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APPLICATION OF HAPTIC FEEDBACK FOR IMPROVED PROSTHETIC CONTROL

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INTRODUCTION

Tactile sensory feedback or haptics is a fundamental element of life. While feedback is vital for interaction with the outside world, current commercially available prostheses do not provide a formal mechanism to convey sensory information (1-3). The current study investigated four fundamental issues relating to external vibrotactile stimulation namely: optimal tactor location on upper arm, feedback signal type, skin desensitization, and the ability of feedback to assist in controlling grasping force. (Fig 1) A total of seven unilateral upper limb amputees participated in this study. Results demonstrated optimum feedback resolution in bicep region based on comfort and effectiveness. The average time for skin to become desensitized was 66 seconds. Among different waveforms tested, the sinusoidal waveform was the most effective (paired t-test, p=0.047). The cognitive loading test results demonstrated an improvement in grasping force due to haptic feedback at 60% of maximum grasping force ($p<0.05$). The preliminary haptic feedback device enhanced grasping force accuracy at specific forces rather than across all forces. (Fig 3)

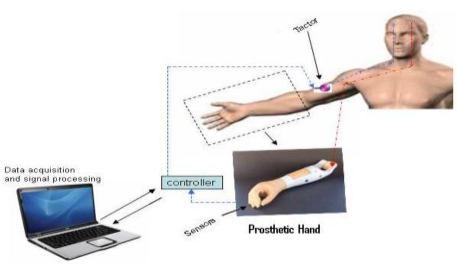


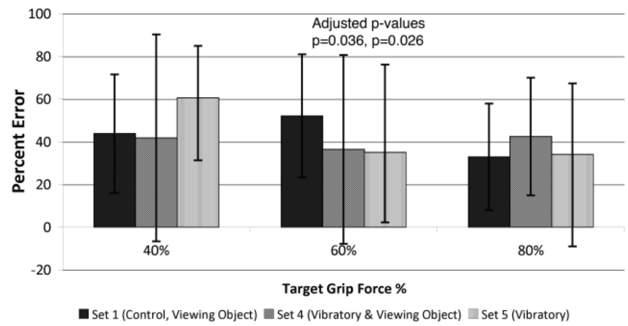
Fig 1 experimental setup for feedback testing control.

The results from Phase I of the study included clinical observations and patient feedback to provide a valuable platform toward development of a modular, customizable and clinically usable haptic feedback device in Phase II. (Fig 2)

Figure 2: some of the tests used to determine the best location and type of feedback

Different locations were tested for sensitivity to the feedback signal and then different frequencies of three different waveforms (square, sine, and sawtooth) were used to find the most effective feedback signal for each individual as they attempted to match a percentage of their maximum grip force. (Fig 3) We then tested the time for loss of sensation due to desensitization to determine how long the signal will be effective as feedback.

Figure 3: grip force accuracy



Subject questionnaire results

The subjects' perception plays an important role in acceptance of assistive devices(4). As part of this study subjects were asked a set of questions relating to overall comfort, ability to use haptic feedback for daily grasping tasks, confidence in using haptic feedback and usefulness if such a device was commercially available (5-8). They were asked to rate their responses as a score from 1(worst) to 5(best). Subjects stated that feedback was helpful to improve the function of the prosthesis and that it did not decrease the comfort of the prosthesis. (Fig 4)

1. Subjects gave the highest scores to level of comfort using haptic feedback for grasping tasks followed by usefulness of such a device for everyday grasping tasks

2. They felt comfortable in using myoelectric controller and reacting to haptic feedback at the same time.

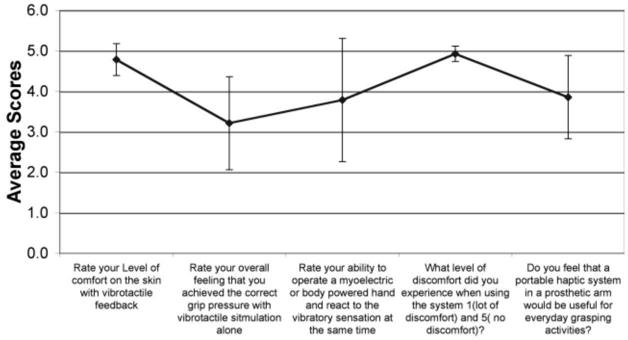


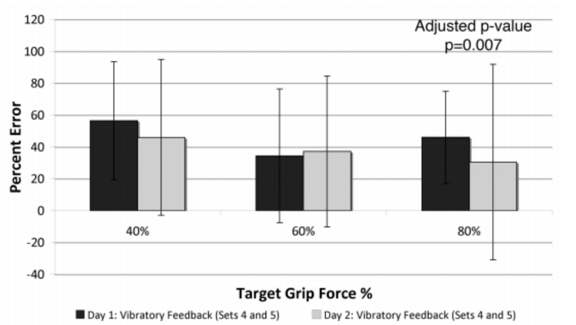
Fig 4: subject feedback on haptics outside of the lab.

Result Analysis

1.The results showed an improvement in grasping force due to haptic feedback at 60% of maximum grasping force for Set 4 (visual and vibratory)(p=0.036) and Set 5 (vibratory only) (p=0.026).

2. Subjects who are adept at using their prosthesis (myoelectric or mechanical) were better able to utilize feedback to improve controls

The percent error while using haptic feedback improved from day 1 to day 2 at the 80% force level (p=0.007).
This indicates that more practice in using vibratory haptic feedback may further reduce gripping errors. (Fig 5)

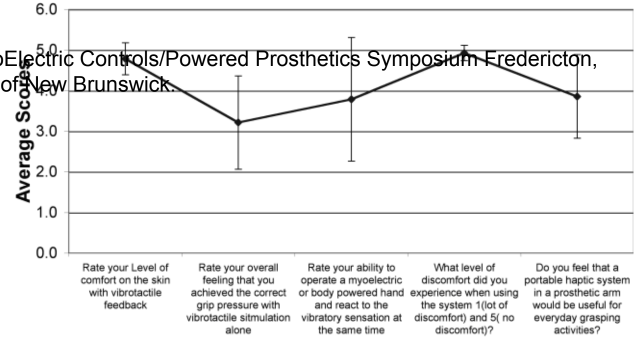


Less gripping force error in day 2 versus day 1 testing when targeting 80% of maximum grip force

Fig 5 Improvement of grip accuracy with practice

Subject Feedback

1. Perceived that vibratory feedback would be helpful for activities of daily living.
2. More training with vibratory feedback would improve ability to use the feedback correctly.
3.Having three distinct force levels instead of continuous feedback would be more useful.



Conclusions

The results from Phase I including clinical observations and patient feedback have provided valuable information for development of a modular, customizable and clinically usable haptic feedback device in Phase II.
The engineering aims in Phase II consist of the design, development and integration of a low profile hardware system with wireless sensor and tactor modules. This will allow for the optimal tactor placement within the socket. Grip force and haptic feedback will be measured during common daily grasping activities to determine the effectiveness of the system and the prosthetic arm usage. Software controls will be developed for patient training and clinical use by the prosthetist to provide the most useful feedback signal. Occupational and functional measure will be used to evaluate the robustness and effectiveness of our haptic feedback system for prostheses in the lab and real world environments.

While it is virtually impossible to recreate the level of awareness of an anatomically intact limb in a prosthesis, additional sensory information through external feedback could provide a limited but valuable level of limb awareness and improved function.

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