EEG AS AN OUTCOME MEASURE FOR COGNITIVE WORKLOAD DURING PROSTHETIC USE

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INTRODUCTION

A primary goal in development of new myoelectric prosthetic technology is to reduce the cognitive workload (CW) associated with limb control. However, current outcome measures addressing CW are subjective, relying on self-report and clinical observation. EEG measures, including event-related potentials (ERPs), have been used to quantify CW in other contexts such as video game playing (Miller et al., 2011) and flight simulator control (Kramer et al., 1987). The purpose of this study is to adapt ERP measures of CW as an outcome tool for prosthetic research.

This study had two goals: 1) Determine the efficacy of ERP measures for evaluating CW under different levels of task difficulty during myoelectric control of a virtual limb. 2) Compare two methods of myoelectric control, direct control (DC) and pattern recognition control (PRC), using the EEG measures of CW.

METHOD

Subjects: 17 healthy control participants (7M/10F) were recruited ranging in age from 21-38 years (mean=25.1).

Apparatus: EEG was collected during testing in accordance with the 10-20 system (Jasper, 1958). EMG was recorded from 6 electrode sites on the forearm during testing. Two channels were used for DC control, and all 6 were used for PRC control. Performance was measured in percent of trials completed, and time to complete trials. Participants also completed a self-report questionnaire addressing perceived effort.

Procedures: Participants were trained and tested on myoelectric control a virtual arm in 1 and 3 degrees of freedom (DOF) for both DC and PRC, with the order counterbalanced. Testing consisted of 3 conditions during EEG collection: passively viewing the hand (view), 1 DOF (easy), and 3 DOF (hard). Novel auditory stimuli designed to elicit cognitive ERPs were presented randomly during testing. ERP amplitude to the sounds has been shown to be inversely related to CW (Miller et al., 2011).

Data Analysis: ERPs were analyzed at the midline electrode sites: Fz, Cz, Pz. CW main effects were examined using a 2 (DC, PRC) x 3 (view, easy, hard) repeated measures ANOVA. T-tests were used to compare DC and PRC conditions for performance, EMG amplitude, and ERP peaks identified a priori (N100, P200, P300, and LPP) based on the literature.

RESULTS

EEG: CW main effects were found for multiple ERPs: P200 at ($p<.01$), P300 ($p<.01$), and LPP ($p<.01$), with higher amplitude reflecting lower cognitive workload. LPP amplitude was higher for PRC than DC in the hard condition.

EMG: Area under the curve (AUC) across all 6 electrodes was higher for DC than PRC in the hard condition.

Behavior: Time to complete trials was significantly longer for DC relative to PRC in the hard condition.

Self-report: No differences between DC and PRC emerged.

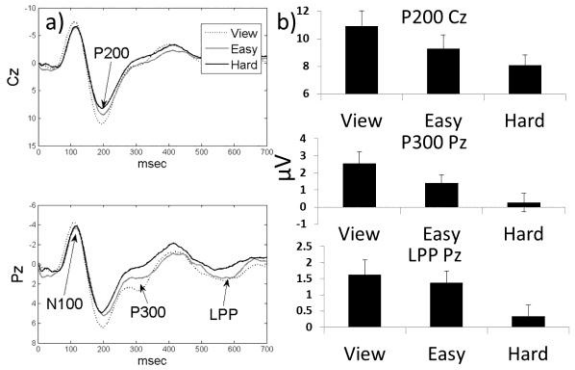

Figure 1. a) ERPs at Cz and Pz electrode sites. b) Bar graphs showing the inverse relationship between ERP amplitude and CW for P200, P300, and LPP.

DISCUSSION

During a myoelectric virtual arm task, ERPs elicited by novel sounds showed an inverse relationship to level of difficulty, reflecting fewer neural resources available to process the auditory sounds under difficult conditions. DC and PRC comparisons showed PRC to be higher in LPP amplitude, consistent with lower CW. PRC was also lower in EMG AUC, and faster in time to complete trials relative to DC in the hard condition.

CONCLUSION

ERPs are effective in measuring CW during a virtual arm task. PRC was more efficient in the hard condition relative to DC, and may be lower in CW.

CLINICAL APPLICATIONS

ERPs can be further explored as viable outcome measures of CW during prosthetic limb use. Studies in patients with upper and lower limb amputations are on-going and planned.

REFERENCES

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