Temporal Dynamics of Stuttered Speech

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INTRODUCTION. Stuttering is a neurodevelopmental communication disorder that manifests itself, most saliently, as intermittent interruptions in speech production (i.e., within-syllable repetitions and audible/inaudible prolongations of sounds). Despite significant progress towards discovering structural and functional abnormalities in the brains of speakers who stutter, little is known about the neural bases of the intermittent interruptions characteristic of stuttering. Due to the difficulty of reliably eliciting stuttered speech during laboratory testing, neuroimaging studies have typically compared the brain activity of people who stutter with that of fluent speakers *during fluent speech*. These studies reveal general processing differences associated with stuttering (e.g., trait differences) but do little to elucidate differences associated with actual stuttering events (i.e., state differences). Thus, it is difficult to know whether previously reported functional differences are associated with stuttering events at all. The goal of the proposed study is to identify the neural mechanisms that differentiate stuttered from fluent speech within a cohort of adults who stutter. This study builds on recent work that established a method for eliciting stuttered speech during neuroimaging leveraging stuttering anticipation (Jackson et al., 2019). In addition, recent data from the research team identified a potential *preparation* mechanism – peak activation just prior to speech initiation – underlying stuttered versus fluent speech that comprises well-known speech and inhibitory regions. However, fNIRS assesses the "slow" hemodynamic response (i.e., peak activation occurs between four-six seconds post-event), leaving the temporal dynamics of stuttered speech mostly unexplored. The current study uses magnetoencephalography (MEG), a neurophysiological technique with excellent temporal resolution, to study the brain temporal dynamics characterizing stuttered speech.

METHODS. To assess the temporal dynamics of neural activity prior to stuttering events, we designed a MEG protocol in which participants produce single words while their brain responses, voice, speech muscle, and eye movements are recorded.

Participants. We will recruit 25 participants in total (and include ~15, see below). Inclusionary criteria include a diagnosis of stuttering by a certified speech-language pathologist with expertise in stuttering intervention; exclusionary criteria include a negative history of hearing, neurological, and speech-language impairment (except stuttering), and psychological impairment.

Protocol. Visit 1: Participants will take part in a stuttering assessment and clinical interview, following Jackson et al. (2019), to determine participant-specific word lists that are most likely to elicit stuttered speech. Visit 2: Participants will complete a MEG experiment during which they will produce 300 words (6 blocks x 50 words), selected from Visit 1. Words will be presented on a screen one at a time in randomized order, followed by a preparation cue and a cue to begin speaking (see Figure 1).

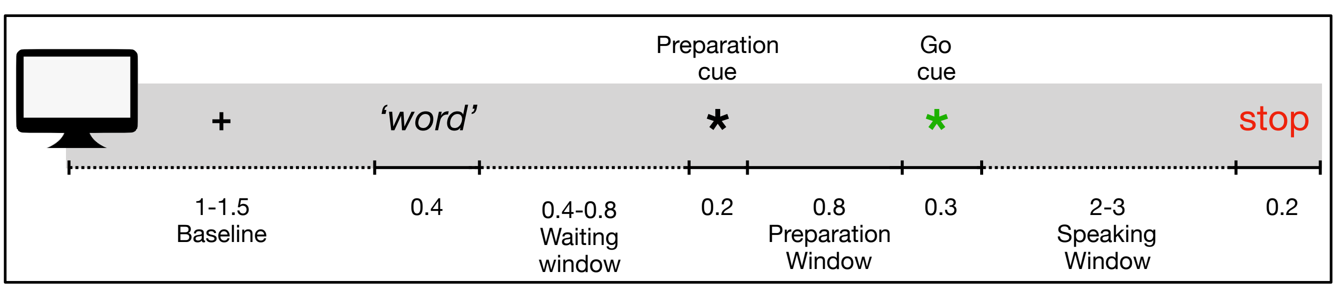

Figure 1. Schematic representation of the prompts displayed on the screen and their corresponding durations. Solid/dashed lines represent fixed/jittered durations. Participants are instructed to view the fixation cross, produce the presented word as soon as they see the green cue, and if necessary, cease production if stuttering is ongoing when the stop cue appears.

MEG Data acquisition and analysis. Neuromagnetic responses are recorded using a 157-channel whole-head axial gradiometer system (Kanazawa Institute of Technology) at the NYU Center for Brain Imaging. Following the removal of externally generated signals and artifacts related to eye-blinks and heartbeat, the continuous MEG data are split into epochs spanning from 200 ms before the Preparation cue to the onset of the Go cue (Figure 1).

