

Impaired auditory feedback control for pitch production in speech in ataxic dysarthria

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Speech in Ataxia

Ataxic dysarthria is a disorder affecting speech intelligibility due to damage to the cerebellum, a neural structure critical for the timing, scaling, and sequencing of speech. In healthy individuals, the **cerebellum facilitates speech production by integrating sensory feedback** (auditory and somatosensory) with cortical motor plans for speech. When cerebellar functioning is diminished in ataxia, pitch control for prosody is impaired because speech movements for respiration, phonation, and articulation are imprecise, poorly timed, and uncoordinated.

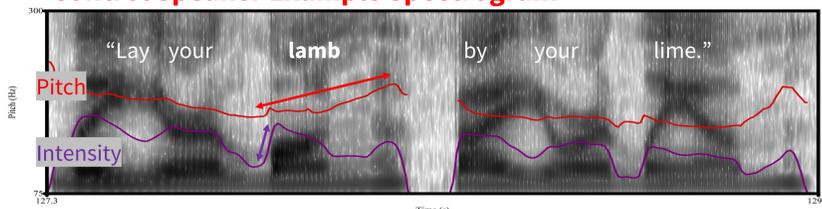
Speech characteristics of ataxic dysarthria

(Darley, Aronson, & Brown, 1969; Duffy, 2013)

- Articulatory characteristics:**
 - Imprecise consonants
 - Vowel Distortions
- Prosodic characteristics:**
 - Prolonged Intervals
 - Variable pitch movements
 - Excessive loudness variation
 - Telescoping: syllables running together
 - Scanning: word-by-word cadence

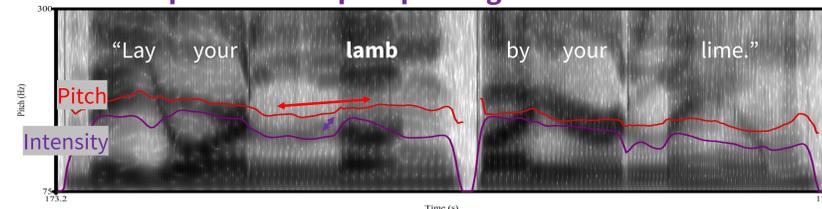
From our sample of **21 participants with ataxia**, participants had on **average 99% speech intelligibility** (scale of 0-100%, 0% meaning no intelligible words, 100% meaning every word is intelligible). On a speech naturalness scale of 1-7, 1 indicating very unnatural-sounding speech, 7 indicating highly natural-sounding speech, the average score for **speech naturalness was 3.8. These results indicate that in ataxia, speech intelligibility is often intact, but speech naturalness is impaired due to prosodic disruption.**

Control Speaker Example Spectrogram



The control speaker makes distinct pitch and loudness movements on the stressed word

Ataxia Speaker Example Spectrogram



Pitch and loudness movements are less salient on the stressed word in the speaker with ataxia

Acknowledgements

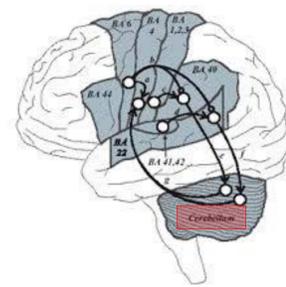
Thank you to Dr. Puneet Opal for his assistance with recruitment for this study. Thank you to all study participants for your time and interest in this research study. This research was funded by the NIH NIDCD F31 DC017877-01A1 and the Council of Academic Programs in Communication Sciences and Disorders.

Models of Speech Production

According to the **DIVA Model** (Directions Into the Velocities of Articulators; Guenther, 2016), the cerebellum plays a key role in feedback and feedforward control of speech production. Specifically, the **cerebellum is important for the sensorimotor integration of sensory feedback with motor plans for speech.**

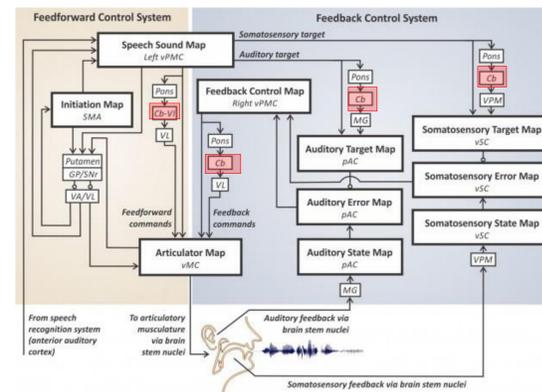
Feedback Control Loop

Guenther, 2016



DIVA Model of Speech Production

Guenther & Perkell, 2004; Tourville & Guenther, 2011



Research Hypothesis: Ataxia results in over-correction of pitch in auditory feedback control of speech production, resulting in prosodic impairment.

