

On the Utility of Affective Feedback in Prosthesis Embodiment

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Abstract—We experience many rich haptic interactions through our natural limbs that involve emotional affect and discriminative task-related information. When the limb is amputated and replaced with a prosthesis, amputees are deprived of these sensations. This lack of haptic sensation limits prosthesis embodiment and can result in device abandonment. Enabling embodiment, however, will require more than restoration of task-specific haptic feedback. Here, we propose a novel haptic feedback approach to provide the C-tactile sensations shown to foster embodiment. We hypothesize that this approach will align sensory expectations with actual sensory afferents and enhance the possibility of embodiment and better prosthesis utility.

I. INTRODUCTION

Experiencing the joy of petting a cat and being able to carefully crack an egg represent two of the many rich affective and discriminative physical interactions that rely on haptic sensation. Current upper-limb prostheses, however, deprive amputees of these affective and discriminative afferent sensations. Most of the haptics research on upper-limb prosthetics has focused on providing task-dependent, discriminative haptic feedback, such as grip force or grip aperture [1]. Few studies, however, have considered the role of C-tactile (CT) afferent haptic feedback in fostering prosthesis embodiment, which is defined as the integration of body parts or objects into the bodily self-representation [2]. Crucianelli et al. demonstrated that CT affective touch increases the sense of body ownership of a rubber hand [3]. Thus, we hypothesize that CT afferent feedback in a prosthesis will help unify an amputee's sensory expectations with the actual sensations felt through a prosthesis, thereby fostering prosthesis embodiment. To test this hypothesis, we are developing the following novel CT afferent based feedback system that senses light touch on a prosthesis and elicits CT afferent stimulation.

II. MATERIAL AND METHODS

We affixed six force-sensitive resistors (FSRs) (Adafruit ADA166) on the dorsal side of the thumb, hand and forearm of a wearable anthropomorphic mock-prosthesis [4]. Six eccentric rotating mass vibration motors (Jameco 2218169) are adhered to the participants' hands and forearms in corresponding locations (See Fig. 1). The device displays a proportional mapping between pressure and vibration intensity using the CT afferent stimulation haptic illusion approach first presented in [5].

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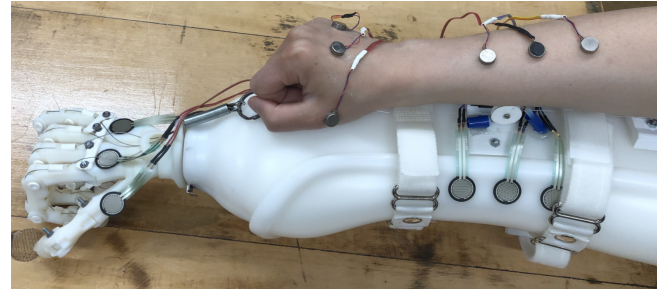


Fig. 1: CT afferent system with force-sensitive resistors (FSRs) and eccentric rotating mass (ERM) vibration motors.

To investigate the effect of CT afferent feedback on prosthesis embodiment and task utility, we will conduct a user study where CT stroking is provided to prosthesis wearers prior to task completion. To unify what the user sees and expects to feel during the CT stroking method [3], we will brush each FSR multiple times while the vibration motors elicit the afferent stimulation. Afterwards, participants will complete the Box and Blocks task and the sensory motor attenuation task to measure functional performance and physiological markers of embodiment. Additionally, participants will complete a qualitative subjective prosthesis embodiment survey.

III. CONCLUSION AND FUTURE WORK

In this work, we beginning to explore the effect of CT afferent feedback on prosthesis embodiment and utility. Our initial investigations with non-amputee participants will be used to validate our approach, and ultimately guide future investigations with amputee participants, where unique actuator positioning will be required. We expect our empirical results will help fill the gap in knowledge on role of CT feedback in prosthesis embodiment and the impact of affective feedback more broadly in prosthesis usage.

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