics, semantic and spatial relevance, hypothesized to affect BCI performance. A positive result of this research validates the benefits of task relevant spoken word stimuli that will simplify user control, promote intuitive learning, and help maintain motivation for users of a purely auditory BCI.

Material, Methods and Results: Approximately 25 participants are being recruited to participate in an auditory BCI task that will move a cartoon icon to a target location by attending to serially presented spoken words corresponding to the desired direction (Fig 1). Decoding intended direction is accomplished through a P300 focused classification using step-wise linear discriminate analysis (SWLDA) classifier as in previous research [1 5]. Condition 1 groups semantically relevant stimuli, while Condition 2 stimuli have no lexical congruence with the direction they represent. Additionally, the stimuli ‘skill’ and ‘care’, ‘left’ and ‘right’ will be presented over loud-speakers with inter-aural level differences (ILD) and inter-aural time differences (ITD) to provide relevant spatial cues to the participant. Stimuli ‘up’, ’down’, ‘joy’, and ‘while’ will be devoid of ITD or ILD cues and will serve as spatial relevance controls. In this way both semantic and audio-spatial relevance are evaluated. Trials consist of ten presentations of each stimulus in a condition and results in a aBCI decision to move the cursor. Eight trials (80 targeted presentations) of training data will be collected for each stimulus at the beginning of each of three experimental sessions, which includes 64 trials of real-time BCI control per stimulus in a condition. The third session will include dynamic stopping of trials [4] in order to estimate the optimal information transfer rates (ITR). The order of completion of conditions will be balanced across participants.

Condition	Stimuli
1	‘up’, ‘down’, ‘left’, ‘right’
2	‘joy’, ‘while’, ‘care’, ‘skill’

Table 1 – Spoken words used in Conditions 1 and 2.

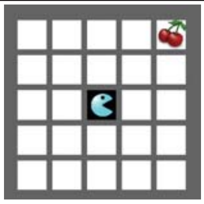

Fig. 1 – User interface screen provides target sound and BCI feedback. Blue icon’s position on the grid is controlled by the BCI system. The task is to move this icon to the {cherry} target corner.

Results of BCI performance (ITR and percent trials correct) over multiple sessions will be used to determine the importance of semantic and spatial relevance to an auditory BCI. Participants will also complete questionnaires, as previously utilized [5], to estimate task workload, ease of use and preference of stimuli in our task.

Discussion: Spatial relevance and semantic meaning of words allows stimuli to be immediately associated with the BCI task choices, facilitates high initial BCI performance and improvements in BCI user experience. The visual feedback is used here for motivation but provides no visual ERP for BCI use. Reduction of cognitive workload and increase in user motivation over previous BCIs are the expected outcomes for this system.

Significance: This study’s results will validate the feasibility and benefits of spoken word stimuli, allowing future studies to eliminate any visual component. Future developments of auditory-only BCI for users with neuromotor and cognitive impairment will benefit from our results on the relative importance of semantic and audio-spatial features of task relevant stimuli. Thus, taking another major step toward creating a clinically effective communication system.

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