A MYOELECTRIC VIDEO GAME TRAINING PILOT STUDY: CHANGES IN CONTROL SIGNAL PROPERTIES

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ABSTRACT

A myoelectric video game controller was developed which maps two-site upper-limb prosthesis control signals to mouse/keyboard commands via wireless Bluetooth. This Myo-Electric Gaming Interface (MEGI) is targeted for exercising and training clinically relevant control signal properties and strategies.

This study evaluated the effects of video game training on myoelectric control signal properties over a six-week period. A racing game was used to training proportional two-site myoelectric control using a differential control strategy and co-contractions. Signal amplitude maxima and distribution of control speeds were observed across the training of three pilot able-bodied subjects.

BACKGROUND

Myoelectric training is an important part of a new patient learning to control a prosthetic limb [1]. Upper limb prosthetic fittings are often not successful and eventually rejected because the prosthesis does not provide the functionality that the user expects [2]. Although this can be related to a number of different factors, it is often associated with the lack of adequate training. Myoelectric prosthetic users must develop control skills by exercising their remnant muscles. Without proper training, users often cannot reliably provide suitable myoelectric signals and can fatigue quickly, thus further negatively affecting their prosthetic performance. Many, if not most, upper limb amputees receive insufficient training on the use of their new prosthesis which may be due to healthcare funding, but also is likely due to the lack of appropriate training tools [2].

Dawson, et al. [1] provide a review of current commercial and research training technologies as well as their benefits and shortcomings. The technologies have been passable as the standard for training but have room for improvement, as they are too simplistic, not motivating, expensive, manufacturer specific, and cannot leave the clinic to allow for independent use by the amputee within their home. Requiring the device to be used in the clinic incurs substantial costs associated with the clinicians' time during the training process as well as the time and inconvenience for the patient to travel to and from the clinicians' office.

Figure 1: Myo-Electric Gaming Interface (MEGI) system.

The development of a new myoelectric training system strives to improve compliance of prosthetic upper-limb devices, and to build a more accessible and engaging approach to myoelectric signal training. Better patient outcomes will stem from prosthetic users being able to have more comprehensive and clinically relevant myoelectric training that is rewarding and entertaining.

The MEGI system is a myoelectric controller which leverages existing video game software, which are curated to elicit clinically relevant exercises [3].

MEGI promotes the use of proportional myoelectric control signals. In the prosthesis the amplitude of the signal controls speed, with larger signals creating faster movements. Good proportional control contributes to more efficiently controlling the prosthesis (especially for grasping and manipulation) and adjusting the grip strength of terminal devices [3]. MEGI trains proportional control by mapping myo-signal amplitude to video game controls like joysticks, where the myo-signal amplitude is mapped to how hard the joystick would be pressed in the game. In the case of racing games (Figures 1, 2) a lower signal is mapped to steering the vehicle gently and as the signal amplitude increases so does the degree of turning the steering wheel in the video game. Directional control is one of the most common control inputs in video games and, so mapping this directional control from the myo-signals encourages users to constantly work these muscles through a range of contraction intensities.

