# Automatic analysis of lexical features in speech of patients with Primary Progressive Aphasia

American Academy of Neurology Annual Meeting, 2020

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**Study funding:**

National Institutes of Health (AG017586, AG053940, AG052943, NS088341, DC013063, AG054519), the Institute on Aging at the University of Pennsylvania, the Alzheimer's Association (AACSF-18-567131), an anonymous donor, and the Wyncote Foundation.

**Disclosures:**

Dr. Grossman participates in clinical trials sponsored by Alector, Eisai and Biogen that are unrelated to this study. He receives research support from NIH, Biogen and Avid that is unrelated to this study. He receives financial support from Neurology for his work as an Associate Editor. All other authors have nothing to disclose.

# Speech

- Speech production is a complex, intentional, and planned activity, which involves multiple brain regions.
  - Speakers select appropriate words from their lexicon that are consistent with the meaning of an intended message, arrange words into a specific order following syntactic rules of the language, plan their articulations, and articulate the prepared message following the phonological rules of the language.

- We can expect that patients with degenerative brain conditions to show impaired speech compared to healthy adults.

# Linguistic impairments in patients with frontotemporal degeneration (FTD)

- Primary progressive aphasia (PPA)
  - Semantic variant PPA (svPPA): impaired confrontation naming, frequent substitution of pronouns for nouns, difficulty in processing concrete words
  - Nonfluent/agrammatic PPA (naPPA): effortful speech, slow speech rate, frequent speech errors, simplified grammar, difficulty in retrieving verbs

- Behavioral variant FTD (bvFTD)
  - Reduced speech rate, tangential speech with irrelevant subject matter, reduced pitch range

# Goals

- In this study, we present implementation of **an objective, quantitative, reproducible, and fully automated approach** to studying lexical characteristics of patients with FTD in a large scale.
  - To examine part-of-speech (POS) categories by analyzing a semi-structured speech sample elicited during a picture description task
  - To investigate lexical-semantic aspects of FTD patients' speech

- Our novel, automated technique for text analysis is based on a modern natural language processing (NLP) program and examines speech samples in a large cohort of FTD patients.

# Participants

| | Control (N=37) | bvFTD (N=74) | naPPA (N=22) | svPPA (N=42) | *p*-value |
|---|---|---|---|---|---|
| **Sex** Female (N, percent) | 24 (64.9%) | 26 (35.1%) | 11 (50.0%) | 23 (54.8%) | 0.019 |
| Male (N, percent) | 13 (35.1%) | 48 (64.9%) | 11 (50.0%) | 19 (45.2%) | |
| **Education** | 37 | 74 | 22 | 42 | 0.437 |
| Mean (SD) | 15.9 (2.5) | 15.8 (2.8) | 15.3 (3.1) | 15.1 (2.8) | |
| **Age** (years) | 37 | 74 | 22 | 42 | <0.001 |
| Mean (SD) | 68.5 (7.9) | 63.1 (8.7) | 70.4 (9.4) | 63.3 (7) | |
| **Mini mental state exam** (0-30) | 31 | 68 | 20 | 38 | <0.001 |
| Mean (SD) | 29.2 (1) | 23.6 (5.5) | 22.7 (6) | 22.1 (6.3) | |
| **Disease duration** (years) | - | 74 | 22 | 42 | 0.239 |
| Mean (SD) | - | 4.4 (3.5) | 3.2 (1.9) | 3.9 (2) | |
| **Time between MRI & cookie theft** (months) | - | 42 | 8 | 26 | 0.326 |
| Mean (SD) | - | 2.2 (1.9) | 1.7 (1.7) | 2.8 (2.6) | |

# Speech samples & POS tagging

- Cookie Theft picture from the Boston Diagnostic Aphasia Examination
- Recordings were transcribed by an expert linguist and quality-checked by a team of trained annotators.
- The basic model of spaCy (‘en_core_web_sm’; Honnibal & Johnson 2015) was used to tag the POS categories of all words.
- We calculated the number of each POS category per 100 words; the number of tense-inflected verbs, unique nouns per 100 words; and total number of words.

