EEG in Dual-Task Human-Machine Interaction: Target Recognition and Prospective Memory

Abstract No:

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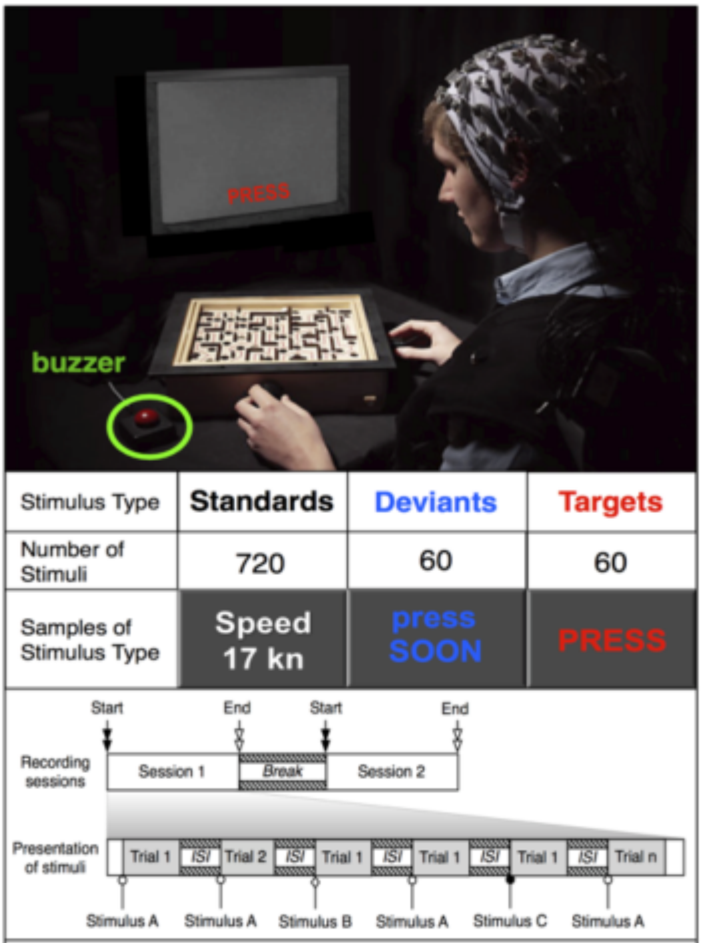
Introduction:

Studies investigating dual-task performance [Isreal et al., 1980] or retrieval of prospective memory (PM) [West 2011] gave insight into the capabilities of the brain to perform tasks in parallel and to switch between tasks [Bisiacchi et al., 2009]. However, most experiments are conducted under controlled conditions. Here, we investigate electroencephalographic (EEG) activity recorded under natural conditions during human-machine interaction (HMI) that can be used to passively support the human [George & Lécuyer 2010] in multi-task situations, e.g. telemanipulation of robotic systems and mission control [Kirchner et al., 2010]. For this passive support, the success of information processing can be predicted with the help of single-trial EEG analysis and classification [Metzen et al., 2011]. A successful execution of multiple tasks requires an efficient strategy of attention division, the detection and evaluation of important, task-relevant information, retrieval of intended action from long-term memory, post-retrieval monitoring, and task-coordination processes characterized by several overlapping event related potentials (ERPs) [West 2011]. The goal of the study was to investigate the effect of multi-task conditions on positive parietal ERP components evoked by infrequent task-relevant and task-irrelevant stimuli.

Methods:

Thirteen subjects (age: 27 to 39 years; right-handed; normal or corrected-to-normal vision; one subject was excluded due to eye artifacts) participated in the experiments (see Fig. 1). EEG was recorded with a 64-channel actiCap system (extended 10-20 system; reference at FCz; impedance below 5 kΩ; digitized with 2500 Hz by two 32-channel BrainAmp DC amplifiers [Brain Products GmbH, Munich, Germany]; filtered between 0.1 Hz to 1000 Hz). Preprocessing and averaging see Fig. 2a and 2b. The averaged data was analyzed by repeated measures ANOVA with "stimulus type" (standards, targets, deviants), "electrode location" (Fz, Cz, Pz), and "time window" (350-600ms vs. 600-850ms) as within-subjects factors and "condition" (labyrinth oddball and oddball) as between-subjects factor. If necessary, Greenhouse-Geisser correction, and for pairwise comparisons, Bonferroni corrections were applied.



Stimulus Type	Standards	Deviants	Targets
Number of Stimuli	720	60	60
Samples of Stimulus Type	Speed 17 kn	press SOON	PRESS

Fig. 1. Experimental Design: Subjects performed two tasks: oddball and labyrinth oddball within two counterbalanced sessions. In each session, subjects performed an oddball task and responded to target stimuli (randomly mixed among frequent standard and rare deviant stimuli with a ratio of 1:12:1 and an ISI of 900 and 1100 ms) by pressing a buzzer. During the oddball condition, subjects were asked to hold both knobs of the labyrinth game while focusing on a ball placed in the middle of the game board; whereas during the labyrinth oddball condition, they were requested to play the game.

