Dry EEG measurement of cognitive load during sitting, standing, and walking

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Introduction

- **Cognitive load**, or mental effort, is important in the evaluation of assistive technologies (e.g., prostheses[1,2], powered wheelchairs[3]).
- Prosthesis wearers experience mobility limitations that lead to:
  - Difficulty in challenging environments (e.g. uneven terrain, hills, stairs)[4-7]
  - Restricted walking ability[8,9]
  - High incidence of falls[7,8,10-12]
- **Cognitive load** during walking is poorly understood, and a *better understanding of cognitive load could inform prosthetic interventions*.[13]
- Oddball paradigms in electroencephalography (EEG) elicit event-related potentials (ERP) which provide a measure of attentional resources.
  - The **P3 event-related potential** (i.e. the 3rd positive peak in ERP) decreases and its onset is delayed as cognitive load increases, as shown in complex mobile tasks such as cycling[14].

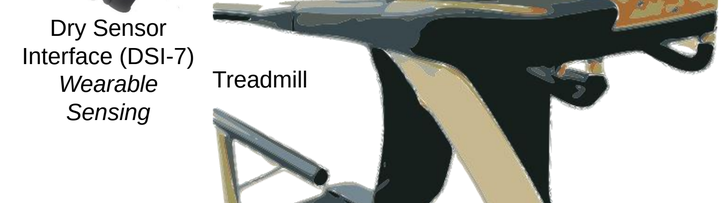

Fig. 1 Example of a P3 peak in the ERP. P3 amplitude represents the summation of processing of stimuli.

Setup

Fig. 2 EEG electrode placement used in the DSI-7, picture of the DSI-7, and participant during treadmill walking (right).

Procedure

- EEG collected via a 7-channel dry EEG (DSI-7, Wearable Sensing) from 10 participants (22 ± 3 years), in accordance with Northwestern IRB. One subject was excluded from the analysis due to cardioballistic artifacts in the EEG (N = 9).
- **Auditory stimuli** included 10% oddball tones (1200 Hz) and 90% standard tones (900 Hz) in approx. 1-sec intervals (675-1365 ms).
- **P3 amplitude** was measured from ERP to determine the cognitive load at each timepoint[15,16]

EEG Processing Pipeline

EEG was band-pass filtered between 0.5-30 Hz
↓
Infomax ICA was applied to EEG
↓
EEG was epoched from -200 to 800ms
↓
Artifactual epochs were identified from ICA components and removed from the dataset
↓
Excess trials were excluded so that each subject had the same number of trials (37 per condition)
↓
P3 was measured from 250-350 ms in grand average ERPs

Results

Dry-EEG measurement of **cognitive load** during sitting, standing, and walking was not correlated with head motion.

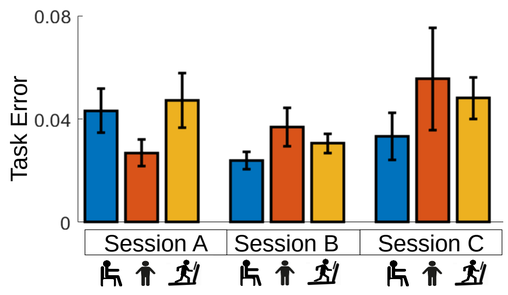

Fig. 3 Task error was not significantly different across condition or session.

