TOUCH FEEDBACK AND CONTACT REFLEXES USING THE PSYONIC ABILITY HAND

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ABSTRACT

The PSYONIC Ability Hand is a commercially available multiarticulated prosthetic hand with six degrees of freedom and sensorized digits. Through using contact reflexes and vibration feedback, users can grasp delicate objects without damaging them. We show results that two subjects successfully grasp hollow eggshells and fragile cups statistically significantly more often when provided with contact reflexes and touch feedback.

INTRODUCTION

The Ability Hand

PSYONIC has developed the commercially available Ability Hand—a compliant, robust, sensorized prosthetic hand to be used by people with upper limb amputations. The Ability Hand is:

- Multiarticulated – all five digits flex/extend and the thumb rotates both electrically and manually
- Robust – compliant fingers allow the hand to withstand blunt force impacts to the fingers
- Lightweight – 460 g, carbon fiber palms make the hand light and strong
- Fast – using brushless motors with field-oriented control, the fingers can close 90 degrees in 200 ms
- Waterproof – IP64 waterproof rating, enabling washing the hand in water
- Sensorized – pressure from the fingertips, fingerpads, and lateral edges maps to a vibration motor

The Ability Hand uses a standard electronic quick disconnect and integrates with commercially available control systems (e.g. Coapt Pattern Recognition, OttoBock/RSL Steeper myoelectrodes, etc.). Apple and Android phone apps are available to configure the hand over Bluetooth as well as make firmware updates. USB-C charging allows the hand to be fully charged within one hour.

Fig. 1 The Ability Hand attached to a socket

Sensory Feedback

Poor manipulability due to the lack of sensory feedback is a leading cause of prosthesis abandonment [1-2]. While body-powered prostheses can give users some sensory feedback, these devices are limited in achievable grasps and can cause overuse injury in the shoulders of the user. There are several functional advantages to providing sensory feedback in a multiarticulated prosthesis, including contact detection and body self-identification [3]. An external study by Matulevich et al. [4] shows that users could grasp foam, crackers, and hollowed eggs statistically significantly faster (between 1.4x-3.3x) when using contact detection from pressure sensors on a prosthetic hand. Another external study by Berke et al. [5] showed users performing tasks more than 15 seconds faster on average when provided with contact detection.

In the Ability Hand, all five digits can be sensorized with four pressure sensors in each digit. The index and little fingers have pressure sensors on the distal fingertip, the fingerpad, and two on the outer lateral edges. The thumb, middle, and ring fingers typically have pressure sensors on the distal fingertip, the fingerpads, and one on each lateral side of the digit. These pressure sensor locations were chosen due to their increased likelihood of contacting objects. The sensor providing the highest pressure value is mapped to a vibration motor whose amplitude changes with the pressure applied.

To test the efficacy of the sensory feedback, we recruited two volunteer subjects. The first subject, S1, was a male, age 42, with a right proximal below-elbow amputation. The second subject, S2, was a male, age 78, with a left distal below-elbow amputation. S1 was fitted with a commercial muscle pattern recognition system developed by Coapt that we integrated to use with PSYONIC's hand. S2 used a custom linear transducer mechanism developed by PSYONIC that uses shoulder movements to control opening and closing the hand.

Subjects S1 and S2 were asked to use the hand at home for 1 week. Immediately prior to and after the home trial, both subjects participated in two experiments: 1) a cup grasping task, and 2) an eggshell cracking test. All methods were approved by IRB #13920 at the University of Illinois at Urbana-Champaign. Subjects also consented to images and videos to be taken during the experiments. Preliminary experiments were performed in Akhtar et al. [6].

In the cup grasping task the subjects were asked to grasp ten empty plastic cups. The distance between the outer tips of the index finger and thumb was measured to determine the amount of deformation of the cup. This process was repeated over 4 conditions: 1) with Touch Feedback and with Visual Feedback, 2) without Touch Feedback and with Visual Feedback, 3) with Touch Feedback and without Visual Feedback, and 4) without Touch Feedback and without Visual Feedback. The order of the conditions was randomized. These conditions were selected to observe differences in grasping performance when providing touch feedback, both with and without visual feedback.

For the eggshell cracking test participants were asked to grasp ten hollowed eggshells without cracking them. We recorded the number of eggshells cracked. Again, the process was repeated under the same four conditions as the cup grasping task. When providing touch feedback to subjects, a contact reflex was implemented in the hand that caused the hand to automatically stop when contact with the object was made. Fig. 2 shows a typical pressure sensor reading when grasping a hollowed eggshell.