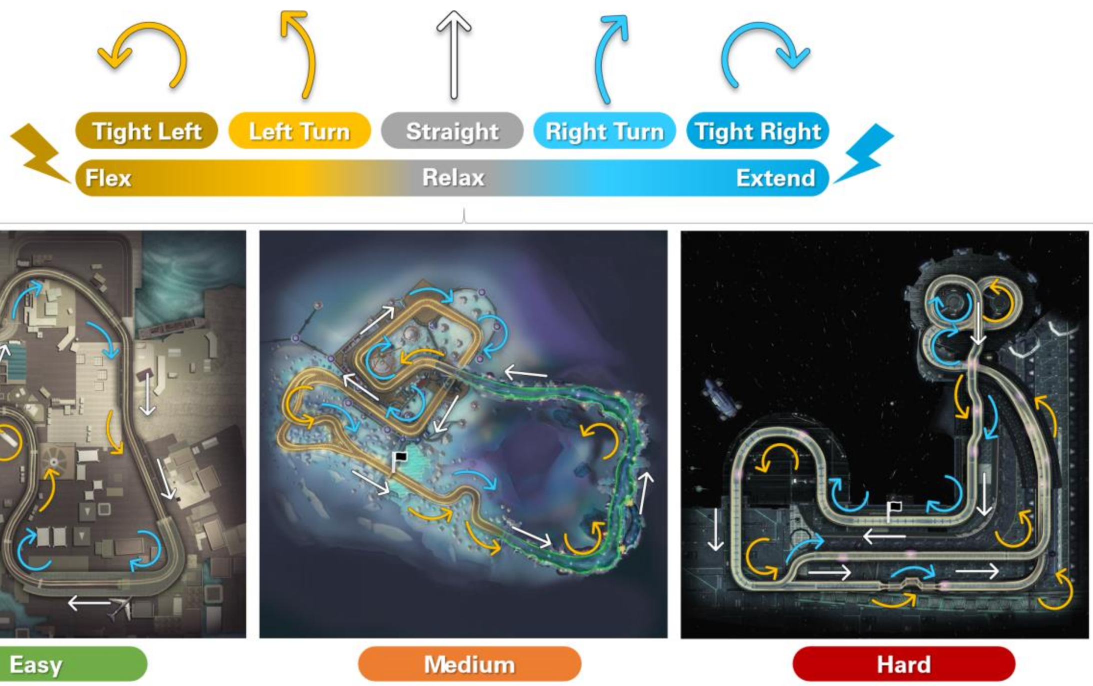

Figure 2: Representative training regimen racetrack courses, observed from a birds-eye view. TOP: Key of elicited differential myoelectric signal based on turn steering direction for right-handed wrist flexion/extension. MIDDLE: Representative courses containing balance of left/right turns. BOTTOM: Course difficulty with respect to road width, frequency of turns, and degree of turns.

Modern prostheses are made up of multiple devices; in upper-limb prosthetics one can have powered elbow, wrist, and hand prostheses. To control multiple devices with two-site myo, switching events are used, which require precise co-contraction or other pulse events. These signals are not typically used repeatedly, but when needed, they require precision and acute timing. Generation of co-contraction signals is one area that users of two-site myoelectric control often struggle with most. MEGI maps co-contraction events to binary button presses that are used periodically in game, but not repeatedly to the point of fatigue. In the racing game used in the study, co-contraction was mapped to using an in-game item for a speed boost or to fire a weapon.

Bimanual coordination is encouraged with the MEGI system mapping additional video game controls to a one-handed joystick peripheral used in the contralateral hand. In the racing game (Figure 1), this peripheral controls the gas pedal and brake.

METHODOLOGY

Subjects underwent informed consent and were instructed upon use of the MEGI device. Three able-bodied participants (2 male, 1 female, age 22±2), with limited previous experience with myo-control, completed the six-week study. Participants utilized two-site surface electromyography and differential control with wrist flexor and extensor muscles. All participants utilized dominant right arms for the MEGI system and their left hand for the joystick peripheral. Trials were conducted in a lab setting with investigators recording data.

Regimen

A commercial car racing game, *Sonic Racing*, for PC was used as the platform for training. The training regimen involved completing 3 racetrack courses per session and 3 sessions per week. Over the 6 weeks of testing, subjects completed a total of 54 courses. Subjects completed trainings every other weekday and rested on off days and weekends.

Eight different courses were selected which had a balanced level of left and right turns, corresponding to the eliciting of equal flexion and extension signals (Figure 2). Easy levels were used the first week of training, with more difficult levels introduced each week.

Data

The MEGI system recorded myoelectric signals with LTI "DC" electrodes acquired with a 10-bit analog-to-digital converter (ADC) onboard. The rectified myoelectric signal data was sampled at 30 Hz and included the differential signal (flexion minus extension) and deadband, as well as the raw signal of each channel. Lap times were recorded for each of 3 laps of each of the 3 courses in a training session.

