Exploring Electrotactile Stimulation as a Modality for Sensation Illusion on the Arm

Xin Zhu, Pranavi Jalapati, Jocelyn Tsai, Zhenghui Su, Shihong Ling and Heather Culbertson

Electrotactile feedback is generated by applying modulated electrical current to the skin, and the perceived sensations are modulated by several factors, including electrode size and material, skin properties, and signal properties [1]. Electrodes can be attached to the skin epidermally or subdermally, and the stimulation can be used in prostheses control, sensory substitution, sensory restoration, and sensorimotor restoration. Sensations such as vibration, tapping, pressure, and pain can be generated by varying the electrical parameters and spatial location, as well as material properties like roughness and temperature. [2] Previous studies on electrotactile perception have developed models to explain the relationship between physical and electrical parameters and perceived sensation, but there is no consensus due to the different implementation of stimulation systems. We aim to gain a deeper understanding of electrotactile perception by examining the effects of feedback location and frequency on perception. Previous studies have highlighted the need for personalization and calibration of electrotactile systems, and our study aims to provide insights for improving such systems in future applications.

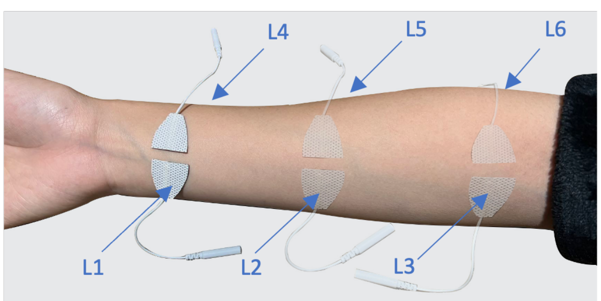

Fig. 1. Placement of electrode pairs on the arm, L1 - L3 are on the ventral side, L4 - L6 are on the dorsal side.

In this work, we designed and implemented an electrotactile feedback system to fill in the gaps in our understanding of the perception of electrotactile feedback with a focus on individual preferences and spatial differences. We conducted a human subject study (N=20) displaying electrotactile feedback on the forearm (Fig. 1) to examine the effect of location, frequency, and skin moisture level on the stimuli's Detection Threshold (DT) (Fig.2) and Pain Threshold (PT) (Fig. 3). Our results showed that the location of the electrotactile stimulation significantly affects electrotactile perception (both DT and PT) even within the same body area (the forearm).

X. Zhu, P.Jalapati, J.Tsai, Z.Su, S.Ling and H. Culbertson are with the Department of Computer Science, University of Southern California, Los Angeles, CA 90089 USA. (xinzhu,jalapati,jatsai,suzhengh,shihongl,hculbert)@usc.edu

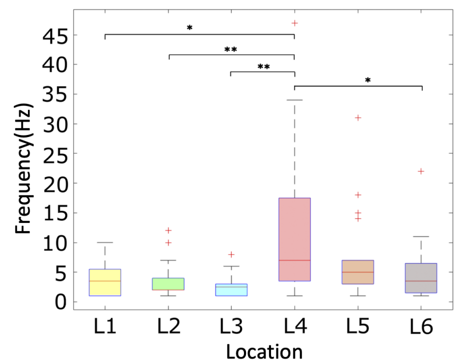

Fig. 2. Detection Threshold DT separated by different locations.

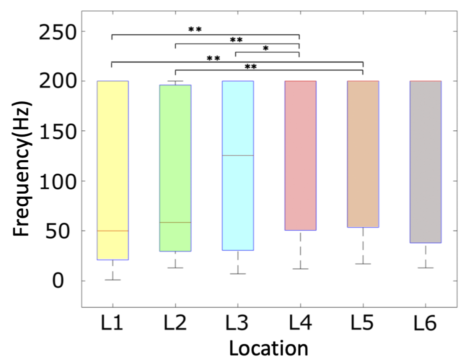

Fig. 3. Pain Threshold PT separated by different locations.

The significant spatial differences in electrotactile perception across different contact areas that we observed indicate the need for location-based customization of electrotactile experiences. These findings can inform the design of our arm-worn electrotactile device by allowing us to optimize electrode placement for enhanced perception and signal calibration. Further studies will be conducted to understand how multiple electrotactile actuators can work together to create more complex sensations, such as in the creation of illusory motion along the forearm.

References

[1] H. Kajimoto, "Electrotactile display with real-time impedance feedback using pulse width modulation," *IEEE Transactions on Haptics*, vol. 5, no. 2, pp. 184–188, 2011.

[2] P. Kourtesis, F. Argelaguet, S. Vizcay, M. Marchal, and C. Pacchierotti, "Electrotactile feedback applications for hand and arm interactions: A systematic review, meta-analysis, and future directions," *IEEE Transactions on Haptics*, 2022.