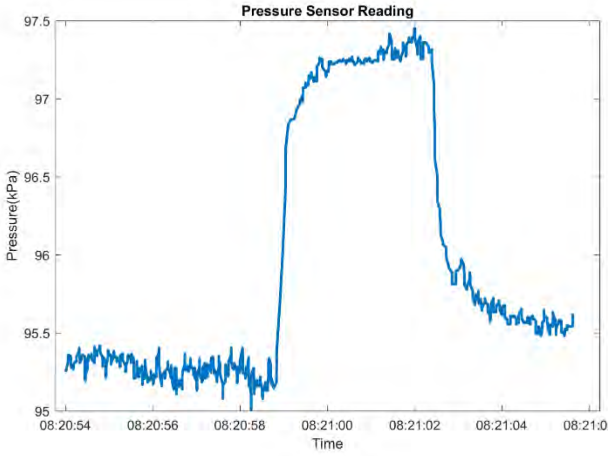

Fig. 2 Reading from pressure sensor on the finger pad of the distal index finger when Subject S1 grasped an eggshell.

Results from Subjects S1 and S2 across both sessions are given in Table I for the cup grasping task and Table II for the eggshell cracking test. For the cup grasping task, there was a statistically significant difference between feedback conditions as determined by a two-way repeated measures ANOVA (F(3,3) = 567.7, $p < 0.0005$). Post-hoc tests revealed that the touch feedback conditions (with or without visual feedback) statistically significantly outperformed both conditions without touch feedback ($p<0.05$). Consequently, we conclude that by providing touch feedback with contact reflexes users deform the plastic cup significantly less. There were no statistically significant differences between sessions, and the session had no significant effect on the condition.

Table I Results from cup grasping task

	Session	Touch, Visual (mm)	Touch, No Visual (mm)	No Touch, Visual (mm)	No Touch, No Visual (mm)
S1	1	80.3	79.5	37.4	39.4
	2	78.7	82.2	51.4	48.9
S2	1	77.3	80.2	38.6	38.9
	2	87.3	89.5	49.5	54.3
Grand Mean		**80.9**	**82.9**	**44.2**	**45.4**

For the eggshell cracking test, there was a statistically significant difference between feedback conditions as determined by a two-way repeated measures ANOVA (F(3,3) = 21.63, p = .016). There was no statistically significant differences between sessions, and the session had no significant effect on the condition. Again, touch feedback with contact reflexes resulted in better performance, with less eggshells cracked compared to when no touch feedback with contact reflexes was given (with or without visual feedback).

Table II Results from eggshell cracking test

	Session	Touch, Visual (# cracked)	Touch, No Visual (# cracked)	No Touch, Visual (# cracked)	No Touch, No Visual (# cracked)
S1	1	0	2	7	9
	2	0	3	6	6
S2	1	0	0	7	7
	2	2	1	8	6
Grand Mean		**0.5**	**1.5**	**7**	**7**

Fig. 3 shows images of the Subject S1 performing the eggshell cracking test. When touch feedback with contact reflexes was turned on, the subject could easily grasp the eggshell without cracking it, even while blindfolded. When touch feedback with contact reflexes was turned off, the subject usually cracked the eggshell, even when he could see it. Fig. 4 shows Subject S2 successfully grasping the eggshell while blindfolded when receiving touch feedback with contact reflexes.

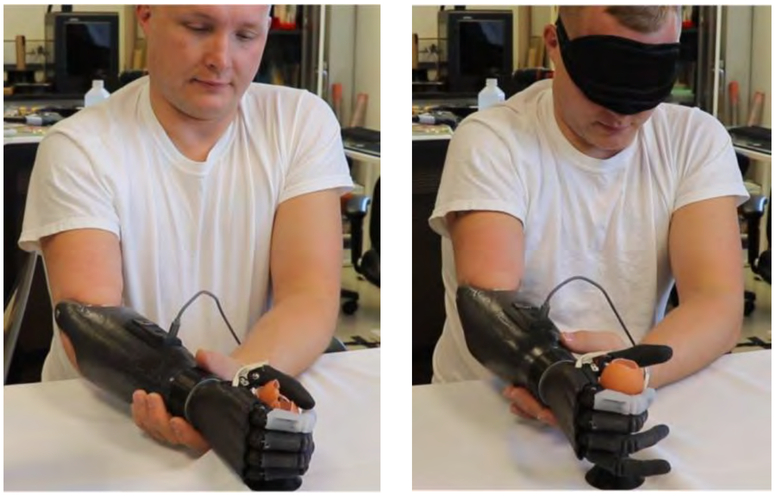

Fig. 3 Subject S1 cracking an eggshell when not receiving touch feedback while seeing the eggshell (left), but successfully grasping the eggshell when receiving touch feedback while blindfolded (right).

Fig. 4 Subject S2 successfully grasping the eggshell when receiving touch feedback while blindfolded.

Qualitative feedback from the subjects after the home trials was positive. Subject S1 reported he mostly wore the hand during work. Common tasks included holding drinks, driving, shaking hands, and sweeping. He liked the light weight of the prosthesis as well as the bionic look. Subject S2 liked the fact that our hand could work with both off-the-shelf myoelectric systems and a linear transducer system. He used a linear transducer system for the trial that he found to perform vastly better than a myoelectric system. He used this mainly to grasp glasses to drink from, for exercising on a stairmaster, and for assistance in typing (e.g. holding down the shift button on a keyboard). For improvements, he expressed that multiple settings for the pressure sensor contact reflexes would be helpful, as some objects require tight grips while others require delicate grips.

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