

# Assessment of Ataxia Using Natural Language Processing and Computational Analysis of Speech

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## Lay Summary

Slurred speech is a meaningful symptom to many individuals with ataxia. We developed an approach to measure speech symptoms using an everyday technology (an iPad) and computer algorithms. This technology could be useful in clinical trials to track speech severity and measure response to treatment.

## Background and Objective

Dysarthric speech is a core clinical feature of most ataxias and has a profound impact on quality of life. Speech abnormalities may be present early in the disease course of degenerative ataxias and progress with disease duration, suggesting that speech may be a useful outcome measure for clinical trials. Measurement of disease progression using current clinical speech assessment scales is impeded by high variability, owing to assessor subjectivity and day-to-day speech fluctuations. As a first step to addressing these limitations, we collected speech samples from ataxia participants on a tablet device in order to determine if computational analysis of speech data revealed known characteristics of ataxic dysarthria

## Methods

- 85 adult participants (43 Ataxia, 42 Parkinson's) aged 50 and above were recruited from Massachusetts General Hospital
- 63 adult (aged 50 and above) controls were select from a pre-existing database of speech samples (all MoCA >26).
- All participants completed the narrative Cookie Theft picture description task
- Responses were recorded, transcribed and processed using natural language process to extract acoustic and linguistic features
- Mean feature values for Ataxia, PD and HC groups were compared
- Correlations were computed between speech features and ataxia related speech impairment (as measured by the Brief Ataxia Rating Scale (BARS))
- Matrix factorization and linear regression were used to examine which features were most predictive of BARS score.

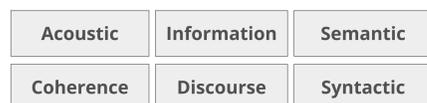
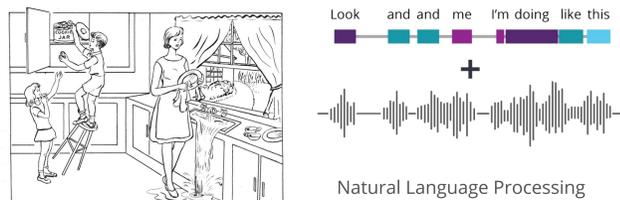
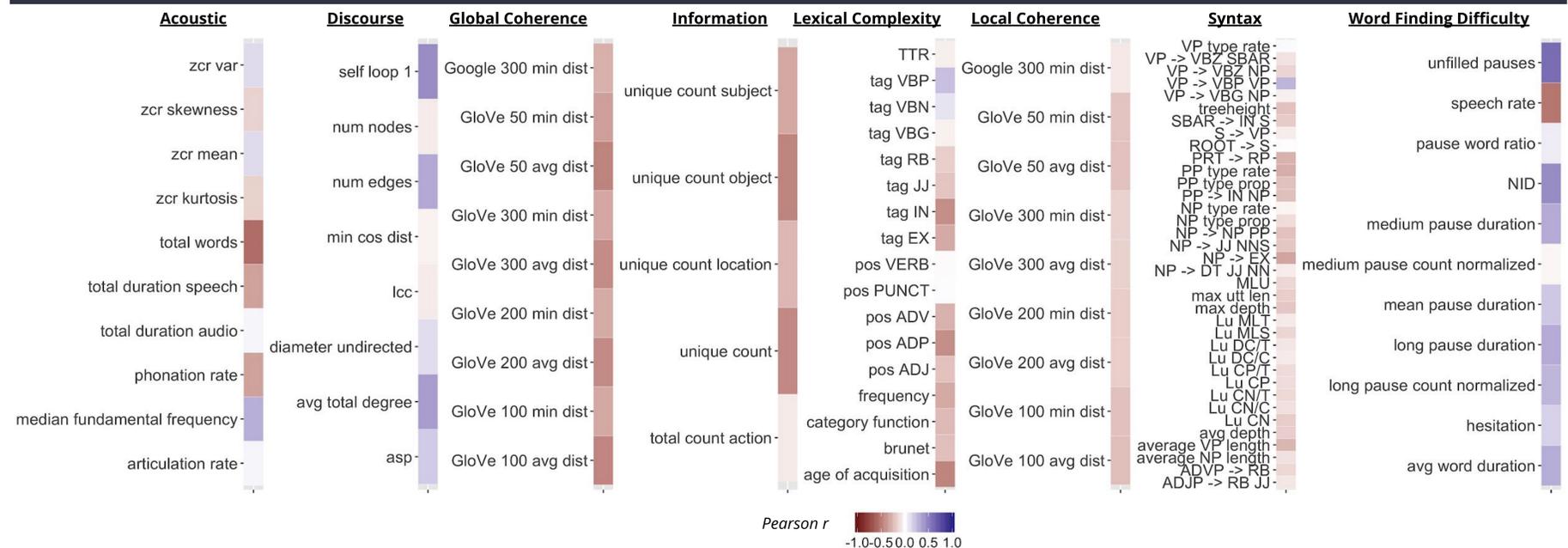


Figure 1: Correlations between ataxic speech impairment (on Brief Ataxia Rating Scale) and acoustic and linguistic features



## Results

- Descriptions of the Cookie Theft were deconstructed into *acoustic* (properties of the sound wave, total words), *discourse* (sentence construction and repetition), *global and local coherence* (sticking to the central topic), *information* (specific details of the picture), *lexical* (parts of speech), *syntactic* (linguistic production rules), and *word finding difficulty* (pauses and hesitations) variables.
- A number of variables were significantly different between groups after multiple comparisons: Ataxia vs. HC - 90 features, PD vs. HC - 40 features, Ataxia vs. PD - 7 features
- For Ataxia patients, strong negative correlations were observed between speech impairment rating and lexical, syntactic, information, local and global coherence as well as acoustic markers (Figure 1)
- The strongest correlations were observed between total words (acoustic), repetitions (discourse), distance between utterances/concepts (local and global coherence), total reported details (information), age of acquisition (lexical), noun phrase length (syntax) and speech rate (word finding difficulty).
- Positive correlations were observed between ataxic speech impairment and variables pertaining to **Word Finding Difficulty**, including **pauses**, **unintelligible words** and **hesitations** (Figure 1).
- Results from matrix factorization suggested that **speech rate**, **lexical complexity (e.g. age of acquisition)** and frequency parameters, including **fundamental frequency** and **zero crossing rate** were most tightly related to speech severity score

## Results Continued

- Follow up linear regression analysis found that a model including only two variables (**speech rate** and **noun age of acquisition**) explained 42% of the variance in BARS speech score (model F = (2,72) 26.92)

Component	t-value	p
Speech rate	-3.23	0.0013
Noun age of acquisition	-4.40	<0.0001

## Conclusions

- These results indicate the feasibility of extracting interpretable speech information from scalable technologies on a low-burden and natural behavioral task.
- Speech analysis revealed that there were both motor and cognitive deficits in individuals with ataxia on the visual scene description task.
- Computational analysis of speech could provide clinicians with additional, objective information to assist with the characterization of speech impairment.
- This fast and inexpensive speech capture and analysis technology may be useful for clinic or home-based assessments in natural history studies and clinical trials.

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