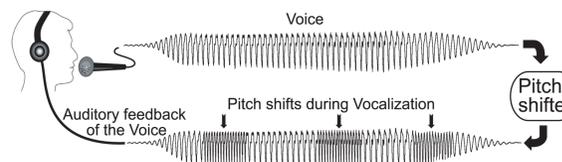
Study Purpose: To test auditory feedback control of pitch in ataxia in simple speech (“aaaa”) and phrase production (“Lay your lamb by your lime”) by using an auditory feedback perturbation paradigm.

Methods

Twenty-one speakers with ataxic dysarthria and 28 age- and sex- matched healthy control speakers produced a **sustained vowel** (“aaa”) and a set of **phrases** (e.g., “Lay your lamb by your lime”) while their voice output was briefly **perturbed in pitch +/- 200 cents for 200 milliseconds** and fed back through headphones. We then measured the **magnitude and latency** of the difference wave (experimental wave – averaged control wave) of the reflexive **pitch-shift response** based on the speech task. The difference wave was used to control for natural vocal variation.

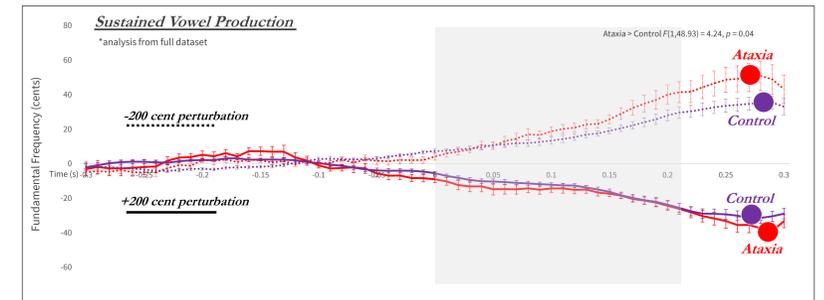
Ataxia etiology included Friedreich’s Ataxia (2 subj), Spinocerebellar Ataxia (16 subj; SCA1, SCA2, SCA3, SCA5, SCA6, SCA7, & SCA15), Gluten Ataxia (1 subj), AOA2 (1 subj), and SCAR8 (1 subj).

Experimental task: vocalize into a microphone while the voice output is perturbed in pitch through headphones.

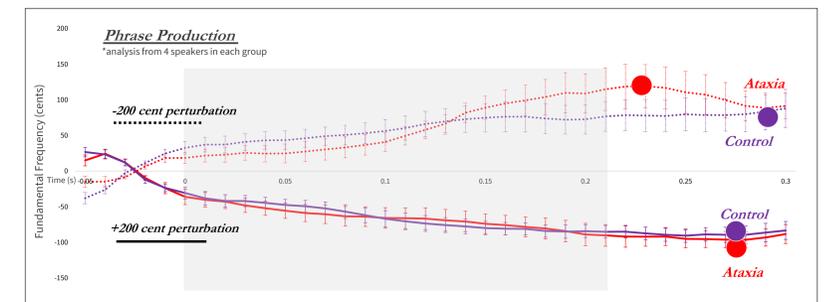


Results: the pitch-shift reflex

In general, speakers with **ataxia** had larger responses than **control** speakers to the pitch auditory feedback perturbations for sustained vowel and phrase production.



For a simple, sustained vowel production, speakers with ataxia exhibited significantly larger reflexive pitch-shift responses than control speakers for upward and downward pitch perturbations.



For phrase production, speakers with ataxia also exhibited larger reflexive pitch shift responses (note that statistics have not confirmed significance due to the small number of participants analyzed in this preliminary analysis).

Conclusion

The pitch-shift reflex was larger in magnitude to downward perturbations in speakers with ataxia, indicating an overshooting of upward pitch correction.

Overall conclusion: There is an overcorrected, hypermetric response in auditory feedback control of pitch in ataxia, which may contribute to the prosodic impairment in speech.

Lay Summary

When people talk, they hear their speech (called auditory feedback) to make corrections if there are unexpected errors. Because of the impairment in the cerebellum in ataxia, **pitch is over-corrected** in speech production. This overshooting in pitch correction could contribute to the speech impairment in ataxia, called ataxic dysarthria.