2021 Boston Speech Motor Control Symposium

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[D2] **Acoustic and Kinematic Analysis of Articulatory Skills in Autism Spectrum Disorder**
Maffei, M., Chenausky, K., Tager-Flusberg, H., & Green, J. R

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Adaptation to delayed auditory feedback: Timing plasticity of the auditory forward model

Tardif, M. C. & Bohland, J. W.

Models of speech motor control typically include forward models that predict the auditory consequences of planned speech. Adaptation experiments have established plasticity of the forward model in the frequency domain, but less clearly in the timing domain. Forward models must encode both when feedback will occur and what that feedback will contain. Experimentally delaying auditory feedback is one way to globally modify when feedback can be expected during speech. The goal of this study is to quantify the adaptative response to gradual exposure to delayed auditory feedback (DAF). In previous work, individuals changed behavior in response to focal temporal perturbations (Karlin, Parrell, & Naber, 2020) and adapted to a DAF task similar to our paradigm (Katz & Lackner, 1977). Here, participants will produce speech under DAF with gradually increasing delay compared to a control condition (sudden DAF exposure). We will quantify the extent of adaptation and correlate these effects to measures of timing acuity. Specifically, we will measure changes in speech rate, known to be reduced under DAF (Yates, 1963). If rate shows a smaller reduction in the gradual than the control condition, this will provide evidence that the forward model allows adaptation to compensate for the altered motor-to-sensory timing. To account for individual variability, we will collect just-noticeable differences for judging delay intervals in speech under DAF and correlate these thresholds to the adaptation results. Using this approach, we aim to assess the extent of plasticity in global timing predictions in auditory forward models used during speech production.

Key Words: Delayed auditory feedback; foward model; adaptation

Cross-domain generalizability of cerebellar timing mechanisms

Karlin, R. & Parrell, B.

There is evidence that the cerebellum is crucial to processing the duration of single events (“event timing”; Ivry et al. 2002; Teki et al. 2012). Speakers with cerebellar ataxia frequently manifest temporal deficits in both speech production and perception, most apparently in phonological length contrasts (Ivry et al., 1993; Ikui et al. 2012), which suggests that these contrasts utilize event timing. However, it is unknown if the same cerebellar circuit is responsible for timing in both the perceptual and production domains, as well as the speech and non-speech domains. We will conduct a study to investigate the domain-generalizability of timing control, using vowel duration as a candidate for event timing in speech. This study comprises four experiments: speech production, speech perception, non-speech production, and non-speech perception. The speech studies will use an 11-step continuum with vowel length manipulated such that the endpoints are perceived as “sib” (long) and “sip” (short). The non-speech studies will use a comparable continuum of pure tones. In the production tasks, participants will hear a step from the continuum and imitate it. The perceptual tasks will use a perceptual staircase to determine perceptual thresholds. We will compare the measures of perceptual acuity to accuracy and variability in speech and non-speech production. We hypothesize that there will be a by-participant correlation between the speech and non-speech

domains in both production and perception. Data collection for 30 healthy controls starting in spring, with planned extension to patients with cerebellar ataxia.

Key Words: perception, production, timing

Effects of Vowel Centralization Auditory Feedback on Sentence Production

Johnson, S. A., Parrell, B. & Niziolek, C. A.

When speakers' auditory feedback is altered experimentally in a consistent way, they modify their speech motor plan to oppose this perturbation, a process called sensorimotor adaptation. Recent work from our lab has used a "vowel centralization" feedback perturbation which alters the first two vowel formant frequencies, pushing them towards the center of the vowel space and making a speaker's vowels sound less perceptually distinct. Using this paradigm in monosyllabic words, we demonstrated that speakers compensate for the feedback centralization by producing corner vowels farther from the center of the vowel space, thus increasing vowel space area and the average spacing between vowels. Here, we use sentence stimuli to examine how a vowel centralization perturbation affects the vowel space area of typical speakers when producing connected speech. Typical speakers from different age groups will read sentences under vowel centralization auditory feedback and, in a separate control session, under normal auditory feedback. Adaptation will be measured through changes in vowel space area and average vowel spacing between the baseline and adaptation phase. We hypothesize that participants will adapt to the vowel centralization feedback during read sentences as they do during single word production, shifting their vowels so that they are produced farther from the center of the vowel space. This finding would further establish the capacity of sensorimotor adaptation to increase the vowel contrast, and potentially the intelligibility, of natural speech production for typical and atypical speakers.

Key Words: auditory feedback, sensorimotor adaptation, vowel contrast

Effects of /ai/ perturbation on the production of following consonants

Karlin, R., Naber, C., & Parrell, B.

