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Grip force and Cortical Responses to Graded Electrocutaneous Stimulation

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***Abstract*— Sensory feedback aided grip force generation is suggested to have a limitation of three distinct levels, but it is not clear what the limiting factor is. Behavioral and event-related potential (ERP) measures were used to investigate the response to trained and untrained sensory feedback intensities in able-bodied subjects. Participants were instructed to grip a hand dynamometer based on the sensory feedback intensity, while force level, reaction time, and electroencephalogram (EEG) activities were recorded. We found evidence in the P300 ERP component that the brain was able to capture the introduction of a newly added higher intensity in the last block of experiment. The identification of P300 as a cognitive component for grip force feedback processing has implications on the limitation of the current sensory feedback parameter design.**

I. INTRODUCTION

Transcutaneous Electrical Nerve Stimulation (TENS) delivers current pulse trains to the median or ulnar nerve in human subjects to elicit referred sensations in regions of the hand [1]. Previous work showed that TENS can be used to guide amputees during graded grip force production, but subjects often reported difficulty generating more than 3 force levels [2]. It is not clear how the brain processes the feedback signals and whether cognitive processing is the limiting factor of grip force feedback. We hypothesize that a somatosensory evoked potential approach can be used to interpret how the brain processes graded feedback information. We identified an ERP component P300, which is related to stimulus categorization, to analyze the brain's translation of sensory information to cognitive representation [3].

II. METHODS

We recruited two intact-limb subjects (1 male, 1 female, aged 20-21) under Johns Hopkins Medicine Institutional Review Board. After identifying the proper stimulation area, we performed a psychometric experiment to determine the perception threshold by adjusting pulse width which relates to stimulation intensity. The threshold and two higher intensities were selected to train subjects to generate three force levels. The EEG experiment consisted three blocks. In *Block One*, subjects received the same three stimulation levels from training and gripped a hand dynamometer accordingly. *Block Two* served as a control, where subjects passively received stimulation and a new stimulation level with subthreshold pulse width was added. In *Block Three*, a new stimulation level with the highest pulse width was introduced to observe if subjects can interpret the signal and generate the correct level of force with no prior knowledge.

The force profiles and reaction time were recorded for each trial. One-way ANOVA test was performed for the force profiles, and linear regression for reaction times. P300 positive area under the curve was extracted from a time window of 232 ms to 386 ms from 2 midline electrodes (Cz, CPz). One-way ANOVA test was performed to locate any variation accounted by the conditions.

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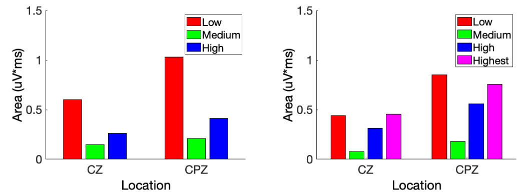

(a) Block 1 (b) Block 3

Fig. 1: P300 positive area for experiment block 1 (a) and 3 (b) from Cz and CPz electrodes. In each block, the lowest and highest stimulation intensities resulted in higher P300 positive area.

III. RESULTS & DISCUSSION

We observed that throughout training and EEG recordings, subjects were able to generate three distinct levels of forces which they were trained on ($F(2, 273) = 266.49,\ p < 1\mathrm{e}{-5}$). However, they were not able to generate a statistically higher force level, corresponding to the newly-introduced highest stimulus, than that of the trained high stimulation level (Bonferroni post-hoc, $p > 0.05$). Reaction time showed a slight downward trend as the stimulus intensity increased ($\beta_1 = -0.02, p = 0.08$). The P300 positive area demonstrated a U-shape (Fig. 1), with the lowest and the highest stimulation intensities showing higher amplitudes compared to intensities in the middle for blocks 1 and 3 ($F(2, 256) = 3.92,\ p < 0.05$ for Block 1, $F(3, 265) = 1.96,\ p = 0.12$ for Block 3).

The P300 amplitude is related to a subject's certainty about the category of the stimulus [3]. Here, although the subjects were not trained on the highest stimulus and was not able to generate a statistically higher force, the brain response identified the new stimulus as the upper bound of the stimulation range in block 3. This result supports our hypothesis that we can identify ERP components to analyze cognitive processing of sensory feedback, and in the future may help break though its current limitation.

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