MOVEMENT HISTORY AND SKILL LEVEL IMPACT MOTOR EXPLORATION OF NOVEL HUMAN MACHINE INTERACTIONS: A PRELIMINARY STUDY

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The current study provides preliminary data from an investigation of the relationship between movement history and skill on the approach a person takes to explore human machine interactions (HMI). We recruited participants representing a spectrum of athletic performers to non-performers to complete a set of manual dexterity tests as well as three tasks related to different aspects of HMI. Currently, our main finding is that dexterity seems to be related to goal discovery in the free search task, though it is not related to task completion time under an instructed task nor rating of utility of HMI. Ultimately, these results might be extended to inform HMI training and determine candidates for devices.

KEYWORDS: dexterity, exploratory movement, pearson correlation, myoelectric, prosthetics.

INTRODUCTION:

Approximately 41,000 people in the United States have upper limb amputations (Resnik et al., 2018). The most common causes of limb loss are trauma, peripheral vascular disease, and diabetes (Winslow, Ruble & Huber, 2018). Myoelectric prosthetics increase function and liveability among amputees, and is a growing field of study. The term myoelectric signifies electrical properties within muscles and prosthetics are artificial replacements for a lost body part. Advanced myoelectric prostheses allow amputees to regain many innate biological abilities using their own neuromuscular control strategies.

Complex human machine interactions (HMI), such as myoelectric control, often require long learning periods and a tolerance for the fit of the device and its functional limitations (Jiang, Dosen, Müller, & Farina, 2012). Activities of daily living are typically aided by the use of an upper limb prosthetic. Though, according to Resknik et al. (2018), less than 50% of amputees with prosthetics are using myoelectric controlled alternatives. Perhaps, a lack of motor confidence and/or knowledge decreases their motor exploration, serving as a reason why so many are abandoning these devices.

Previous researchers found in a sample of 34 pediatric patients that 44% of users preferred a passive cosmetic device, 41% chose a body-powered voluntary closing terminal device, and only 15% chose the myoelectric prosthesis (Crandall & Tomhave, 2002). Reportedly, participants desired the prosthetic with the simplest design and that the complexity of the myoelectric prosthesis is what deterred them.

Efficient control requires understanding of movements and confidence for motor exploration. It is unknown whether a skilled group would be better fit for myoelectric prostheses use. Bouwsema, et al. (2004) suggest longitudinal learning studies to improve training, though it is unclear whether myoelectric use and training should be tailored according to prior skill and movement history.

Therefore, the purpose of this project is to test and observe user experience of persons (healthy young adults) with different skill sets to aid in understanding the kind of patients that might be more comfortable with the process of discovering and learning the control of a myoelectric prosthetic.

METHODS:

Participants were recruited to represent a spectrum of movement skill and experience, including 5 athletes (2 pitchers and 3 non-pitchers) and 2 non-athletes. All participants were healthy, college-aged, and able to perform low to moderate upper limb activity. Health history was confirmed with DASH (disabilities of the arm, shoulder, and head) survey (Hudak, 1996).

Measuring Dexterity:
Four tests were completed to evaluate various aspects of manual dexterity, depicted in Figure 1. Strength was assessed using a handgrip dynamometer (Mathiowetz, 1985). Participants squeeze a device to determine the strength of their grip. Speed was assessed using web-based simple reaction time software (Human Benchmark). This task involves pressing the spacebar as soon as a stimulus light is presented in the middle of the screen. A set of five trials is completed, with the mean average taken as the final score. Coordination and tactile sensitivity were assessed with a box and block task (Mathiowetz, 1985) and a custom coin selection task, respectively. During the box and block task, participants spend 30 seconds moving the blocks as quickly as they can from one box to another, one at a time. The score is the number of blocks moved in the given time. The coin selection task involves participants reaching into a bag filled with quarters, dimes, nickels, and pennies. They are asked to select a specific coin using only tactile sense. After ten trials, their score will be the percentage of correct coin selections.
Each participant's performance on the four dexterity tasks was converted to a z-score, with respect to the group performance on the given test. The four scores were then added together to provide the Dexterity Summary Score for each participant.