# Lexical parameters

- We performed additional analyses of nouns for their potential value in distinguishing FTD patient groups.

- We rated nouns for concreteness/abstractness (Brysbaert et al. 2014), semantic ambiguity (Hoffman et al. 2013), word frequency (Brysbaert & New 2009), age of acquisition (Brysbaert et al. 2018), and word familiarity (Brysbaert et al. 2018).

- We also computed cross-entropy estimation, which is an estimate of the predictability of a document, using all the words of the participants' speech.

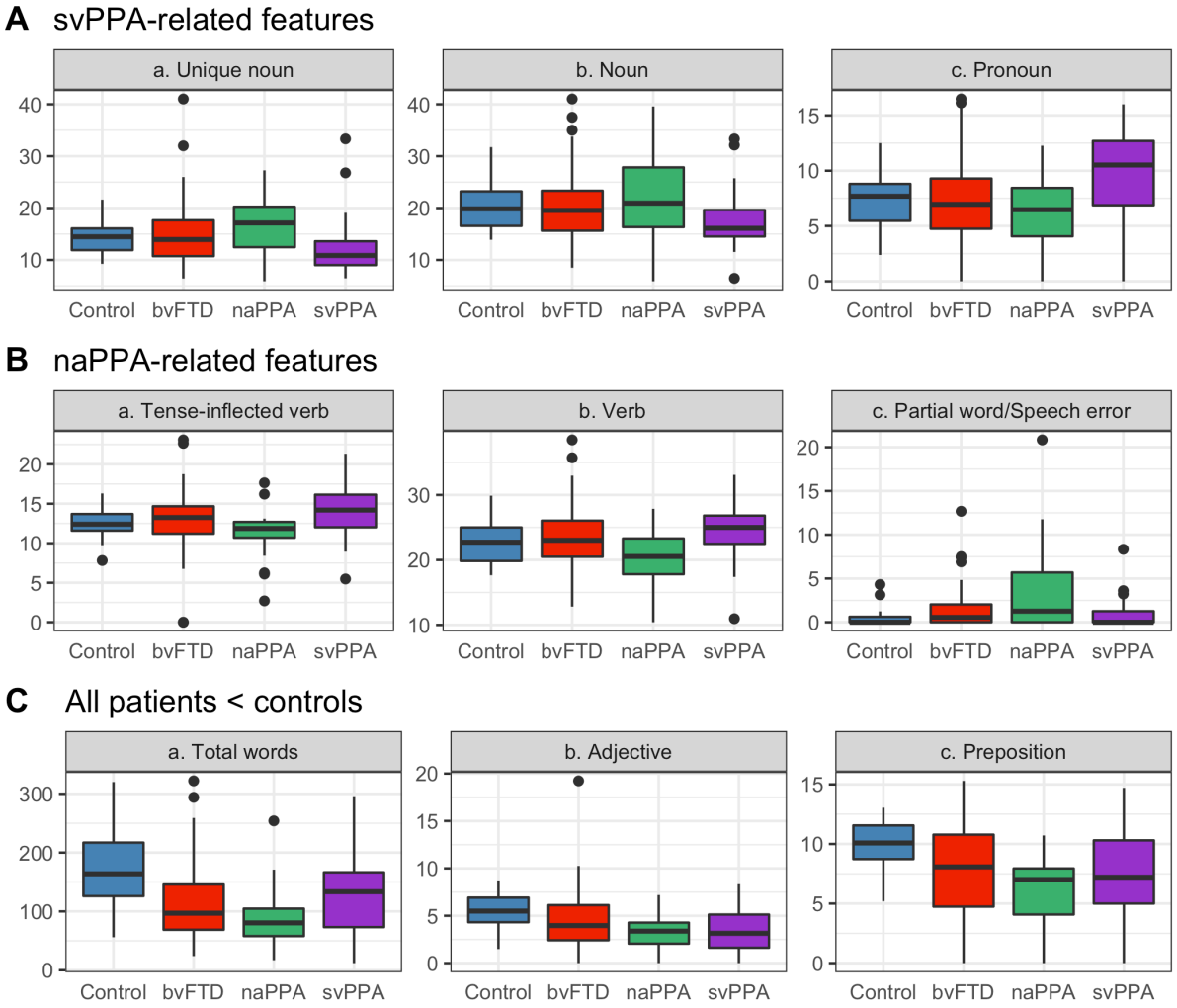
