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Movement-based navigation of a matrix-speller via EEG

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Introduction: Restoring communication for locked-in patients is an important task to improve their quality of life [1]. Although invasive methods have demonstrated great advances, they are associated with surgical implantation and therefore not feasible for all patients. Non-invasive methods such as electroencephalography (EEG) can offer an alternative. The current study investigates the implementation of a training paradigm and online matrix-speller to restore communication via movement detection using EEG. Such spellers offer an alternative to P300-spellers for locked-in patients or people with cerebral palsy [2]. The paradigm was designed to enable fast, cue-based data collection. This preliminary study explored the general feasibility of the approach with five healthy participants.

Material, Methods and Results: Participants executed two paradigms: a training paradigm and an online spelling task. The training paradigm consisted of three cue-based runs and one run of self-paced movement execution. During cue-based runs, participants executed finger flexion whenever a rotating cross overlapped a static cross. Each run lasted $330\,\mathrm{s}$ during which 100 movements were executed. In the self-paced run, participants executed movements at times of their choosing. The online spelling task contained six runs with matrices of size 3×3 (run 1-3) or 5×5 (run 4-6). Row-column scanning was implemented by sequentially highlighting the rows until a motion was detected and the currently highlighted row was selected. Subsequently, columns were highlighted until another motion was detected and the highlighted tile was selected. In runs 1 and 4, tiles were empty and the current target tile was marked with a red dot. In runs 2,3 and 5,6, participants spelled two five-letter words with upcoming letters being highlighted in red (runs 2,5) or participants having to locate the letters themselves within the matrix (runs 3,6). Runs 1-3 and 4-6 had timeouts of 3 and $4\,\mathrm{min}$, respectively, after which the next word was displayed. Five participants (3 male, 2 female) completed the study. All participants were equipped with 60 EEG electrodes and 4 EOG electrodes for measuring eye movements. Movement onsets were tracked via motion capture software. EEG data was bandpass-filtered between 0.5 and 70 Hz and eye-artifacts were removed using the EOG channels [3]. Features were extracted by lowpass-filtering the data (cutoff frequency: 3.5 Hz), downsampling to 10 Hz and re-referencing to the common average. A shrinkage linear discriminant analysis (sLDA) was trained on data from the training paradigm to detect movement onsets from neural signals. The model was evaluated on data from the self-paced movement execution and the probability threshold of the sLDA was adapted to result in a maximum of one false positive per minute (FP/min) while achieving the maximal true positive rate. The grand average true positive rate over all matrix modes in the online spelling task was 59.1 % with a grand average of 0.87 FP/min. 65.8 % of all words were correctly completed within the timeout period.

Conclusion: The results from the spelling task show that the introduced training paradigm and the utilized model lead to an online performance feasible for spelling complete words. The success rate of 65.8 % within the timeout period shows that a useful communication can be achieved. Future work will investigate the performance of the model in people with motor-impairments and the possible adaptations of the algorithm required for these patients.

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