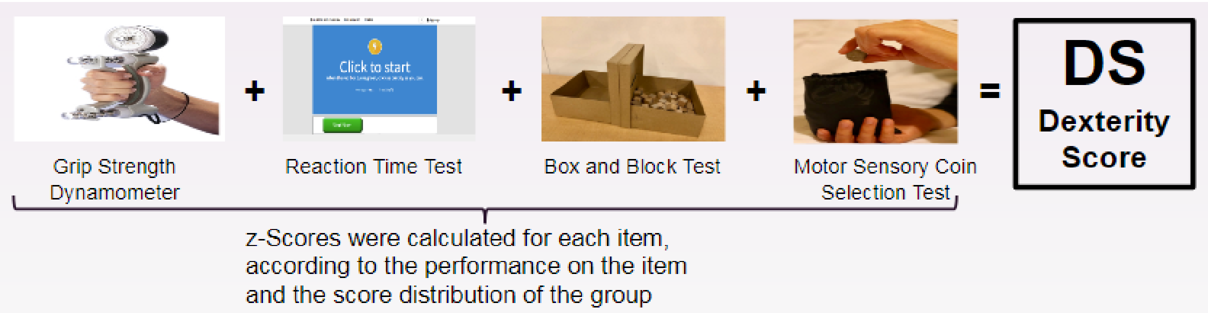

Figure 1: Depiction of the four manual dexterity tasks performed by participants, and calculation of the dexterity score as the sum of the z-score for each of the four tasks.

Measuring Myoelectric Device Performance and Perceived Utility:
After dexterity tests were completed, participants were fitted with a Myo armband (Thalamic Labs). This device allows myoelectric control of Windows and custom software by measuring arm orientation and electromyography (EMG) patterns of the forearm that allow interpretation of hand gestures (including fist, open, wave in, wave out, and a double tap of index finger and thumb). Participants were informed of these features of the device, and that it would be their means of interacting with the software and hardware used in the three HMI tasks.

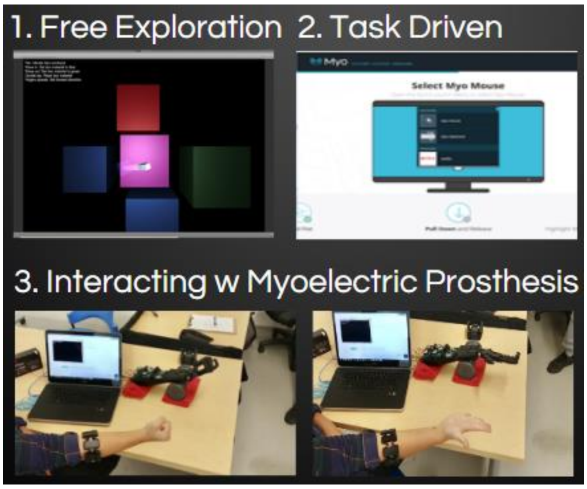

Figure 2: Depiction of the three measures of human machine interaction including 1) free exploration, 2) task driven, and 3) interactions with a myoelectric controlled robotic hand.

Task 1 was completed in front of a computer screen that displayed an empty environment created on the Unity game platform (Unity). Participants were asked to explore different hand and wrist movements with minimal instruction. Various combinations of location and hand gesture triggered the appearance and color change of target blocks in the environment. After 2 minutes, the number of discovered movement combinations (out of 20) was recorded to represent exploratory goal score.
Task 2 also took place on a computer, but this time participants were given instructions on different gestures and their functions. They were provided a tutorial on how to use these movements to pull down a menu, activate the mouse, and play the Human Benchmark reaction time test from a desktop icon. This task was timed to determine the efficiency of each participant's movements and understanding of how to use the myoelectric controller.
Task 3 was completed via interaction with our 3D printed myoelectric controlled robotic hand and wrist (Inmoov). This most closely resembles the simulation of myoelectric prosthesis use, where hand gestures of the robot were controlled according to the EMG patterns detected by the Myo. The participant was given one minute to interact with the hand freely. Participants were then asked to report their perceived utility of the device, rated on a five-point scale.

