Projection-based visual feedback of classification outputs improves efficacy of prosthesis training for myoelectric pattern recognition

György Lévay[1], Richard Yang[2], Christopher L. Hunt[1], Megan C. Hodgson[1], Rahul R. Kaliki[1], and Nitish V. Thakor[2]
Infinite Biomedical Technologies, LLC[1], The Johns Hopkins University[2]

INTRODUCTION
Myoelectric prostheses are often controlled via pattern recognition (PR) algorithms that translate surface electromyograph (EMG) activity into motor outputs [1]. Prosthesis users often require extensive training to consistently generate distinguishable EMG patterns of activity for prosthesis operation [2]; however, current training paradigms do not provide individuals with enough feedback to modulate EMG activity to accomplish these goals in an informed manner. To aid in the process, we present the results of a real-time feedback visualization method that presents prosthesis users with a projection of their EMG activity into the classification-space defined by a user's PR system.

METHOD
The Johns Hopkins University Institutional Review Board approved this study and informed consent was obtained from the subjects prior to participation.

Participants: 12 naïve participants (4 males and 8 females between the ages of 18 and 31) with intact limbs took part in a longitudinal study.

Apparatus: EMG data was collected with an 8-channel surface electrode band that interfaced wirelessly with a host PC. Participants were also required to wear a bypass prosthesis attached to their dominant limb.

Procedures: Each participant underwent an initial 10-session longitudinal protocol over 14 days. Participants were assigned to one of two groups: the experimental group (EG), which visualized their control by driving the position of a 3D cursor in the classification-space projection; and the control group (CG), which visualized their control by operating a virtual limb.

During each session, participants trained a PR system on several hand and wrist movements. Participants trained 4 movements (Sessions 1 – 4), 6 movements (Sessions 5 – 7), and 8 movements (Sessions 8 – 10). Participants then explored the performance of the PR system in an unstructured manner using their prescribed visualization method for a period of 2 min per active movement class (i.e. 4 movement classes has an 8 minute exploration period). If unsatisfied with their performance, participants were allowed to retrain any of the required movements before the assessment.

After the training period, participants were asked to complete a series of Fitts Law tests (FLTs) to assess the efficacy of their control. Each FLT required the participant to modify the aperture and orientation of a virtual cursor to a target configuration within a 15 s time limit using their PR control outputs [3].

After the completion of the initial 10-session study, participants were asked to return after 30 days for a final session. 11 of 12 participants returned for this post-washout evaluation.

Data Analysis: Python 3.6.8 (Python Software Foundation, Wilmington, DE) was used to collect and process the EMG data in real-time. Statistical significance was calculated using the two-sample two-sided t-test for between-group comparisons.

RESULTS
EG participants demonstrated an increased task completion rate, outperforming CG participants in every session (including post-washout; Session 11). Furthermore, EG participant performance was robust to the addition of novel movements (Sessions 5 & 8).

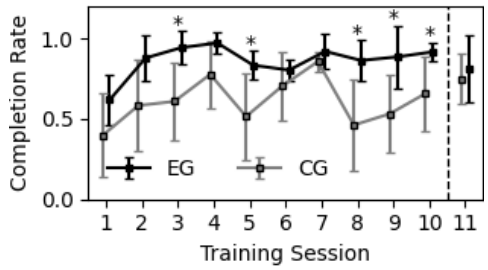

Figure 1. EG participants demonstrated a greater mean task completion rate than CG participants in every session. Statistically significant difference between participant groups are denoted with * ($p < 0.05$).

DISCUSSION
By providing real-time visual feedback on where EMG signals lie in the classification-space of a PR controller, it is possible that users can more efficiently and effectively learn EMG patterns that generate their desired motor output. While the results achieved are promising, future studies including individuals with upper limb loss (ULL) are required. Preliminary work in this regard has been encouraging.

CONCLUSION
Projection-based visual feedback of classification outputs is an effective method for increasing the efficacy of PR-based prosthesis training.

CLINICAL APPLICATIONS
This work provides a new paradigm for visual feedback that improves the efficacy of prosthesis training.

REFERENCES
[1] Englehart, K. IEEE Trans. Biomed. Eng. 50, 848-854, 2003.
[2] Powell, M. IEEE Trans. Neural Syst Rehabil Eng. 22, 522-532, 2014.
[3] Wurth, S. J. NeuroEng. Rehabil. 11, 1-13, 2014.

Funded by the National Institutes of Health under 5U44NS119842.