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Intracortical Microstimulation as a Feedback Source for Brain-Computer Interface Users

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Introduction: Somatosensory feedback is necessary for skilled movement. While brain-computer interfaces (BCI) have enabled users to achieve high degree-of-freedom control using a prosthetic limb, feedback has been limited to vision. In tasks such as object manipulation however, providing somatosensory feedback could be an important step to improving BCI limb control. One possible mode of delivering this feedback is by using intracortical microstimulation (ICMS) of the primary somatosensory cortex (S1).

Material, Methods and Results: A twenty-seven year old participant with a chronic C5 motor and C6 sensory AIS B spinal cord injury was implanted with two intracortical microelectrode arrays (MEAs) in S1. The MEAs were targeted to the hand region of area 1 in the left hemisphere based on presurgical imaging. The goal was to elicit cutaneous percepts that project to the fingers of the right hand (see Fig 1c).

Electrodes were stimulated at supraliminal intensities so that the participant could describe the locations and qualities of the percepts. The projected fields of the electrodes (see Fig 1a and b) were located in digits 2-5 and at base of each of those fingers. Sensations were reported from 59 of 64 electrodes, and no painful sensations or paresthesias were reported. We also investigated the effect of increasing amplitude on perceived intensity. The relationship appeared to be linear ($R^2 = 0.98$) for the 5 electrodes tested (see Fig 1d).

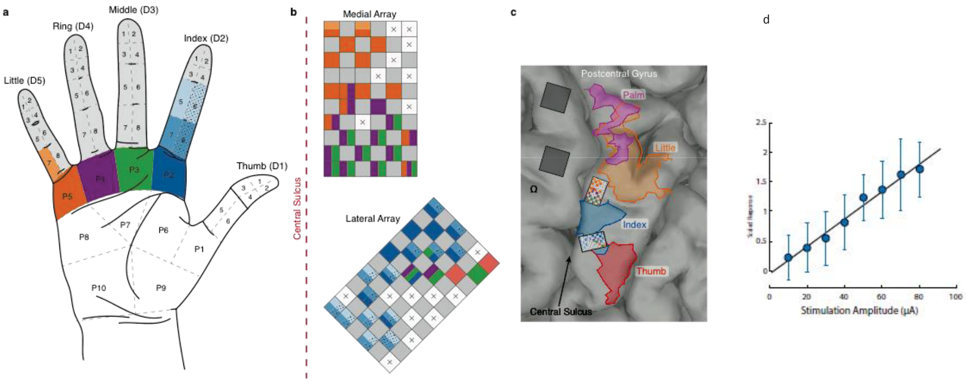

Figure 1. *Locations and intensity of percepts elicited by ICMS delivered to S1 a. A segmented hand was shown to the subject to document the projected fields elicted by ICMS. Colored areas represent locations of the hand where focal percepts were reported. Gray regions represent locations where percepts were reported as part of large, diffuse projected fields. b. Layout of projected fields on implanted arrays. Gray squares indicate unwired electrodes, while white crosses indicate electrodes that did not elicit any percepts c. Regions of cortex activated during presurgical imaging experiments. The locations of the arrays and projected fields are overlaid. d. The perceived intensity scaled with increasing stimulus amplitude. The averaged data from 5 tested electrodes are shown normalized to its mean response. Error bars represent one standard deviation from the mean. The black line shows the linear regression fit to the data.*

Discussion: These results demonstrate that ICMS delivered to area 1 of S1 has the potential to provide somatosensory feedback to people who use BCIs. We found that percepts were evoked at somatotopically relevant locations, and that the perceived intensity of stimuli scaled linearly over a large range. These features enable us to relay both the location and intensity of object contact, two sources of information that would be helpful for BCI users to interact with objects.

Significance: The ability to provide artificial somatosensory feedback to BCI users could improve the user's control and experience with the device. This is an important step towards a clinically relevant neuroprosthetic.

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