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The Impact of Directed Attention on ICMS in Human Somatosensory and Motor Cortex

Ali H. Alamri[1*], NatalyaD. Shelchkova[1*], Nicholas G. Hatsopoulos, Charles M. Greenspon[1]
[1]*Department of Organismal Biology and Anatomy, University of Chicago, Chicago, IL, USA*
[*] E-mail: ahalamri@uchicago.edu

Introduction: Intracortical microstimulation (ICMS) can be used to restore touch perception to individuals with spinal cord injury (SCI) using. Here we explore how top-down attention modulates ICMS-induced sensations in participants with Utah arrays implanted in the primary somatosensory and motor cortex. Attention is crucial for filtering relevant sensory inputs, a process which will be important for the effective operation of densely sensorized prosthetics. In this study we assess whether attention enhances or suppresses the perceptual clarity of ICMS sensations and if the locus of attention can be decoded from the sensorimotor cortices.

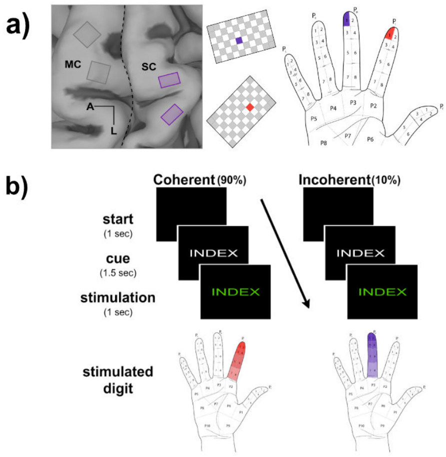

Figure 1. ***(A)*** *Left panel: Participant implants, showing two arrays in the motor cortex (left of the central sulcus, dashed line) and two in the sensory cortex (right of the central sulcus). Middle panel: Sensory arrays with two example electrodes highlighted. Right panel: Stimulation projection fields for the two highlighted electrodes.* ***(B)*** *The Posner-like detection task begins by directing the participant's attention to one of the two digits selected for the session, indicated by white text on a screen. Stimulation is delivered to the electrode corresponding to the cued digit, with the text turning green as feedback. The participant reports whether they perceived any stimulation. On 10% of trials, stimulation is instead delivered to the electrode corresponding to the unattended digit.*

Material, Methods and Results: Participants performed a Posner-inspired ICMS task to examine attention's effects on ICMS detection. Two electrodes targeting distinct fingers (Fig. 1a) were selected based on their projected fields. Psychometric detection functions were computed for each electrode during attention to the stimulated finger. A detection task followed, with trials interleaved between electrodes (Fig. 1b). On 90% of trials, participants were cued to the correct finger (coherent trials), while on 10%, stimulation occurred at the other finger (incoherent trials). Effects of spatial attention were minimal and inconsistent across electrodes, suggesting challenges in directing attention to individual fingers or the salience of unattended stimulation (Fig. 2a,b). Incorporating baseline stimulation may improve consistency. Some channels showed increased activity with digit-specific firing rate increases, while others decreased during the cueing period (Fig. 2c). Motor cortex activity increased relative to baseline during cueing, whereas sensory cortex activity decreased. Post-stimulation, ICMS-evoked responses were elevated and strongly digit-dependent in both cortices (Fig. 2d,e). The attended digit was decodable above chance from the motor cortex but not from the sensory cortex (Fig. 2f,g).

Conclusion: Spatial attention minimally influenced detection consistency, likely due to the salience of unattended stimulation. Neural activity revealed decreased sensory cortex activity during cueing and elevated ICMS-evoked responses in both motor and sensory cortices post-stimulation. Notably, motor cortex activity allowed above-chance decoding of the attended digit (Fig. 2f), unlike sensory cortex activity. This work advances the understanding of attention-driven ICMS modulation and suggests strategies for optimizing sensory prosthetics.

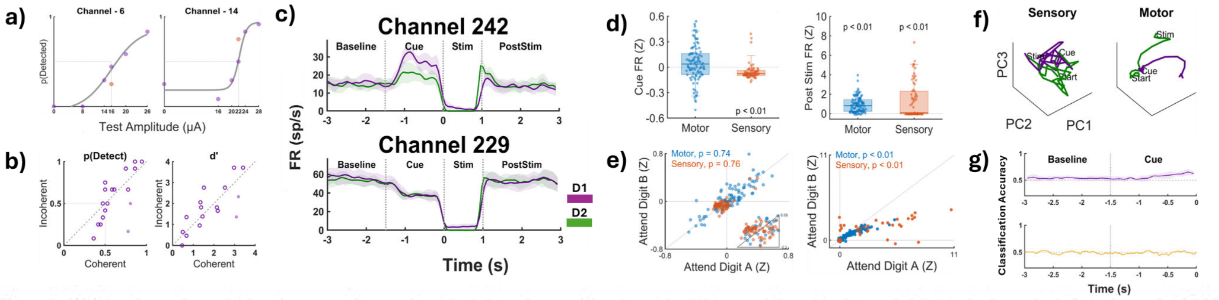

Figure 2. ***(A)*** *Example psychometric detection curves for two channels during coherent trials, where stimulation was delivered to the cued digit (purple data points). Detection at the DT-50 amplitude, where incoherent trials (stimulation was delivered to the unattended digit) were tested, is shown in orange.* ***(B)*** *Left panel: Scatterplot depicting detection performance for each channel at the DT-50 amplitude across coherent and incoherent conditions. Right panel: Corresponding scatter plot displaying d' (discriminability) values, a measure of sensitivity in distinguishing between signal (stimulation present) and noise (no stimulation) conditions.* ***(C)*** *Average firing rates for two representative channels across task phases, including baseline, cue, stimulation, and post-stimulation periods.* ***(D)*** *Left panel: Scatter box plot illustrating changes in average firing rate for all channels during the cueing period relative to baseline, separated by motor (blue) and sensory (orange) cortex. Right panel: Same analysis for the post-stimulation period.* ***(E)*** *Left panel: Scatterplot of Z-scored firing rates relative to baseline for "attend digit A" (x-axis) versus "attend digit B" (y-axis) during the cueing period, separated by motor and sensory cortex. Right panel: Corresponding scatterplot for the post-stimulation period.* ***(F)*** *Projection of neural activity onto the top 3 PCs for each digit for sensory vs motor arrays.* ***(G)*** *dashed line indicates deployment of attention. [top] The classification accuracy of the attended digit from motor cortex. [bottom] Control, to determine whether what we were decoding was actually motor intention to move.*

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