Statistical Design:
Pearson correlation coefficients were computed to test the relationship between Dexterity Summary Scores and the scores from each of the HMI tasks, separately (Excel), alpha=0.05.

RESULTS:

Results on the individual dexterity summary score tests can be seen in Table 1. All seven study participants completed these tests, as well as the three HMI tasks. One participant on task 1 performed significantly below the group mean (score = 13.8 ± 1.8) with a score of 3, leading to the decision to continue with n=6 for correlation testing for task 1. Performance on tasks 2 & 3 appear normally distributed with scores 142.3±73.3ms and 3.1±0.8, respectively.

Table 1: Dexterity Score Results (n = 7)

Test	Score	SDev
Box & Block	21.4	5.2
Coin Test	71%	16%
Hand Grip	74.1kg	30.2kg
Reaction Time	258.7ms	26.5ms

Pearson correlation coefficient tests (Figure 3) indicate a significant relationship between Dexterity Summary Scores and Goal Discovery as measured by performance on Task 1 (r = 0.816, t = 2.82, p = 0.048). No significant relationship was indicated for Task 2 or Task 3.

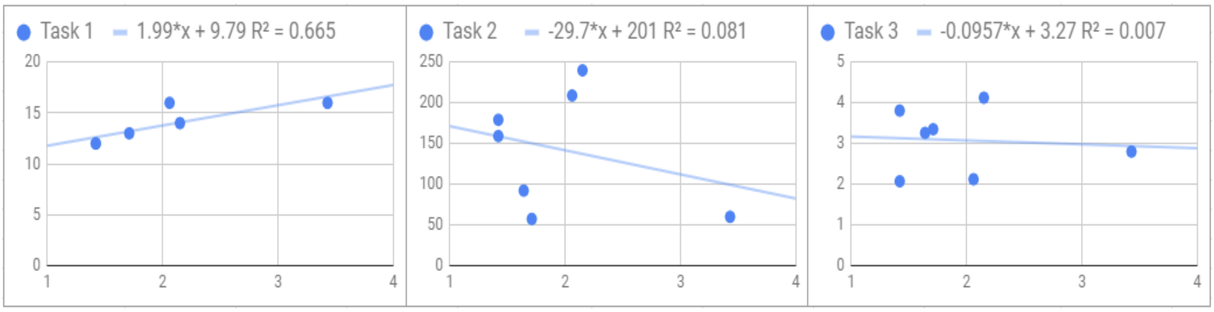

Figure 3: Scatterplots of Dexterity Summary Score results (x-axes) with each of the HMI tasks 1) count of blocks found, 2) time to complete in seconds, and 3) rating of device utility

DISCUSSION:

The results of this preliminary study indicate that movement history and skill have an impact on the approach to subsequent motor learning opportunities. Dexterity score was significantly related to the number of goal movement and hand gesture combinations in Task 1, which suggest that more dexterity and the ability or willingness to try various movement and gesture combinations are linked. We propose that this type of information about a person (higher dexterity) might be used to determine candidacy for fitting and training with a myoelectric prosthetic device if such conditions make it needed. Though, the directionality of the relationship is not tested, extension of our finding could inform device training to include skills that promote dexterity. A lack of relationship between dexterity score and Task 2 or 3 performances reduce its efficacy as a means of determining who might do well with, or enjoy, the use of a myoelectric prosthetic device. In contrast, this suggests that persons from a broad movement history and with various movement skillsets might have similar challenges in trying to accomplish pre-determined series of instructions while using such a device.

CONCLUSION: This study indicates that more dexterous individuals tend to be more effective during an exploratory task using a myoelectric controlled computer interface. Though, the same individuals did not show improved performance in a task with explicit instructions, nor did they indicate increased perceived utility of a myoelectric controlled robotic hand. Such findings may improve device fitting and training procedures, in the hopes of decreasing abandonment. Further study is warranted to replicate and extend these results.

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