A COMPARISON OF HOME TRIALS WITH MULTIPLE DEVICES AND CONTROLS WITH A SINGLE TH TMR SUBJECT

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ABSTRACT

Outcomes can be influenced by both componentry and by the type of control. A case is presented in which one subject completed minimum 6 week home trials with 4 different configurations: commercial arm system with a powered hook with direct control (DC), commercial arm system with a powered hook with pattern recognition (PR) control, a lab developed prosthesis with a powered hand with pattern recognition control and a lab developed prosthesis with a powered hook with pattern recognition control.

INTRODUCTION

Targeted Muscle Reinnervation (TMR) is a surgical technique that increases the number of control signals available as input to a myoelectric prosthesis [1, 2]. This is especially advantageous for higher level amputees who are limited in the number of inputs that might be available. Originally, individuals were limited to using one signal to control one motor movement, DC. With DC, the subject must isolate each individual muscle and the prosthetist then sets individual gains and thresholds for each channel [3].

With pattern recognition, multiple EMG channels can be used as input with the information all considered globally to calculate which "pattern" is being recreated. Since muscle signals do not need to be targeted and isolated, more information can be extracted from the user, potentially increasing the ability to control a multi-degree-of-freedom system [4].

As part of an ongoing study, individuals with a transhumeral amputation as well as TMR were recruited to compare DC to PR using a commercial arm (Boston Digital Arm, with a Motion Control wrist rotator and a single-degree of freedom terminal device, either a hook or hand). Following this first phase subjects were then fit with a system built at the Shirley Ryan AbilityLab, formerly the Rehabilitation Institute of Chicago (RIC), which had a powered elbow, wrist rotator, wrist flexor and hand. However, subjects who had used a hand with the commercial arm phase commented that the hand was not as functional as a hook. Therefore, a powered hook (Motion Control ETD) was fit to the RIC arm and the home trial repeated.

METHODS

The first subject recruited to this study was a 35-year-old gentleman who sustained a R-TH amputation secondary to trauma (military) four years previous. His TMR surgery was performed at the Walter Reed Army Medical Center approximately nine months post-amputation. At the time of recruitment, he was wearing a four-site TMR system with a Dynamic Arm, Wrist rotator and ETD. The project was approved by the Northwestern University Institutional Review Board and written informed consent was obtained from the subject.

As the first subject to take home a pattern recognition TH-TMR system, his participation was not randomized. This choice was made to confirm success of the control system in a home environment for the remaining subjects. This individual had experience with multiple laboratory fittings of pattern recognition systems leading up to the development of a clinically viable configuration.

The subject then completed a home trial with the commercial arm system in four-site direct TMR control. The two TMR sites controlled hand open and hand close. The native biceps and triceps controlled elbow up and elbow down with an elbow flexion impulse signal switching control to his wrist rotator to mirror his home DC system.

Originally, the final phase of the study was the fitting of an RIC developed prosthesis. The design specifications for this device were to be small and light while matching the performance of commercially available components. The device had powered motors at the elbow, wrist rotation, wrist flexion and hand (Figure 1). The hand had a motor in the thumb and one in the fingers. This allowed multiple positions but the two grips used were a tripod, where the thumb would move to a position and stop to oppose the index and middle as they closed, and a power, where the fingers would close and then the thumb close around the fingers.

It was later noted that by this subject and others that had used a hook commented that tasks were much more difficult with a hand than a hook. It was suspected that this

might obscure the benefits of an added wrist flexor so the RIC developed prosthesis was modified to allow the use of an ETD and the home trial was repeated (Figure 2).

Figure 1: Subject completing the Clothespin Relocation task with the RIC arm/hand system

Figure 2: Subject completing a subtest of the Jebsen using the RIC arm/ETD system.

Outcome measures were collected with all systems pre- and post-home trial. These included the Southampton Hand Assessment Procedure (SHAP), Box and Blocks, Jebsen, Clothespin and, post-home only, the ACMC [5-9]. Each home trial for each of the 4 configurations lasted a minimum of 6 weeks.

RESULTS

All pre-home outcomes have been completed and are presented. Post-home outcomes have been completed for the first 3 systems and are scheduled to be completed for the final system by May 1. ACMC results for the three completed home trials are listed in table 1.

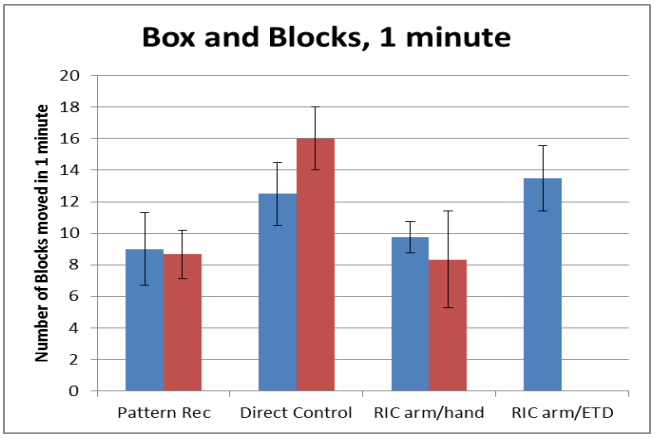

Figure 3: Number of blocks moved in 1 minute for each of the 4 configurations (average/standard deviation of 3 trials per configuration). Pre-home results are on the left and post home results are on the right for each.

