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Detailed Somatotopy of Speech Articulators in the Somatosensory Cortex to Define Electrocortical Stimulation Location

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Introduction: Communication through speech is an important aspect in our daily life. People with severe motor impairment, caused by neurological disorders such as brainstem stroke or amyotrophic lateral sclerosis, are unable to speak or communicate effectively. Brain computer interfaces (BCIs) may offer a solution to this problem by using voluntarily induced signal changes in the sensorimotor brain areas, produced by attempts to move a body part (e.g., hand or speech articulators), to control a communication device. Achieving reliable BCI control can be a difficult and time-consuming process, likely related to the absence of relevant somatosensory feedback on the movement attempts. Indeed, somatosensory feedback through electrocortical stimulation improved robotic arm control in a person with tetraplegia [1], which suggests that also communication BCIs may benefit from this strategy. To determine where to apply electrical stimulation to the somatosensory cortex for relevant feedback, it is necessary to understand the underlying brain processes of tactile perception. Previous research consistently found an ordered representation of the hand and fingers in the somatosensory cortex [2], but the somatotopic organization of the speech articulators in this brain region remains unclear. We aimed to investigate the detailed representation of the speech articulators in the somatosensory cortex and assess how this representation relates to the location of sensations induced by electrocortical stimulation.

Material, Methods and Results: We recorded 7 Tesla functional magnetic resonance imaging (fMRI) data of ten healthy participants (mean age 26.8±6.7 years, 7 female) during pneumatic stimulation of the speech articulators (inner mouth, upper/lower lip, left/right cheek, chin, and neck) with an in-house developed air puff device. We mapped fMRI activity patterns per participant to a common surface space and calculated the mean activity map per articulator. In addition, we performed electrocortical stimulation on a high-density 32-channel electrocorticography (ECoG) grid implanted over the left ventral sensorimotor cortex of an individual with epilepsy (age 46 years, female). The epilepsy participant was asked to inform the researcher when she felt a sensation, and to indicate its location. The left hemisphere fMRI data revealed a ventral to dorsal arrangement of the speech articulators: the inner mouth (including tongue) covered a relatively large area of the somatosensory cortex, followed by the lips, and subsequently by overlapping areas of the chin and left and right cheek. The ECoG grid of the epilepsy participant only covered the inner mouth and lip regions of the fMRI activity maps. Stimulation of several electrodes in the ECoG grid induced sensation in the palate, teeth, jaw, tongue, right lower lip, and right cheek.

Conclusion: The speech articulators were found to be orderly represented in the somatosensory cortex, and results between fMRI and a preliminary electrocortical stimulation experiment seemed to align. These findings indicate that non-invasive methods, such as fMRI, may predict the optimal electrode locations for providing relevant somatosensory feedback and are therefore important for the correct placement of ECoG grids for communication BCIs. However, the results need to be confirmed with inclusion of more participants.

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