Biomimetic Intracortical Microstimulation Improves Percept Naturalness in Humans

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Introduction: Without tactile sensation, even simple, everyday tasks are nearly impossible [1]. Intracortical microstimulation (ICMS) in the human somatosensory cortex (S1) provides an innovative way to restore tactile sensations by using electrical stimulation to activate sensory neurons in the brain that would normally respond to touch [2]. ICMS evokes vivid tactile percepts from paralyzed limbs and significantly improves control of BCI controlled limbs [3]. However, it remains unclear how 'natural' ICMS-evoked percepts are and whether different stimulation paradigms can modify naturalness. In this work, we use both mechanical stimulation and ICMS in a psychophysical task to determine the effects of biomimetic ICMS on naturalness.

Material, Methods and Results: Two microelectrode arrays were implanted in both the motor and somatosensory cortices of 2 participants with tetraplegia. Both participants retained some cutaneous sensations from their hands. In a two-alternative forced choice task, participants were presented with a mechanical indentation to sensate skin on their hand followed by two ICMS trains. The mechanical stimulus was 1 s long and indented the skin to a depth of 2 mm at a rate of 10 mm/s. The ICMS trains were presented in a random order and used either a linear or biomimetic encoding scheme at 250 Hz. The biomimetic trains captured essential features of neural activity in S1 during touch and consisted of a transient phase at the beginning and end of the train, each lasting 0.2 s at an amplitude of 80 µA. Between the transients, the amplitude was 40 µA. In the linear trains, the stimulus amplitude profile matched the mechanical indentation and the maximum stimulation amplitude was set either to the amplitude during the hold phase of the biomimetic train (40 µA), or to match the total charge during the biomimetic train (70 µA). After the two ICMS trains, the participant was asked which train felt more like the reference mechanical stimulus. Preliminary results show that biomimetic stimulation encoding feels more natural compared to both control linear trains ($n = 8$ electrodes, $p < 0.05$, chi-squared test).

Discussion: These experiments demonstrate that study participants are able to directly compare tactile percepts evoked by ICMS and mechanical input, and more importantly, that biomimetic stimuli feel more like actual physical touch than linearly encoded stimulation trains. We interpret these results to mean that biomimetic stimuli are perceived as being more natural. Future experiments will expand these experiments to additional electrodes and participants.

Significance: A better understanding of how stimulation parameters and encoding schemes modulate naturalness will help ICMS more closely mimic natural sensations and improve the quality of restored sensation.

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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] S. N. Flesher *et al.*, "A brain-computer interface that evokes tactile sensations improves robotic arm control," *Science*, vol. 372, no. 6544, pp. 831–836, 2021, doi: 10.1126/science.abd0380.