Results:

Reaction time on target stimuli was 0.82 s (SD = 0.13) (labyrinth oddball) and 0.79 s (SD = 0.79) (oddball). The observed positive broad ERP complex at parietal sites is depicted in Fig. 2a and 2b. For both conditions we found a maximum in amplitude difference between the ERP form on target versus standard and deviant versus standard stimuli at electrode "Pz" [labyrinth oddball: $p < 0.001$, oddball: $p < 0.001$] (late positivity effect; see Fig. 3). For the early window, the late positivity effect on targets was under both conditions bigger than the late positivity effect on deviants [labyrinth oddball condition: $p < 0.001$, oddball condition: $p < 0.001$]. However, for the late window, a bigger late positivity effect on targets was only observed in the labyrinth oddball condition [labyrinth oddball condition: $p < 0.049$, oddball condition: p = n.s.].

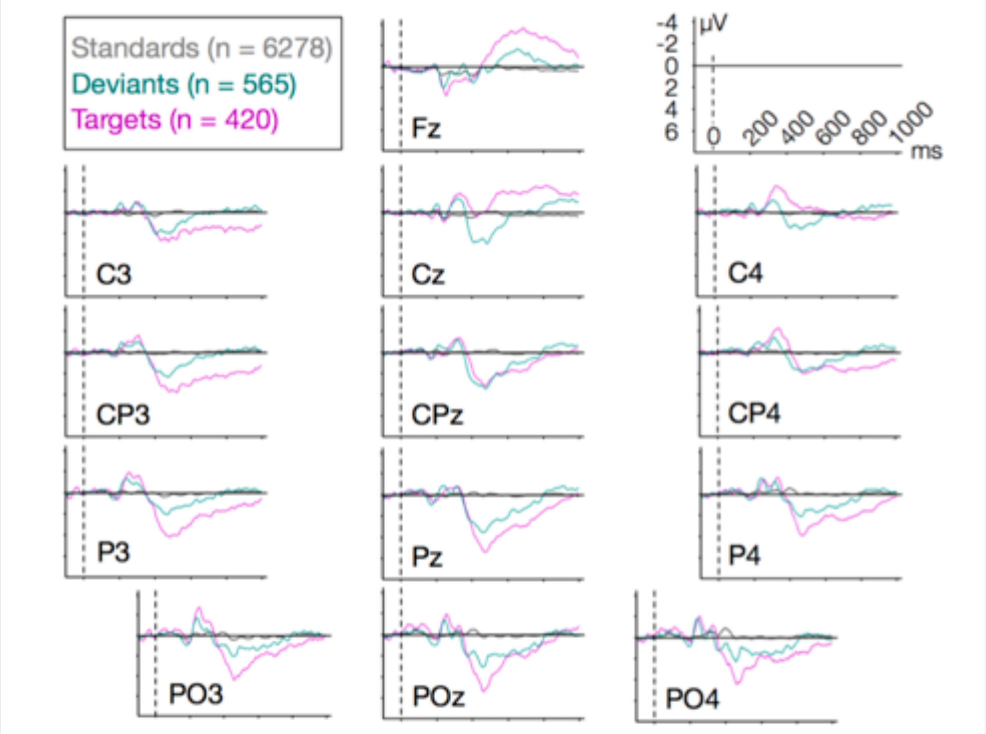


Fig. 2a. Parietal ERP Activity under Oddball condition: A broad, sustained positive activity starting at 300ms could be observed at parietal sites. EEG was re-referenced to an average reference and filtered between 0.2 Hz and 30 Hz. Segments from 100 ms before to 1000 ms ms after stimulus onset were averaged based on stimulus of interest (segments containing artifacts were rejected semi-automatically (amplitude 100/-100 µV, gradient 75 µV); target epochs required response within 200 to 2000 ms after stimulus onset).