Accurate timing is crucial to speech and requires the coordination of various articulators. Recent studies have demonstrated motor adaptation in response to auditory perturbations of segment duration (Mitsuya et al., 2014; Oschkinat and Hoole, 2020), indicating that speakers use auditory feedback to maintain accurate timing in speech. It has also been hypothesized that coordination of articulatory movements within syllable is less dependent on auditory feedback than coordination across syllable boundaries (Gafos 2002; Tilsen 2016). We will test the effect of temporal perturbation on the planning of upcoming motor movements by accelerating and decelerating the formant transition in /a?/. We will compare cases where the following consonant is across a word boundary (the sigh [sa?] dwells there) vs. in the coda of the same syllable (the side [sa?d] wins there). The

implementation of temporal perturbation will be pseudorandomized in blocks of six trials for each sentence, with four unperturbed trials, one accelerated trial, and one decelerated trial. We will compare the timing of both the perturbed vowel and the following segments between baseline conditions and the perturbed trials. We hypothesize decelerated formant transitions will delay the timing of the following /d/ when it is across a word boundary, but not when it is in the same word. We intend to collect data from 20 healthy controls beginning in the spring. We will ultimately extend to 20 speakers with cerebellar ataxia, who have shown higher dependence on feedback than healthy controls (Parrell et al., 2017; Houde et al., 2019).

Key Words: timing, auditory feedback

The Role of Attention in Compensation for Altered Auditory Feedback

Krakauer, J., Naber, C., Niziolek, C., & Parrell, B.

Speech production relies on auditory feedback (hearing one's speech) to correct for potential errors as they occur. These feedback-based corrections can be studied using altered auditory feedback. In this paradigm, a participant's speech is recorded, altered, and played back to them in real time with an alteration in either pitch or formants (the resonant frequencies of the vocal tract). Speakers tend to oppose these alterations on a trial-by-trial basis (compensation). However, the magnitude of compensation varies both within and between participants, and the source of this variability is currently unknown. Specifically, it is unknown whether these responses are due to processes intrinsic to the speech motor system, or arise through other cognitive processes. Previous studies have found that divided attention modulates feedback-based corrections in vocal pitch; conversely, attention does not affect feedback-based corrections in upper limb reaching movements.

Here, we examine the role of attention in the feedback control of speech through a dual-task paradigm. Participants will speak monosyllabic words ("bed", "dead", "head") while their F1 feedback is shifted (±125 mels) on a pseudorandom subset of trials. In the experimental condition, participants will also perform a secondary distractor task (detecting the direction of a field of moving dots presented during the speaker's vocalization). We hypothesize that divided attention will reduce the magnitude of a speaker's compensatory response. If confirmed, this would suggest that fluctuations in attention contribute to the widely observed variability in compensation, and that, more generally, speech motor control may be influenced by higher-order cognitive systems.

Key Words: attention; feedback control; altered auditory feedback

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Analysis of the Vowel Space Area in Speakers with Parkinson's Disease Before and After Lee Silverman Voice Treatment and Transcranial Magnetic Stimulation

Millard, K., Cannito, M., & Narayana, S.

Parkinson's Disease (PD) with hypokinetic dysarthria, is characterized by decreased loudness and unintelligibility. Reduced vowel space area (VSA) and articulatory undershoot may contribute to unintelligibility. Formants 1 and 2 (F1; F2), related to jaw and tongue movement, are centralized in PD due to articulatory undershoot. Lee Silverman Voice Treatment (LSVT) can improve intelligibility in PD with the goal of increasing loudness via greater vocal effort and oral opening. LSVT may also improve vowel articulation and formant production, resulting in expanded VSA and improved intelligibility. Additionally, LSVT combined with transcortical magnetic stimulation (TMS) might be beneficial if activating the articulatory cortex. The present research uses acoustic metrics for the VSA (triangular and quadrilateral VSA [tVSA, qVSA]; formant centralization ratio [FCR]) to investigate whether there is a larger vowel space after LSVT.

22 persons with PD underwent LSVT with either left, right or sham TMS. Participants were recorded reading the rainbow passage pre and post LSVT and at 3-month follow-up. F1 and F2 of corner vowels /i, ?, ?, u/ were acoustically measured using TF32. Vowels, /?, ?/ were also measured to calculate a lax vowel space together with /?/. tVSA, qVSA, and FCR were calculated and each will be submitted to ANOVA. Effect sizes will be calculated to determine the magnitude of potential differences and vowel plots generated for visual qualitative comparison. An expanded vowel space area after LSVT would suggest greater articulatory achievement of F1 and F2 and may support a positive effect of LSVT on articulation.