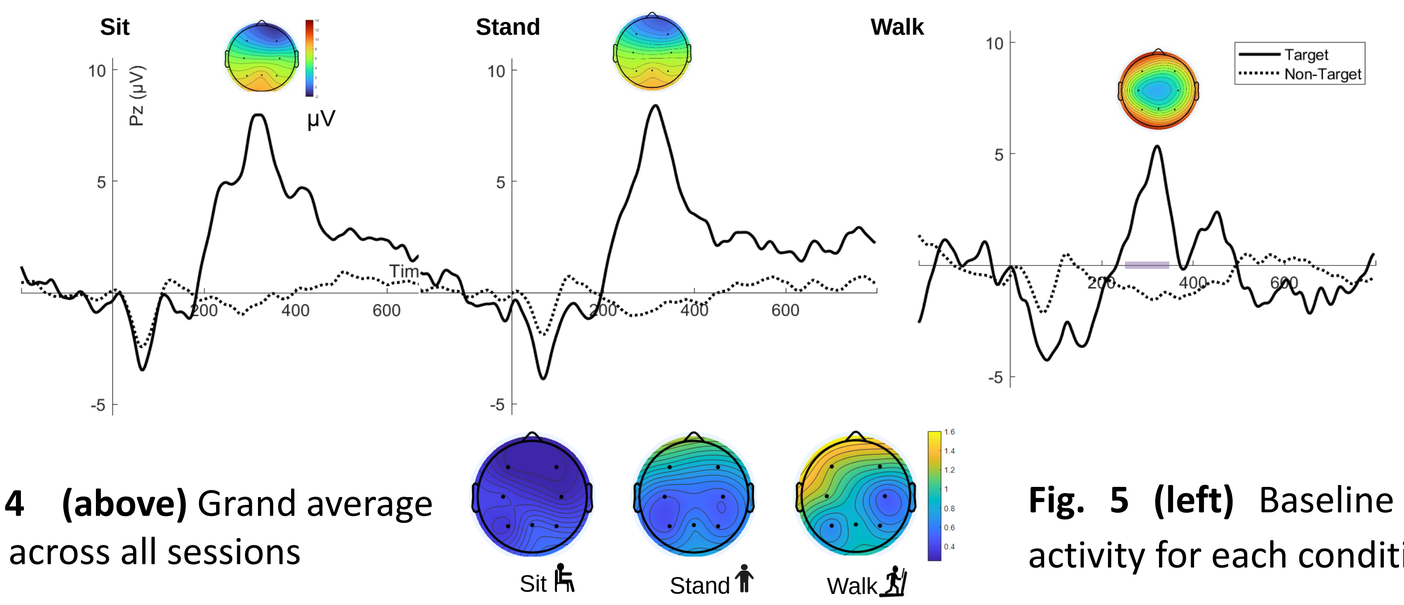

Fig. 4 (above) Grand average ERP across all sessions

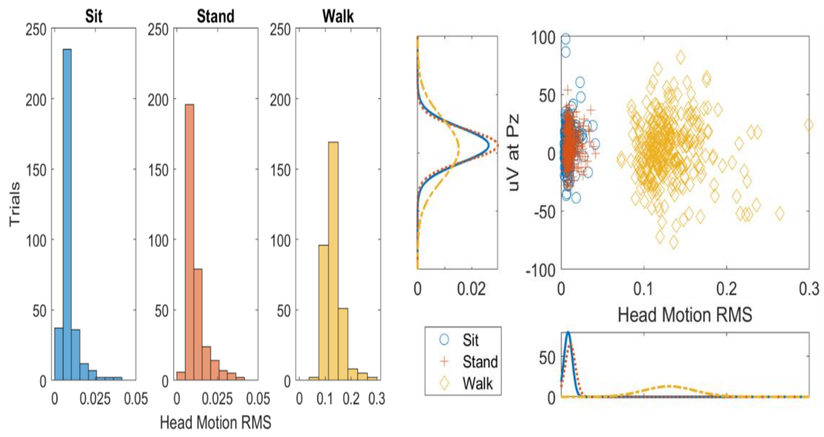

Fig. 6 (left) Accelerometer RMS magnitude. (right) Individual trials RMS plotted against P3 with Gaussian probability distributions along axes.

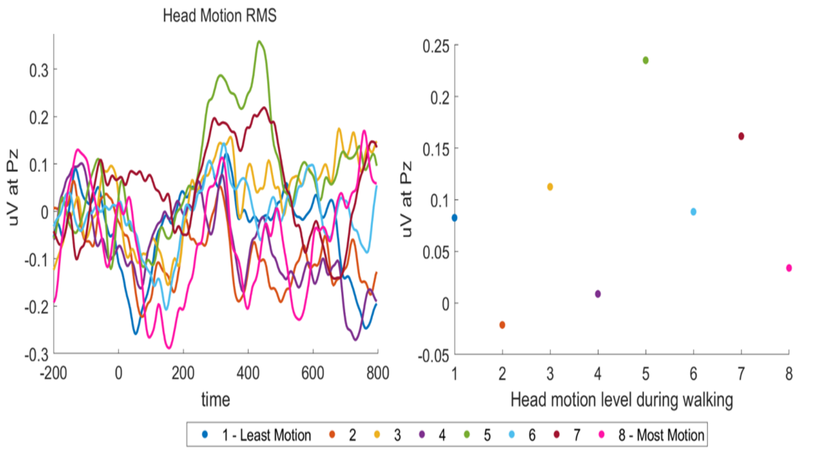

Fig. 7 (left) Averaged ERP for each motion level during walking. (right) Mean P3 voltage plotted against motion level.

Discussion

Main findings: P3 amplitude was lowest during walking, indicating that walking was the most cognitively burdensome task. P3 amplitude was not correlated to head motion.

- Agreement with previous P3 during walking and sitting[17-21].
- Walking had the lowest P3 amplitude, as in Protzak et al. [19]
- No significant difference in P3 amplitude for sitting and standing, in contrast to a dual-task study that found slower reaction times during standing compared to sitting[22]

Future Work

- More difficult auditory task.
- Identify gait events that are more cognitively burdensome.

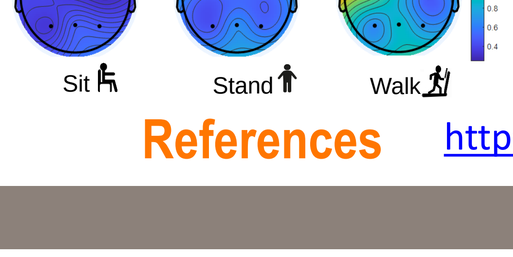

Fig. 5 (left) Baseline EEG activity for each condition.

References

https://bit.ly/swerdloff2022

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