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Decoding speech and internal speech on the single unit level from the supramarginal gyrus in a tetraplegic human

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Introduction: Speech is a natural and intuitive way for humans to express their thoughts and desires. Neurological diseases like amyotrophic lateral sclerosis (ALS) and cerebral brain lesions can lead to the loss of this ability, leaving patients without any means of communication. Brain-Machine-Interfaces (BMIs) offer a promising technological path to restoring communication by recording neural activity related to speech. While important advances in overt, attempted, and mimed speech decoding have been made, results in internal speech decoding are sparse, and have yet to achieve high functionality in real-time. We hypothesized internal speech would modulate single unit activity in SMG, due to its involvement in vocalized speech and other language processes.

Material, Methods and Results: In this work, a C5 - C6 tetraplegic patient implanted with Utah arrays in the supramarginal gyrus (SMG) performed an internal and vocalized speech task. In an offline task, trials were composed of six phases, beginning with a brief inter-trial interval, followed by an auditory or written cue to one of eight words (6 words, 2 pseudowords). Then, after a delay period, the subject was instructed to internally say the word, and after a second delay, to vocalize the word. We found single units tuned to words during cue, imagined and vocalized speech phases. Decoding accuracies averaged 55% for internal speech, and 74% for vocalized speech. An online task strictly using data recorded during internal speech was implemented. Online internal speech decoding accuracies increased with number of trials used to train the model and reached up to 91% accuracy (chance level ~ 12.5%). Shared representations between imagined and vocalized speech were demonstrated through overlapping tuned units and cross-classification analysis. Evidence for both phonetic and semantic representation were found by decoding words with identical semantic meanings and homonyms.

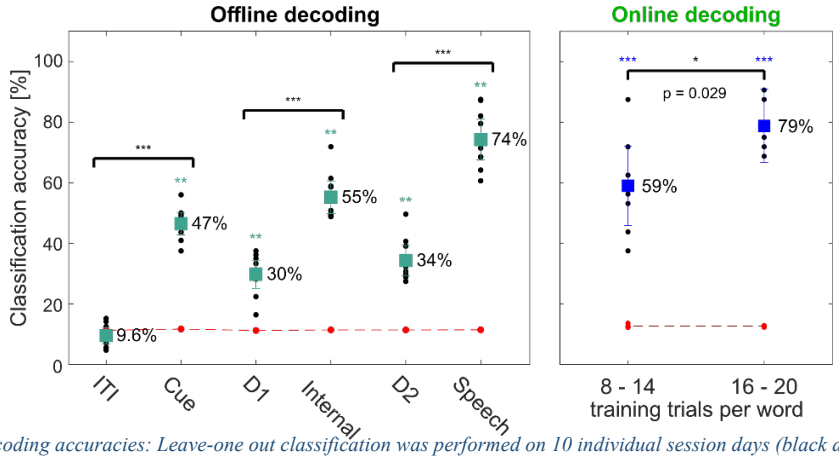

*Figure 1 Offline decoding accuracies: Leave-one out classification was performed on 10 individual session days (black dots). PCA was performed on the training data keeping 95% of the explained variance, a LDA model was constructed, and classification accuracies were plotted with 95% c.i, over the session means. Significance of classification accuracies was evaluated by comparing results to a shuffled distribution (averaged shuffle results = red dots, * = $p < 0.05$, ** = $p < 0.01$). Classification accuracies during action phases (Cue, Internal, Speech) following rest phases (ITI, D1, D2) were significantly higher (t-test: ***$p < 0.001$). Online decoding: Classification accuracies for internal speech were evaluated in a closed-loop internal speech BMI application, demonstrating significantly better decoding accuracies when increasing the number of training trials to construct the decoding model.*

Discussion and Significance: Current speech BMIs rely on the patient's ability to produce sounds or movements of the mouth, which is not feasible for those affected by complete paralysis. Here, we show robust internal speech modulation within an area of the SMG, located in the posterior parietal cortex. The work provides proof-of-concept that internal speech BMIs can be built using multielectrode arrays implanted in a single brain area, and that findings could translate to the locked - in population.