# Imaging methods

- High resolution T1 volumetric brain MRI data was available for a subset of our patients: 18 controls, 42 bvFTD, 8 naPPA, and 26 svPPA patients.

- Easy_lausanne (Daducci et al. 2012) was used to create a standard cortical parcellation. We calculated the mean cortical thickness in each ROI of the Lausanne 250 scale.

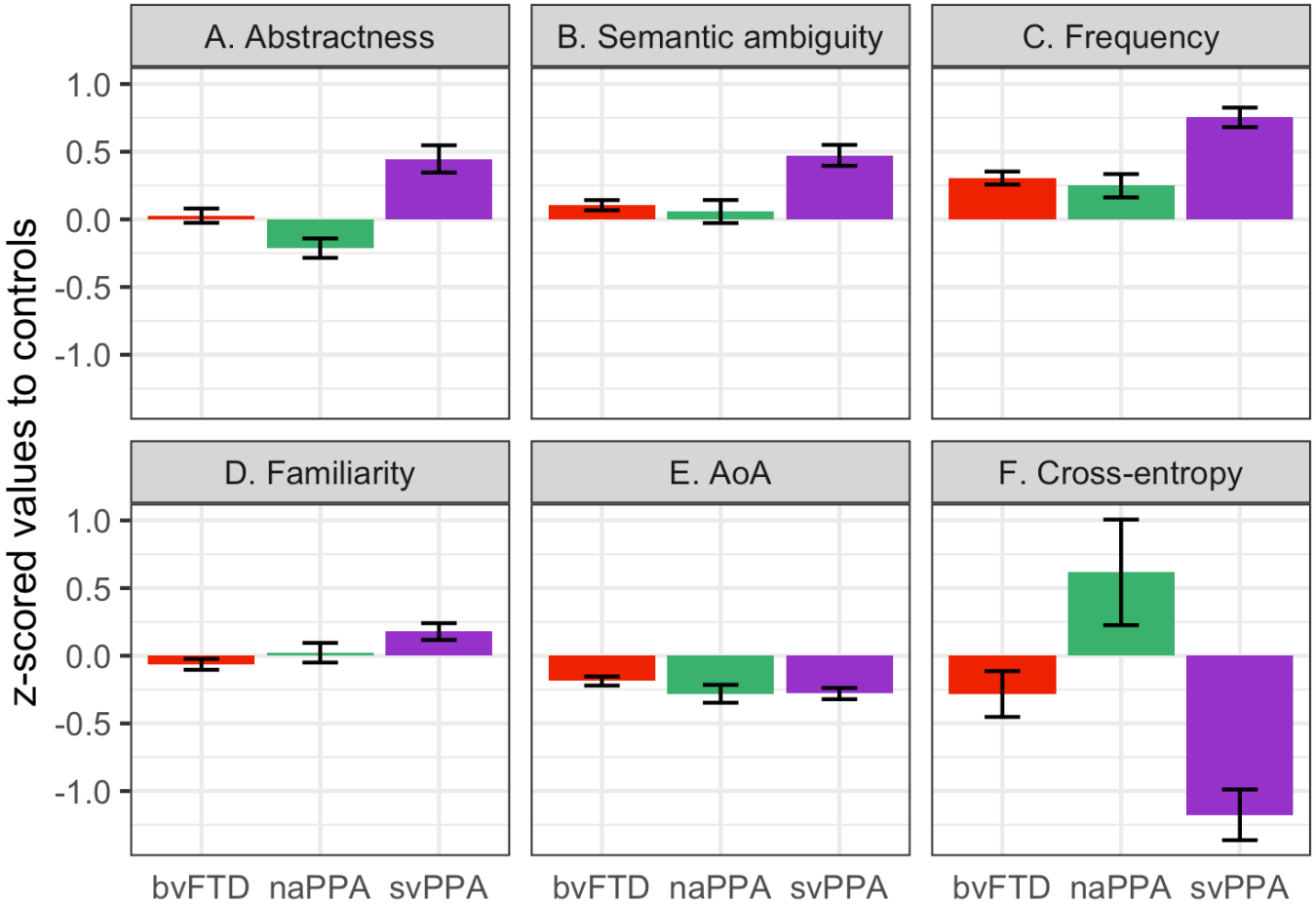
- To identify regions of atrophy in patients, we compared cortical thickness of all patients in each group with those of the controls for all cortical regions of interest (ROIs) and selected our specific ROIs per patient group.

