# Technical Considerations for Generating Somatosensation via Cortical Stimulation in aClosed-loop Sensory / Motor Brain Computer Interface System in Humans

Daniel R. Kramer MD; Spencer Kellis PhD; Michelle Armenta PhD; Ian Andre Buchanan MD; Charles Y. Liu MD, PhD; Richard Andersen PhD; Brian Lee MD PhD

Department of Neurosurgery, University of Southern California, Los Angeles, California, USA

CNS 2017 ANNUAL MEETING BOSTON, MASSACHUSETTS OCTOBER 7–11, 2017

## Introduction

Here we evaluate the utility of a small-area, high-density subdural electrocorticography (ECoG) grid as a cortical stimulating array to generate the percepts of somatosensation for use in a closed-loop BCI system.

### Grid Comparison

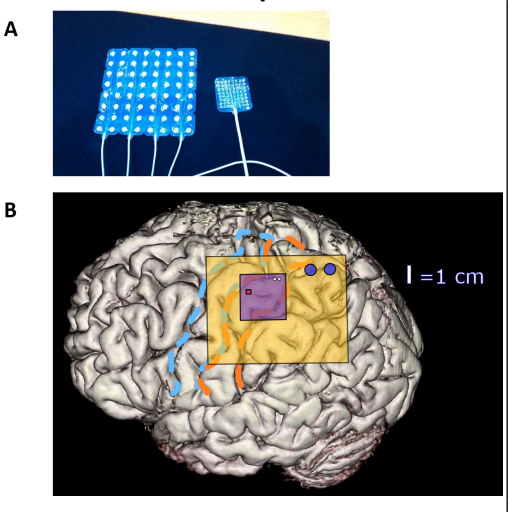



Fig 1. A. Standard 8x8 electrocorticography grid (left) next to a "mini" electrocorticography grid (right). B. To scale comparison of grid size overlaid on a 3-dimensional reconstruction of the brain.

## Methods

We compare "mini"-electrocorticography grids (mECoG), standard grids (sECoG), and microelectrode arrays (MEA), as vehicles for delivering cortical stimulation to generate sensation. An epilepsy patient undergoing invasive seizure localization was also implanted with a 64-channel mECoG (2-mm diameter contacts with 3-mm spacing) over the hand area of primary somatosensory cortex (S1). Another patient was implanted with a sECoG (5-mm contacts with 1-cm spacing) over the S1 hand area (S2). Finally, we reference data in the literature from a patient implanted with a (MEA) in the S1 hand area (Flesher et al., 2016). We compare stimulation results to assess coverage and resolution of the percepts in the hand. Percentage of surface area covered, electrodes per anatomically spaced dermatomal box (broken into 16 boxes per Figure 3), and the boxes per electrode, were calculated to estimate the area covered and the resolution of the coverage. If stimulation occurred anywhere in a dermatomal box, the entire box was included.

## Results

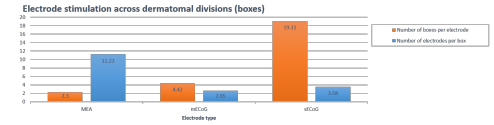
For the mECoG, hand mapping revealed coverage of 41.7% of the hand area versus 100% for the sECoG, and 18.8% for the MEA. Each electrode created sensation in 4.42 boxes (on average, range 1-11 boxes) for the mECoG array, 19.11 boxes (range 4-48 boxes) for the sECoG grid, and 2.3 boxes (range 1-5 boxes) for the MEA. Each box was stimulated by an average of 2.65 electrodes with the mECoG grid (range 1-5 electrodes), 3.58 electrodes for the sECoG grid (range 2-4 electrodes), and 11.22 electrodes (range 2-17) for the MEA. Stimulation was stable throughout testing, with no loss of ability to interpret artificial percepts described or exhibited by the subjects with mECoG or sECoG arrays.

### Surface area coverage and resolution of stimulation by electrode array type.

A.

| | Surface area covered (%) | Electrodes with hand sensation (%) |
|---|---|---|
| MEA | 18.9 | 68.8 |
| mECoG | 41.7 | 40.6 |
| sECoG | 100 | 29.2 |

B.




MEA= Microelectrode array; mECoG= Mini-electrocorticography grid; sECoG= standard-electrocorticography grid.

Fig 2. A. The surface area of the hand included in stimulation by electrode array type and the percentage of electrodes that resulted in somatosensory stimulation by electrode array type. The mECoG array was most balanced covering 41.7% of the hand and using 40.6% of the electrodes. B. A comparison of the average dermatomal boxes stimulated per electrode and electrodes per box.

### Representations of the stimulation across the grid types, the surface area, and location of the sensations.

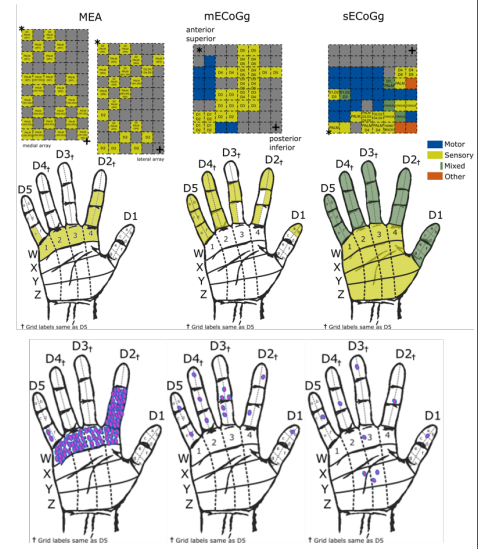



Fig 3. A. Each grid type exhibiting where on the grid, and how much of the grid, was involved in somatosensory percepts. B. The location of the areas covered by the sensory percepts. The MEA was concentrated in the upper palm area, whereas the mECoG showed excellent representation in the fingers. C. The central location of each sensation from stimulation. Each dot represents an electrode stimulation, highlighting the concentration of electrodes in the same area for the MEA and the limited resolution of the sECoG.

## Conclusions

Based on these findings, we conclude that mECoG grids provide an excellent balance between spatial coverage of the hand area of S1 and high resolution.