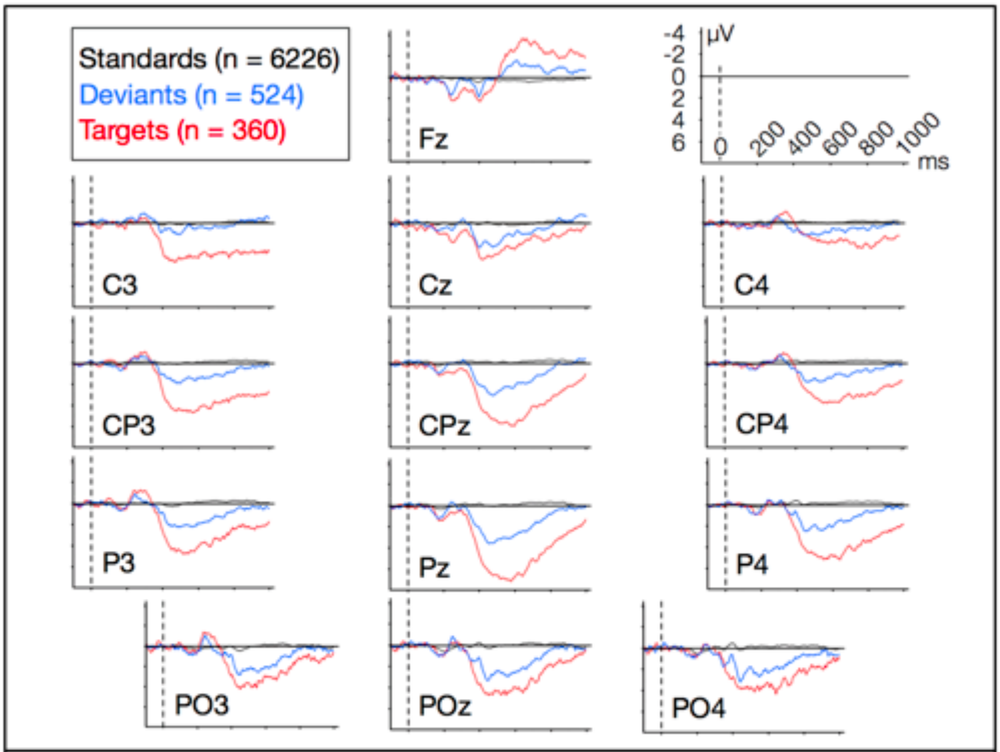


Fig. 2b. Parietal ERP Activity under Labyrinth Oddball condition: A broad, sustained positive activity starting at 300ms could be observed at parietal sites. EEG was re-referenced to an average reference and filtered between 0.2 Hz and 30 Hz. Segments from 100 ms before to 1000 ms ms after stimulus onset were averaged based on stimulus of interest (segments containing artifacts were rejected semi-automatically (amplitude 100/-100 µV, gradient 75 µV); target epochs required response within 200 to 2000 ms after stimulus onset).

Conclusions:

Our results indicate that complex behavior in natural scenarios not only requires attention and target detection [Kok 2001; Polich 2007] but dual-task performance and PM retrieval [Bisiacchi et al., 2009; West 2001]. We could show that dual-task behavior during HMI elicits a broad parietal positive ERP complex on target stimuli distinct from ERP activity on infrequent deviant stimuli (see Fig. 3). The significant difference of the later part of the parietal positive ERP complex evoked by the cognitive processing of irrelevant infrequent stimuli versus task-relevant infrequent stimuli might be detectable by a classifier. Hence, results found in this study are highly relevant for the improvement of the passive support of HMI by the prediction of cognitive states, i.e., the prediction of successful recognition of task-relevant stimuli [Kirchner et al., 2010; Haufe et al., 2011].

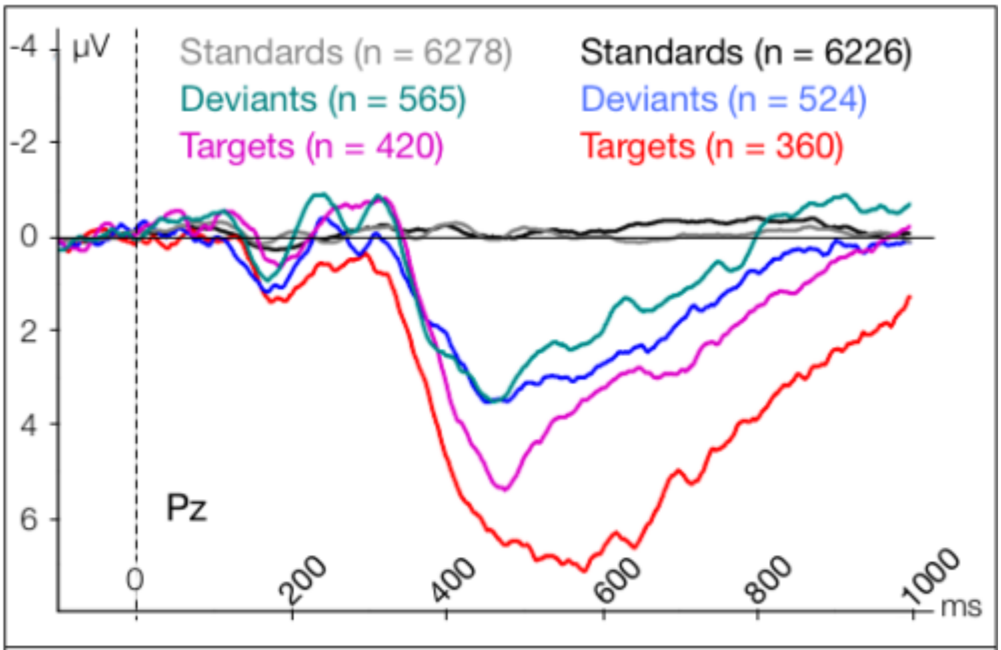


Fig. 3. ERP Activity at Electrode Pz: Broad sustained ERP activity on deviant and target stimuli under both conditions at electrode Pz starting at 350 ms. We found a bigger late positivity effect on targets for the late window in the labyrinth oddball condition compared to the oddball condition.

Motor Behavior:

Brain Machine Interface

Abstract Information

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