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Broca's Area: A Single-Unit Recording Perspective

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Introduction: Left inferior frontal gyrus (LIFG), encompassing Broca's area, has long been associated with human speech and language, including articulation. Furthermore, LIFG has more broadly been implicated in diverse functions of human cognition extending beyond speech, language and grammatical processing to tasks like rhythm processing, arithmetic, working memory, and more [1,2]. While functional MRI (fMRI) has paved the way in attributing such diverse cognitive functionality to this region of the brain, understanding the exact role LIFG plays in these diverse tasks of human cognition requires greater spatial and temporal resolution. Here we present early data from the first LIFG recordings from intracortical microelectrode arrays during cognitive tasks historically associated with the region.

Material, Methods and Results: A Braingate participant ("T12") with anarthria due to bulbar ALS received two Utah arrays in LIFG and two in ventral precentral gyrus. T12 is left-handed but exhibited strong left-sided language processing on fMRI. Most tasks included in this study were conducted in an instructed-delay paradigm: each trial was cued with either displayed text or an audio recording during a 'delay' period followed by a 'go' period, during which the participant attempted to vocalize the answer to the prompt or perform the desired action. We have to date collected microelectrode array recordings during tasks involving simple instructed movements (e.g., "close your hand"); speaking, reading, and listening to words and sentences; free-response speech; rhythm and melody; arithmetic; grammatical processing; spelling; action imitation and observation; sequential and bimanual gestures; as well as the classic Stroop task. Notably, we found that while LIFG recordings showed increased modulation during listening and speaking tasks as compared to resting state, there was little to no cross-condition modulation differences that would demonstrate that LIFG plays a strong role in producing or interpreting the content of what was being spoken or heard. LIFG was also not strongly modulated for simple instructed movements. This was in contrast to other tasks that showed high cross-condition modulation, including a spelling task in which T12 was instructed to spell a word aloud either forwards or backwards, a grammar fill-in task in which T12 was instructed to complete a sentence with a root word while applying any necessary semantic or phonological changes to the root word, and an action imitation task in which T12 had to imitate short sequences of gestures or sign language (not previously known to the participant).

Discussion: The results from T12's LIFG microelectrode array recordings implicate LIFG as having a role in a variety of cognitive tasks, including tasks that do not involve language or speaking. Federenko et al 2020 summarize a large body of previous fMRI literature and propose that Broca's area contains two functionally-distinct subregions, a "language network" and a domain-general "multiple-demand network." Our preliminary findings in T12, which show little cross-condition modulation for low-level speech articulation, but large cross-condition modulation for higher-level cognitive tasks align well with this proposal, with the possibility that T12's arrays are in the domain-general region of LIFG. Further data collection and analysis will aim to elucidate any unifying role that LIFG may play in the diverse set of cognitive tasks for which it has been implicated, including language, speech planning and production.

Significance: High-resolution neural ensemble recordings in LIFG in a person with anarthria due to ALS afford a new, in-depth perspective on the role of LIFG in general human cognition.

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