# Results



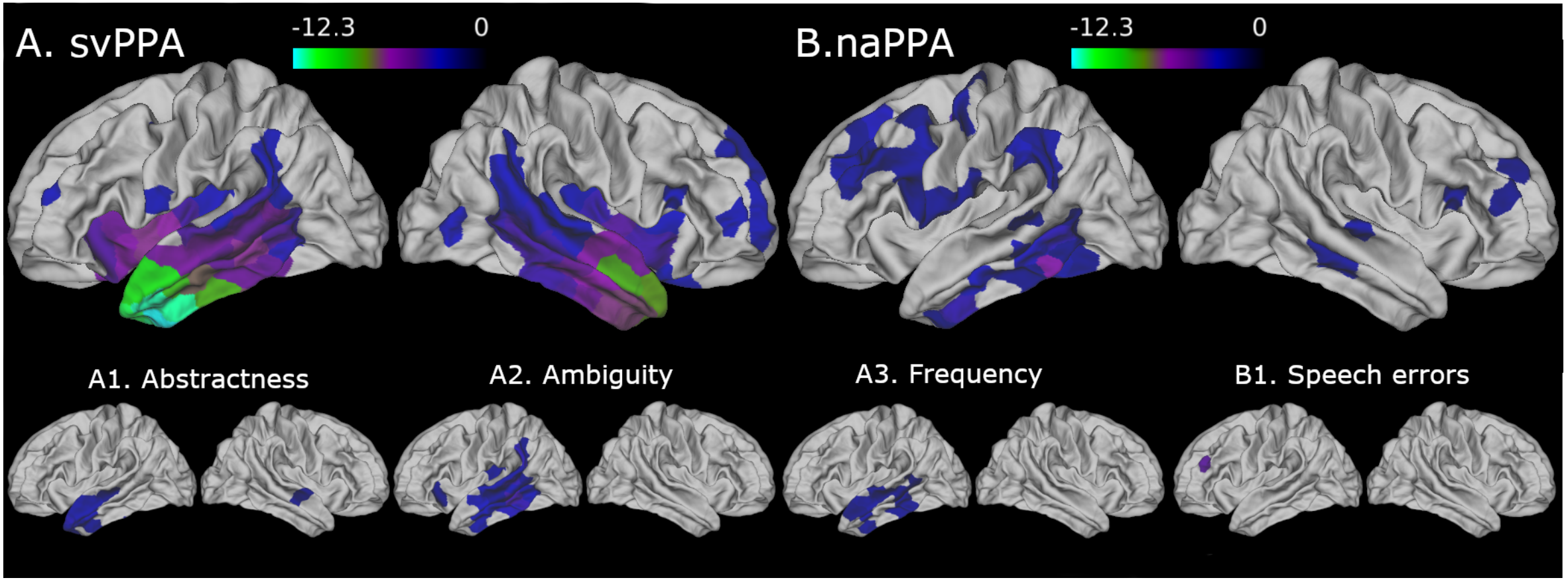

- svPPA: fewer unique nouns, fewer total nouns & more pronouns than naPPA & bvFTD
- naPPA: fewer tense-inflected verbs, fewer total verbs, and more speech errors than svPPA or bvFTD or controls
- All patients: fewer total words, adjectives and prepositions

# Results




- svPPA produced more abstract, ambiguous, frequent, and familiar nouns than the other groups.
- No significant difference in AoA
- svPPA: low cross-entropy

# Results


A. svPPA
-12.3
0
B.naPPA
-12.3
0
A1. Abstractness
A2. Ambiguity
A3. Frequency
B1. Speech errors

# Results

- svPPA patients' noun & pronoun counts, abstractness, ambiguity, frequency, familiarity scores, and cross-entropy estimation showed significant associations with cortical atrophy in anterior and middle temporal regions of the left hemisphere.

- naPPA patients' production of speech errors was related to cortical atrophy in the left rostral middle frontal gyrus.

# Word use in svPPA

- More pronouns, fewer nouns (abstract, ambiguous, frequent, familiar)

- Left temporal lobe: visual association cortex
  - In line with previous studies that attributed svPPA patients' impairment in part to the degradation of visual feature knowledge associated with object concepts.

- Pronouns are more frequent, ambiguous, and familiar, and we also found that svPPA patients produced nouns with a higher frequency, ambiguity, and familiarity.

# Word use in naPPA

- Fewer tense-inflected verbs
  - due to a syntactic deficit
  - and/or due to impairment of the motor association regions of the frontal lobe
  - Future work is needed to assess these claims

- Speech errors in naPPA patients
  - Poor coordination of motor articulators during speech production due to atrophy in the left middle frontal gyrus

# Word use in bvFTD

- Our bvFTD patients were a purely behavioral group without obvious aphasia, and they were the most similar to the controls among the patient groups.