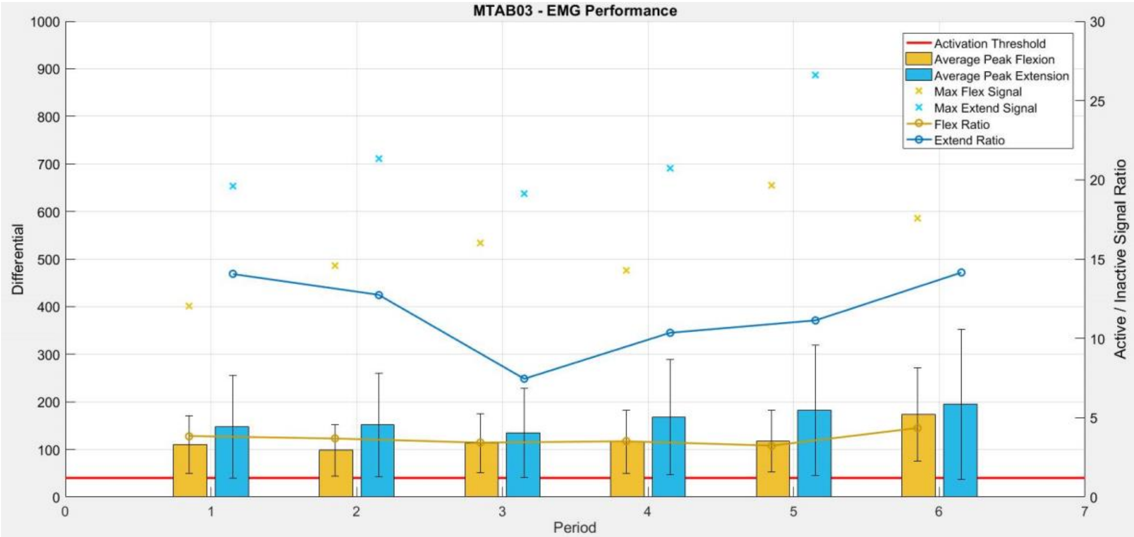

Figure 3: Myoelectric signal amplitude properties for representative subject (MTAB03).

RESULTS

The track and myo signal data collected during the training were analysed across the six weeks of training. Game performance was quantified across each track for the group. Signal characteristics such as maximum amplitude, peak flexion/extension, separation via flex/extend ratio during peak, and distribution of speeds were quantified for the dataset.

Previous studies have demonstrated that in video game training, participants can improve at the game itself while translation to improved prosthesis use can be less transferable [4,5]. This study focused on quantitative changes to the myo signals themselves and not prosthesis or functional testing.

Game Performance

In-game performance was quantified by measuring the lap time of every trial. Across the three subjects and eight courses, lap times decreased on average over the six test periods (Table 1).

Table 1: Average video game racetrack completion times for all subjects (n = 3).

		Lap Time (sec)		Time/Period
	Course	AVG	STDEV	Slope
Easy	A	57.7	1.2	-0.06
	B	55.8	2.0	-0.09
Medium	C	68.4	3.5	-0.14
	D	60.8	1.3	-0.04
	E	76.5	0.5	-0.08
Hard	F	78.2	2.0	-0.01
	G	92.4	3.2	-0.27
	H	94.2	3.5	-0.11

Amplitude

The flexion and extension signal amplitudes were tracked over time (Figure 3). Peak flexion and extension signals were calculated. As a measure of signal separation, the ratio of flexion to extension was calculated for each peak value. Flexion ratio was the peak value over the corresponding extension value, and vice versa. Generally, overall amplitude did not change outside of a 95% confidence interval.

Distribution

The range of myo signal amplitude elicited by a person can be correlated to the distribution of speeds that a prosthesis can be actuated. Similar research has evaluated prosthesis control performance by measuring the distribution of speeds across degrees of freedom in a prosthesis [6].

The distribution of myo signal amplitude was evaluated across the six test periods (Figure 4). For the differential signal, kurtosis (Eq. 1) was calculated to quantify the distribution at the tails, corresponding to the higher end of the flexion and extension ranges.

EQ 1.

$$Kurtosis = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{x_i - \bar{x}}{SD(x)}\right)^4$$

The hypothesis was that the myo-training would promote muscle growth and an increase in the range of the signals available. This could be quantified with a measure of kurtosis, indicating whether there is more signal distributed at the higher (flexion and extension) values, compared to the centre of the distribution. A lower kurtosis value correlates to a flatter distribution across the full range of amplitude.

