OUTCOME MEASURE RESULTS OF PATTERN RECOGNITION CONTROL OF A MULTIFUNCTION HAND-WRIST SYSTEM: A CASE STUDY

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INTRODUCTION

Pattern recognition (PR) has been described as a method of controlling a larger number of prosthetic arm movements than those that are possible with currently available commercial myoelectric control devices.\textsuperscript{1} PR has also been used by individuals with higher levels of amputation who have had targeted reinnervation to control advanced prosthetic components.\textsuperscript{2}

Previous testing was performed on five individuals with transradial amputations using a virtual reality system with 10 wrist/hand movements. The performance of the participants using the residual limb was compared to their performance using the intact arm.\textsuperscript{3} Performance metrics included motion selection time, motion completion time, and motion completion (“success”) rate. Classification accuracies with the residual limb (approximately 79\%±11\%) were not as high as with the intact arm (94\%±3\%). When only one hand movement was tested, residual limb classification accuracy increased to 93\%±4\%.

Work to date has now shown that PR can also be used for transradial amputees (without targeted reinnervation) to control a physical device: a multifunction hand-wrist system with seven degrees of freedom (DOFs), including wrist pronation and supination, wrist flexion and extension, hand open, lateral/key grip, and opposition/pinch grip (Figure 1).

BACKGROUND & CONFIGURATION

The subject was a 62-year-old male who sustained a transradial amputation approximately 25 years ago. We compared his ability to control his existing two-site myoelectric prosthesis with his ability to control a multifunction hand-wrist system with PR (Figure 1).

Figure 1: Range of motion of the multifunction hand-wrist system. Device at maximum range of motion of wrist flexion (top left) and extension (top right), pinch and lateral/key grip (center), and hand open (bottom). Wrist rotation moves through 360 degrees.
The existing (or home) system was a two-site myoelectric prosthesis with a single DOF hand (Otto Bock DMC) and a nonpowered quick-disconnect wrist. It was self-suspending with a pelite liner. The subject had worn his myoelectric prosthesis for many years. He used the device for specific tasks, especially biking and weight-lifting, but did not use it every day.

As stated above, the multifunction device had seven DOFs and was controlled using myoelectric PR. It was only used within the laboratory. It was fit with a socket and a gel liner with lanyard suspension and six modified Otto Bock electrodes (analog filtering was removed to record appropriate signals for PR). Myoelectric signal processing was done in real time. Electrode signals were sent to the computer via a Bluetooth connection; using PR, the software program then determined the appropriate movement class and wirelessly returned motor command signals to the hand. The PR classifier was retrained at the beginning of each visit. During pattern classifier training, 3 to 6 seconds of data were collected as each movement was performed and were used to create the pattern classifier.

Since the subject was an established user of his home device, therapy with this device was not performed as part of these experiments.

Testing

Testing was done with both the multifunction system and the home system. Data were collected from the two devices on different days. The outcome measures and functional tests included the SHAP\(^4\), Jebsen-Taylor Hand Function Test\(^5\), Box and Block Test\(^6\), UNB Test of Prosthetics Function\(^7\) (with self-selected, age-appropriate tasks), Assessment of Capacity for Myoelectric Control (ACMC)\(^8\), Clothespin Relocation Test, and a cup-stacking test. For the Clothespin Relocation Test, the subject was required to move three clothespins from a lower horizontal bar to a higher vertical bar using the hand functions and wrist rotation. For the cup-stacking test, the subject removed cups from an inverted stack and then placed six inverted cups into a pyramid configuration with a seventh cup placed right-side-up on the top of the pyramid, thus using all available DOFs.

RESULTS

Results of the various tests are shown in Table 1. Better scores are highlighted in gray. The subject performed better using his home device on all of the various measures except for the Box and Block Test and the UNB test; however, not all of the prosthetic DOFs were utilized during UNB testing with the multifunction system.

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Device</th>
<th>Multifunction</th>
<th>Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAP: Index of Function Score</td>
<td>47</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Jebsen-Taylor Total Score (sec)</td>
<td>325</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>Box and Block Test (num. of blocks)</td>
<td>18</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>UNB Total Time</td>
<td>502.21</td>
<td>937.32</td>
<td></td>
</tr>
<tr>
<td>Total Spontaneity Score</td>
<td>40/40</td>
<td>40/40</td>
<td></td>
</tr>
<tr>
<td>Total Skill Score</td>
<td>31/40</td>
<td>35/40</td>
<td></td>
</tr>
<tr>
<td>ACMC</td>
<td>0.55</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>Clothespin: time (sec)</td>
<td>22</td>
<td>12.75</td>
<td></td>
</tr>
<tr>
<td>Pyramid Cup Stacking</td>
<td>63</td>
<td>46.62</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Subject moving blocks during training

METHODS

Initial Training

Initial training with the multifunction PR system was done using a virtual environment. The experimental socket was fabricated during this time. The subject worked with the arm over the course of a year as software and hardware were developed, with visits occurring approximately one to two times per month for 2 hours at a time. During these visits, tasks performed included manipulating many objects of different sizes, weights, and fragility. Items from the various testing kits—including the Southampton Hand Assessment Protocol (SHAP), Box and Block Test, and Clothespin Relocation Test—were used during training to practice various functions. Once the subject was comfortable with the function and control of the device, the pattern classifier was created with as little as 3 seconds of data for each DOF.

Table 1: Results of Outcome Measures.
DISCUSSION

The subject was able to complete all testing tasks using the additional DOFs of the multifunction system. Some scores were close between the two systems, but in general, use of the additional DOFs of the multifunction system came at the cost of increased time. For example, compensating for a lack of wrist rotation by using shoulder abduction was faster than using the wrist rotator in the multifunction system. As a result, the home device scored more favorably on all timed tests except the Box and Block and UNB. The ability to position the hand into flexion may have improved the score on the Box and Block Test. The multifunction prosthesis demonstrated a faster time on UNB tasks. This was because the subject had difficulty opening the hand of his two-site system. The skill level was higher with this device, however, because when using the multifunction system, we found that despite asking him to do the task in what we thought would be an appropriate way (as the nondominant hand), he often insisted that he would “show us what it could do” and therefore did the tasks in a less natural way, using the prosthetic hand as the dominant extremity. For example, when removing money from a wallet, he stabilized the wallet with the intact hand and removed the money with the prosthetic; when using a dustpan, he held the whisk broom with the prosthesis; and, when tearing tinfoil, he held the box with the intact hand and tore the foil with the prosthesis.

One of the reasons the subject did not perform as well with the multifunction system in the standardized tests is that he was less familiar with it. Our next goal is to have a home trial to allow the subject to become better at controlling and incorporating the device into daily tasks as an assistive device. As previously mentioned, for tasks where he was allowed to choose how the device was used (UNB and ACMC), he often inappropriately chose to use the prosthesis as the dominant hand.

FUTURE WORK

Although we have shown that it is possible to control a two DOF hand and two DOF wrist with PR, there are still many factors that need to be resolved before this system can be viable as a home system. For example, the processing that is done on an external computer needs to be transferred to an embedded system. Additionally, a system that detects when an electrode stops providing dependable signals (e.g., loses contact with the skin) may provide more reliable control. Also, six electrodes can be difficult to integrate into a transradial system due to socket size constraints and the difficulty in keeping six electrodes in contact with the skin through all movements of the residual limb. Efforts are underway to improve the socket function and comfort for home trials.

Once hardware issues have been resolved, home trials are planned. These trials are expected to begin this year.

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REFERENCES