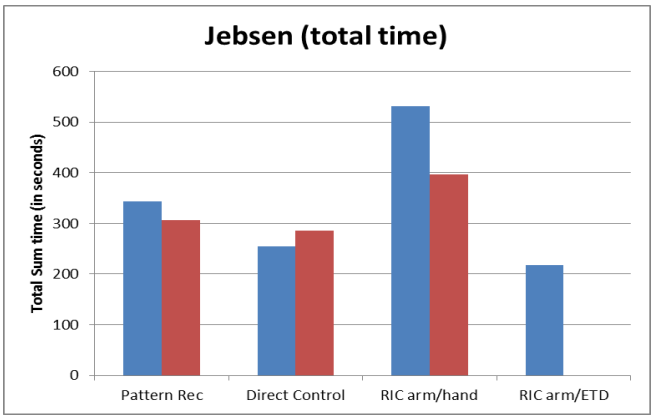

Figure 4: Total sum time of the seven subtasks for each of the 4 configurations. Each subtasks had a max of 120s. Pre-home results are on the left and post home results are on the right for each.

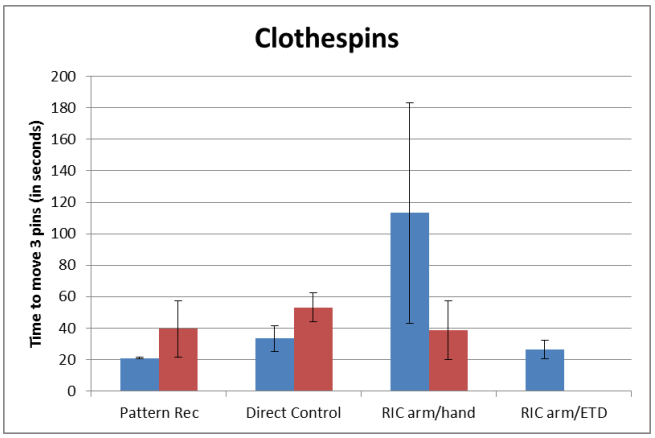

Figure 5: Total time to move 3 clothespins from a low horizontal bar to an upper vertical bar (average/standard deviation of 3 trials per configuration). Pre-home results are on the left and post home results are on the right for each.

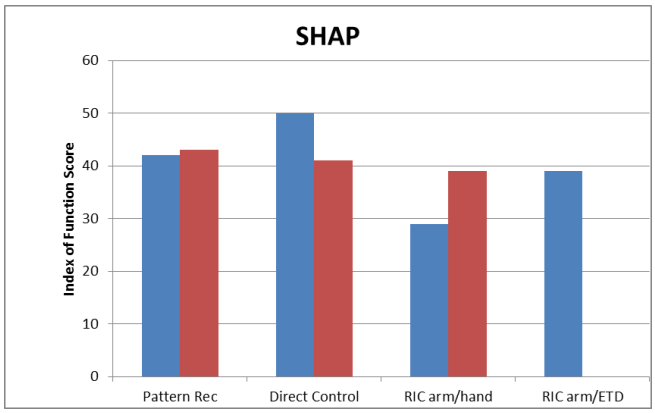

Figure 6: SHAP index of function score. Each subtasks had a max of 120s. Pre-home results are on the left and post home results are on the right for each.

Table 1: ACMC results (post-home trial)

Home trial configuration	***ACMC score***
Commercial Arm with PR	67.6
Commercial Arm with DC	62.0
RIC arm/hand (with PR)	41.3

Subjectively, PR was preferred over DC for the commercial arm. The subject's specific feedback was "I felt I had better control with pat rec with less fatigue. I would also prefer not to have to switch modes" but that both PR and DC were "easy" to make move when he wanted (5/5 for both). During the DC phase he complained of inadvertent movements (hand open/elbow extension with strong signals). With the RIC arm, he gave feedback "the wrist flexor was great" and that "hooks are better" than hands and observationally he used the wrist flexor frequently in both the RIC arm hand and hook systems.

DISCUSSION

The results show that for simpler tasks, where only one degree-of-freedom might be needed at a time, such as box and blocks, there is improved performance with direct control which is less likely to result in inadvertent movement of the wrist rotation since an intentional switching is required to access this additional movement. With tasks where wrist rotation is clearly helpful, such as the clothespin relocation task, there is improvement in function with pattern recognition control where it is easier to access wrist function without switching. This user performed well on most outcomes and, with the more complex tasks, such as the Jebsen and SHAP, performed equally well.

When evaluating the RIC arm/hand, there were notable differences in the clothespin task pre and post home trial. This was partially due to learning to better control the additional degree-of-freedom (wrist flexion) and to accommodate to the hand, but there were updates made to the finger shape during the trial to improve the pinch.

Additional improvements have been made to the device since the RIC arm/hand home trial including updates to the motor controllers to allow for smoother slow control of the wrist rotator and wrist flexor. With these improvements as well as the use of ETD, it is expected that there will be a trend towards improvement.

Final results will be available for presentation at the meeting and it is expected that the subject will be available to demonstrate the function of the full system at the meeting as well.

ACKNOWLEDGEMENTS

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