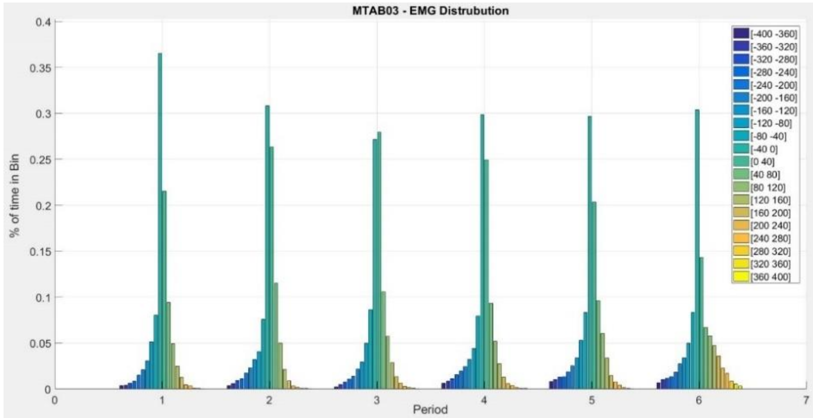

Figure 4: Distributions of myo signal amplitudes across the six weeks of training for one representative subject (MTAB03). Amplitude binned by analog-to-digital counts from a 10-bit DAC. Extension in blue, flexion in yellow.

Globally kurtosis values (Figure 5) are all greater than a value of 3, which indicate a leptokurtotic distribution which is defined as having fewer extreme values than a normal distribution. Across subjects, the trends in kurtosis over time seem inconsistent. Subject MTAB01 saw a nearly monotonic increase of kurtosis over time, while MTAB03 saw a decrease. Subject MTAB02 had a decrease in kurtosis after the first week, and then oscillated about a steady value for the remaining periods.

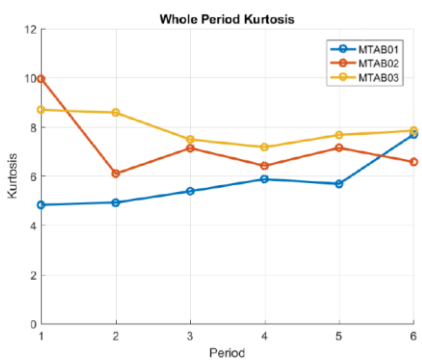

Figure 5: Kurtosis values over time for three subjects.

DISCUSSION

The signal amplitude and distribution data insofar are inconclusive. The distribution of electromyographic amplitude can be further evaluated in terms of uniformity and skewness. More signal distribution at higher amplitudes may not necessarily be indicative of good control. While a wide range of signal would correspond to more proportional control, some distribution at moderate values could be indicative of efficient control of the prosthesis. LTI is considering different measures of the myo-training separate from the game training itself. Standalone myo-signal tests and tracking tasks are under development, along with a suite of functional outcome tests.

Future Work

More work needs to be done to separate the learning effects and improvement of gameplay, and to quantify how that affects myoelectric control.

LTI is conducting the full study with research participants with upper-limb absence, over the course of multiple six-week periods, in order to evaluate changes in the target population and over longer terms of time.

ACKNOWLEDGEMENTS

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REFERENCES

[1] MR Dawson, JP Carey, and F Fahimi, *Myoelectric training systems*, Expert review of medical devices, vol. 8, pp. 581-9, Sep 2011

[2] E. Biddiss, T. Chau, *Upper-limb prosthetics: critical factors in device abandonment*. Am J Phys Med Rehabil, vol 86, pp. 977–87, Dec 2007.

[3] H. Bouwsema, C. K. van der Sluis, and R. M. Bongers, *Guideline for Training with myoelectric prosthesis*, University of Groningen, Jul 2013

[4] A. Tabor, S. Bateman, and E. Scheme, *Improvements in Myoelectric Control over Multiple Game-Based Training Sessions*. In Preparation for submission to Transactions in Neuroscience and Rehabilitation Engineering (TNSRE), 2017.

[5] L. van Dijk, C. K. van der Sluis, H. W. van Dijk, and R. M. Bongers. *Learning an EMG controlled game: task-specific adaptations and transfer*. PloS one.11(8), 2016

[6] LA Miller, BA Lock, LJ Hargrove, S Finucane, K Turner, J Sensinger; *Evaluation and Recording of Use in a Transhumeral TMR Home-Trial*, Institute of Biomedical Engineering, University of New Brunswick, MEC 2014