DOI: 10.3217/978-3-99161-050-2-117

Combatting percept adaptation to intracortical microstimulation in humans

Taylor Hobbs[1,2]*, Charles Greenspon[3], Michael Boninger[1,4], Robert Gaunt[1,4]

Rehab Neural Engineering Labs[1], Depts. of Bioengineering[2], University of Pittsburgh, Dept. of Organismal Biology and Anatomy[3], University of Chicago, Physical Medicine and Rehabilitation[4], University of Pittsburgh

*1622 Locust St, 4th Floor, Pittsburgh, PA, USA, 15219, Email: tgh28@pitt.edu

Introduction: Without tactile sensation, even simple, everyday tasks become nearly impossible [1]. Intracortical microstimulation (ICMS) in the human somatosensory cortex (S1) can restore tactile sensations by using electrical stimulation to activate sensory neurons in the brain that would normally respond to touch [2]. Typically, ICMS trains consist of unmodulated single-channel stimulation with a constant amplitude and frequency. These stimuli evoke vivid tactile percepts originating from the participants' own hands. Unfortunately, the perceived intensity of these sensations can rapidly decrease during stimulation, falling below the perceptual threshold in tens of seconds [3]. Desensitization may occur, in part, because these ICMS trains do not resemble naturally evoked neural activity.

Material, Methods and Results: Two microelectrode arrays were implanted in both the motor and somatosensory cortices of 3 participants with tetraplegia as part of a clinical trial (NCT01894802). We designed two ICMS encoding schemes leveraging biological principles: biomimetic ICMS, which mimics natural spatiotemporally modulated neural activity, and interleaved ICMS, which takes advantage of overlapping sensory fields to distribute stimulation across multiple electrodes. For biomimetic ICMS, we co-modulated frequency and amplitude (40 to 80 µA at 100 to 200 Hz) with a large but brief (200 ms) onset and offset transient stimulation bursts. For interleaved ICMS we used four electrodes with overlapping projected fields and cycled through each electrode using 200 ms of ICMS at 40 µA at 100 Hz, parameters that were above threshold for each of the four electrodes. To test percept resiliency, participants either watched a clock face and were asked to report how long the sensation lasted or used a tablet to continuously report the stimulation intensity. Stimulation durations were randomly chosen from 1 to 180 s intervals. Preliminary results show that unmodulated ICMS led to rapid adaptation, biomimetic stimulation increased the perceived duration, and interleaved ICMS completely eliminated percept adaptation (see Fig. 1, n = 7 electrodes). In fact, sensations from interleaved ICMS could be reliably felt for over a minute.

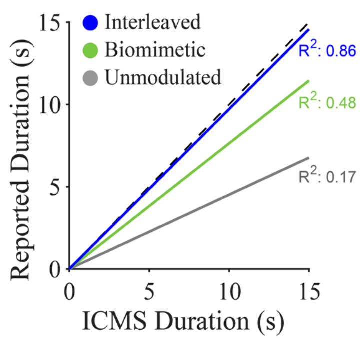

Figure 1*: Best-fit lines comparing true stimulation duration to the reported perceived duration. Lines below the dashed unity line indicate percept adaptation, where perceived duration is shorter than the actual stimulation duration.*

Conclusion: These experiments demonstrate that both biomimetic and interleaved ICMS encoding schemes greatly extend the perceived sensation duration compared to traditional unmodulated stimulation. These improvements likely arise from dynamic and distributed stimulation patterns, which may reduce neural adaptation. Notably, biologically inspired ICMS overcomes a critical limitation for the practical use of ICMS in restoring sensation, providing reliable and uninterrupted sensory percepts for neuroprosthetics. Future experiments will expand these experiments to additional electrodes and participants.

Acknowledgements and Disclosures: This work was supported by NIH UH3NS107714 and NDSEG Fellowship. RG is on the advisory board of Neurowired and previously consulted for Blackrock Neurotech.

References:

[1] R. S. Johansson, "Hand and Brain," *Part 5 Sensorimotor Hand*, pp. 381–414, 1996, doi: 10.1016/b978-012759440-8/50025-6.

[2] S. N. Flesher *et al.*, "Intracortical microstimulation of human somatosensory cortex," *Sci Transl Med*, vol. 8, no. 361, 2016, doi: 10.1126/scitranslmed.aaf8083.

[3] Hughes, Christopher L., Sharlene N. Flesher, and Robert A. Gaunt. "Effects of stimulus pulse rate on somatosensory adaptation in the human cortex." *Brain stimulation* 15.4 (2022): 987-995.

Published by Verlag der Technischen Universität Graz