Key Words: Parkinson's Disease; Vowel Space Area (VSA); Voice Treatment

Longitudinal remote monitoring of articulatory motor performance in individuals with amyotrophic lateral sclerosis (ALS)

Coladarci, J., Rowe, H. P., Berry, J. D., Green, J. R., & Connaghan, K. P.

Speech decline significantly impacts communication and quality of life for individuals with amyotrophic lateral sclerosis (ALS). Smartphone technology provides promising low-cost and low-burden approaches for efficiently monitoring speech decline and informing optimal communication intervention. The current study explored the utility of extracting a novel set of acoustic features from cell phone recordings to longitudinally track articulatory performance in individuals with ALS. The Beiwe smartphone research platform was used to record syllable sequences (pa-ta-ka) produced by eight speakers with bulbar ALS as part of a larger protocol. The set of acoustic features—derived from a novel framework of motor control (i.e., Coordination, Consistency, Speed, Precision, and Rate)—were extracted from audio recordings at baseline, two months post baseline, and four months post baseline. Time since disease onset (in months) were also recorded for each participant. Results revealed that time since disease onset was inversely correlated with baseline Speed,

Precision, and Rate (r = -.66, -.59, and -.70, respectively), but not with baseline Coordination (r = -.27) or Consistency (r = -.07). These findings are consistent with prior work demonstrating primary deficits in Speed, Precision, and Rate in ALS. Individual participant data revealed that speakers who were more than 20 months post disease onset, as opposed to earlier in the disease, demonstrated the greatest decline in Speed and Precision across the three sessions. These preliminary findings support the implementation of this novel framework for remote monitoring of articulatory decline. Future work will include a larger sample size with more frequent data collection.

Key Words: remote; articulation; acoustics

Semi-automatic vocal tract extraction from real-time magnetic resonance images

Belyk, M., Carignan, C., & McGettigan, C.

Real-time magnetic resonance imaging is a technique that provides high contrast videographic data of vocal tract anatomy. These images allow researchers to observe the internal structures that shape the sounds of speech. However, features of interest need to be extracted from these images to make them useful to researchers. We have developed a novel semi-automated processing pipeline that produces outlines of the vocal tract for further analysis. Our approach uses simple tissue classification constrained to pixels that are likely to contain the vocal tract and surrounding tissue, supplemented by multiple opportunities for the analyst to intervene. Although this approach is more labour intensive than more strongly automated alternatives, these costs are offset by the benefits of having opportunities for quality assurance. We plan to test the portability of this approach to data sets collected across multiple imaging sites and for a wide variety of behaviours that may interest speech scientist. These include the articulation of spoken words in German, vertical movements of the larynx, the tongue's influence on the pitch of oral whistling, as well as genuine and feigned laughter. We also present analyses of a cross section of these data by multiple analysts to assess the potential for for-analyst variability.

Key Words: rtMRI; videography; method

Acoustic and Kinematic Analysis of Articulatory Skills in Autism Spectrum Disorder

Maffei, M., Chenausky, K., Tager-Flusberg, H., & Green, J. R

The factors underlying the wide variation in speech and language deficits among children with autism spectrum disorder (ASD) are not well understood. This study seeks to objectively quantify impairments in articulatory motor control among children with ASD (n = 30, age 6:0 – 8:11) compared to age-matched typically developing controls using acoustic and kinematic data. The study also seeks to determine if the severity of these articulatory deficits predicts concurrent speech and expressive language skills while controlling for age and non-verbal IQ. Using syllable and phrase repetitions, 3D optical motion capture will be used to obtain measures of coordination (lower lip and

jaw coupling), consistency (spatiotemporal index), and speed (lower lip and jaw speed); acoustic analysis will be used to measure precision (acoustic vowel space) and rate (articulation rate). Expressive language and speech skills will be measured using the Clinical Evaluation of Language Fundamentals, 5th Edition and Goldman Fristoe Test of Articulation, 3rd Edition, respectively. The instrumental assessment of articulatory motor control will provide results that are more reliable and less vulnerable to bias than commonly used perceptual methods, and the proposed study would be among the first to use optical motion capture technology to assess speech in this population. Resulting data are critical to (1) furthering our understanding of language deficits in ASD, (2) informing intervention planning for children with ASD, and (3) addressing ongoing clinical and scientific issues including early detection of ASD and the identification of neurobiological mechanisms influencing communication development.

Key Words: autism spectrum disorder; acoustic assessment; kinematic assessment