Auditory ERP speller applications as a tool for BCI end-users

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Background and objective

Using Brain Computer Interfaces (BCIs), one can establish a communication pathway which does not rely on muscular activity. This is a promising tool for patients suffering from neuromotoric diseases as well as for patients with locked-in syndrome. Neural degenerative diseases such as Amyotrophic Lateral Sclerosis (ALS) also cause a deterioration of vision, in particular a loss of gaze fixation. Since visual BCI paradigms might not be suitable for these patients [1], auditory speller paradigms were recently investigated [2-4]. Spatio temporal hearing has been introduced as informative cue in a BCI paradigm [2], revealing that subjects are able to focus attention to a target direction. Two online studies were performed to investigate the usability of speller paradigms with spatial auditory cues.

AMUSE Paradigm

The AMUSE paradigm (standing for Auditory MUlticlass Spatial ERP), as presented in [2-3], was adapted for online text writing. It consists of a ring with 6 audio speakers around the subject (Figure 1) which produces auditory cues in a pseudo random order. In an online experiment, participants were asked to spell two sentences: “FRANZ JAGT IM TAXI QUER DURCH BERLIN” and “SYLVIA WAGT QUICKE DEN JUX BEI PFORZHEIM.”

6 class auditory paradigm: 6 directions with a different tone at each direction
- Stimulus duration: 40ms, ISI: 175ms
- Stimulus presentation with a ring of 6 speakers
- Spelling procedure is analog to Hex-O-Spell [5]
- 21 healthy subjects, two sessions
- Early stopping in the second session

Methods

Spelling procedure

An adapted version of the hex-o-spell speller [5] was created in which characters can be selected in a two step process. First a group of letters is selected (example: A-E) by focusing on the corresponding direction. In the second step, the characters are divided over five of the directions and an individual letter can be selected. Choosing the sixth direction returns the user back to the first selection step.

Results

Performance

- 16 out of 21 subjects were able to spell
- Mean accuracy: 85%
- First session: 0.59 char/min
- Second session: 0.92 char/min

Physiology

- Early negative ERP: 90-200ms after stimulus onset in frontal lateral areas
- Late positive ERP: 280-450ms after stimulus onset in central areas

Discussion

Two auditory ERP speller paradigms are investigated in two separate online experiments. The paradigms use spatial cues presented in a pseudorandom order (oddball principle). In both studies, more than 80% of the participants could use the paradigm for a spelling task. Compared to visual paradigms, the performance (assessed to be below 1 char/min for both paradigms) is relatively low. However, as PASS2D and AMUSE can be used strictly auditorily, they may better serve the need of late-stage ALS patients with vision deterioration. With an average spelling speed of up 0.92 char/min for AMUSE and 0.845 char/min for PASS2D, these paradigms outperform all other state-of-the-art auditory BCIs [3].

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References