- Patients with bvFTD did differ from controls in their reduced number of adjectives, prepositions, and total words, but this deficit was evident not only in bvFTD but in all patients.
  - Reduced production of adjectives, prepositions, and total number of words may reflect general cognitive decline.

# Questions? Please email to:

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A full-length manuscript of this study is currently under review.

# Appendix A: Accuracy validation

- We validated the accuracy of spaCy's POS tags with a subset of our data (6 controls, 5 naPPA, 7 svPPA and 7 bvFTD patients).

- The error rate was generally low in all groups; the overall accuracy of spaCy on this subset of data was 91.1% with no group difference in a one-way ANOVA test ($F(3,21)=2.7$, $p=0.075$).

- Since the error rate was reasonably low, we used the POS tags that spaCy generated without manual correction.

# Appendix B: References


- Honnibal & Johnson. 2015. An improved non-monotonic transition system for dependency parsing. *EMNLP 2015: Conference on empirical methods in natural language processing*, 1373–1378.
- Brysbaert et al. 2014. Concreteness ratings for 40 thousand generally known English word lemmas. *Behavior Research Methods, 46*(3), 904–911.
- Hoffman et al. 2013. Semantic diversity: A measure of semantic ambiguity based on variability in the contextual usage of words. *Behavior Research Methods, 45*(3), 718–730.
- Brysbaert & New. 2009. Moving beyong Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41*(4), 977–990.
- Brysbaert et al. 2018. Word prevalence norms for 62,000 English lemmas. *Behavior Research Methods, 51*(2), 467–479.
- Daducci et al. 2012. The Connectome Mapper: An open-source processing pipeline to map connectomes with MRI. *PLoS ONE, 7*(12).