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Decoding hierarchical elements of language from speech motor cortex to restore communication for people with ALS

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***Introduction**:* One of the most disabling symptoms of ALS is loss of communication. For people with dysarthria and loss of dexterous control of hand movement, commercially available augmentative and alternative communication devices can be used to maintain communication. However, these devices are often slow, error prone, and require frequent caregiver interaction, limiting their utility. Recently, intracortical brain computer interfaces (iBCIs) have been used to decode the neural correlates of intended speech, allowing users with speech-motor paralysis to communicate by attempting to talk [1, 2]. These systems work by identifying the phonemic components of intended speech based on neural activity recorded from speech motor cortex; however, they lack robustness for sub-optimal signal-to-noise ratio. Information pertaining to higher-order components of language, such as intended semantic content or sentence syntax, could be used to improve the speed and accuracy of speech decoding. It is unknown, however, which, if any, higher-order elements of language are encoded within speech motor cortex.

Methods and Results: In this work, we examine the cortical representation of linguistic information beyond the phoneme level, and characterize how this hierarchical linguistic information is encoded within speech motor cortex in two participants in the ongoing BrainGate clinical trial, both with ALS: participant T17, a 33-year-old man with quadriplegia, anarthria, and ventilator-dependence due to the advanced symptoms of ALS, implanted with six 64-channel microelectrode arrays in the dominant precentral gyrus, including four in the speech motor cortex (Brodmann areas 6v and 55b), and participant T15, a 45-year-old man with ALS, with tetraparesis and severe dysarthria, implanted with four microelectrode arrays in his left ventral precentral gyrus. To investigate the encoding of semantically and syntactically different stimuli in the neuronal activity within these areas, we asked the participants to attempt to speak one of four different types of visually-presented text [3]: (1) grammatically correct sentences, (2) agrammatic lists of words, (3) grammatically structured sentences with gibberish content words, or (4) agrammatic lists of gibberish words. Interestingly, our results show distinct, participant-dependent roles for areas 6v and 55b. Within area 6v, we find for both participants reliable decoding of phonemes that appears minimally modulated by sentence structure. In contrast, within area 55b, we observe a different behavior for the two participants: while for T15 area 55b shows similar characteristics to area 6v, for T17 we find strong encoding for the text category but minimal phonemic information. These results suggest that the area identified as 55b indeed encodes higher-order elements of intended language, however to different degrees for different participants.

Conclusion: Combining the data from the two participants, we show evidence for sentence-level representations in these motor cortex areas and suggest how this neuronal information can be used for improving the performance of iBCI speech neuroprostheses.

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