A cross-validated decoding approach is then applied to the responses generated during the preparation window (see Figure 1) to classify an event as stuttered or fluent. This approach quantifies the extent to which stuttering can be predicted from the brain activity prior to vocalization onset, implying an atypical articulatory planning stage. Moreover, this method reveals the precise time point(s), before vocalization onset, at which brain activity differs between subsequently stuttered versus fluent productions. Multivariate logistic regression models are fit at each time point independently; thus, the feature inputs to the model are the responses at time *t*, across all MEG sensors. MEG data, at the time points for which decoding of the stuttering event is successful (i.e., significant), can then be projected onto the brain surface to estimate the cortical regions where abnormal activity occurs.

Pilot Data. Behavioral: Two of three pilot participants produced between 30-70% stuttered speech using this paradigm. This ratio is similar to Jackson et al. (2019) in which nearly two-thirds of participants did the same. We plan to recruit 25 participants—which is feasible given the first author's extensive clinical network and relationships with stuttering organizations in New York City—of which approximately 15 will achieve the desired stuttered-fluent ratio (30-70% stuttered). Neural: To test the feasibility of the MEG paradigm, as well as using concurrent EMG activity to demarcate speech initiation, we used the paradigm to differentiate one- versus three-syllable words in a control speaker. Recorded EMG activity consistently preceded speech onset, suggesting a reliable marker for speech initiation (Figure 2). In addition, the decoding procedure showed promise in differentiating one- versus three-syllable words, using a conservative distribution (30% one syllable, 70% three syllables) to match our anticipated proportion of stutter versus non-stutter events (Figure 3). We will begin running participants for this IRB-approved project in early February.

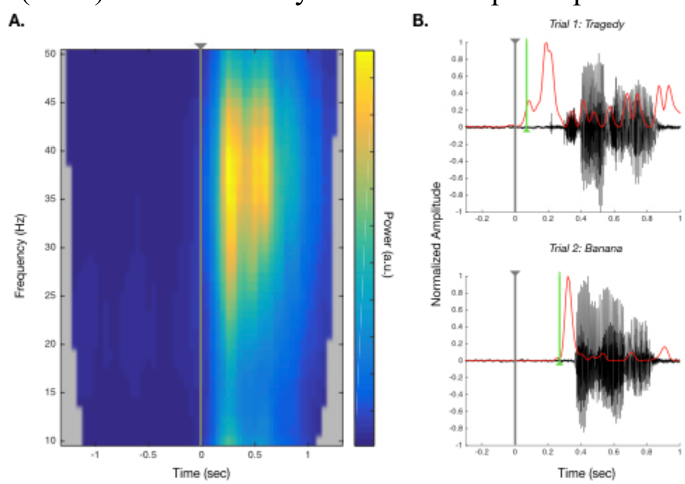

Figure 2. EMG, orbicularis oris muscle activity. (A) Average spectrogram (300 trials). The power increment in the 35-40 Hz range indicates onset of muscle activity after the Go cue (grey line). (B) Two representative trials showing variability in the reaction time and in the lag between muscle activation and speech onset. Red, EMG signal; block, sound wave.

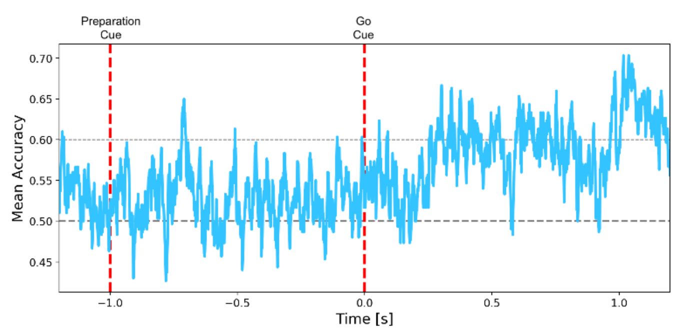

Figure 3. Multivariate logistic regression decoding accuracy across time from the Preparation cue (-1.0 s) to the Go cue (0.0 s), and in subsequent production states (0-1.2 s). See Figure 1 for procedure details.

REFERENCES.

Jackson, E. S., Gracco, V., & Zebrowski, P. M. (2019). Eliciting Stuttering in Laboratory Contexts. *Journal of Speech, Language, and Hearing Research*, 1-8.