# Automatic analysis of natural speech in patients with Alzheimer's disease

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## Introduction

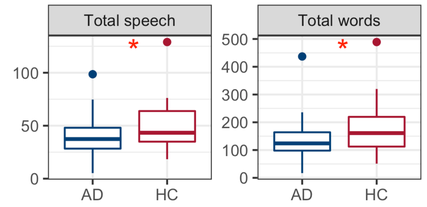
- Language impairments seen in patients with Alzheimer's disease (AD) have been often discussed in the literature, yet not many studies looked at both lexical and acoustic aspects at the same time.
- In this study, we characterized lexical and acoustic characteristics of patients with pathologically determined AD using a natural language processing (NLP) tool and a speech activity detector (SAD).

## Methods

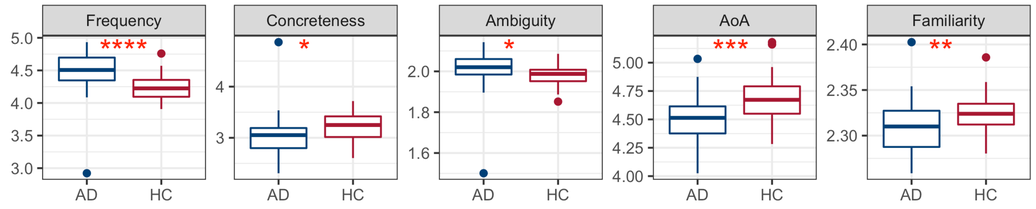
- Data: Cookie Theft picture description [1]
- 49 AD patients (28 females, mean age=62.6, mean Mini-Mental State Exam (MMSE)=20.3) with confirmed pathology & 35 healthy controls (HC; 18 females, mean age=64.6, mean MMSE=29) matched on age, sex, education.
- Lexical pipeline [2]: automatic part-of-speech (POS) tagging with spaCy [3] => automatic rating of content words for concreteness, semantic ambiguity, word frequency, familiarity, age of acquisition (AoA) using published norms and number of phonemes and syllable with Natural Language Toolkit [4]
- Acoustic pipeline [5]: segmentation of audio signal with SAD => automatic calculation of mean speech and pause segment durations, pause rate per minute, total speech and pause time.

## Results

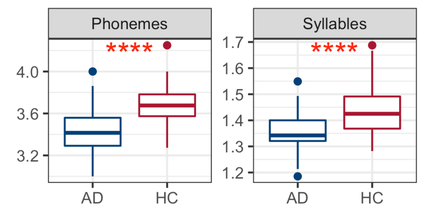
### AD produce fewer words in total and shorter total speech time than HC.



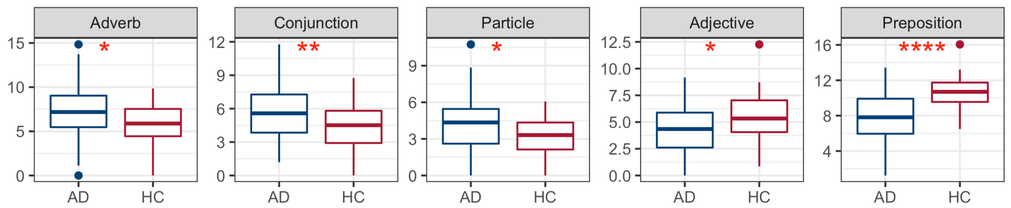

### AD use frequent, abstract, ambiguous, familiar, and early-acquired words.



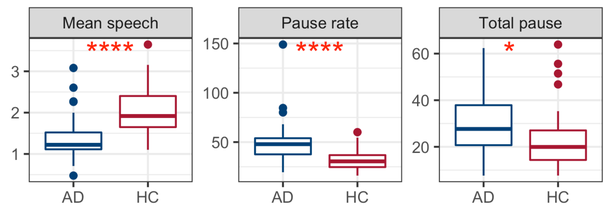

### AD's content words are shorter than those of HC.




### AD > HC: adverb, conjunction, particle; AD < HC: adjective, preposition.



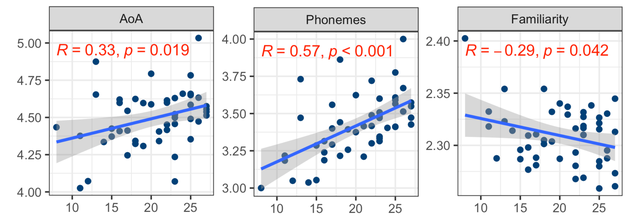

### AD produce short speech segments, but their pauses are long and frequent.



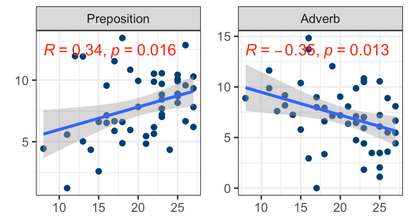

*: $p$<0.05, **: $p$<0.01, ***: $p$<0.001, ****: $p$<0.0001

## Correlation with MMSE in AD

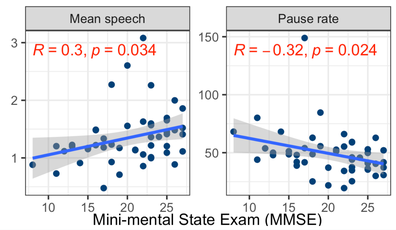
### Correlations with lexical measures




### Correlations with POS counts




### Correlations with acoustic measures




## Conclusion

- AD patients differed in lexical and acoustic aspects from those of HC.
- NLP and SAD tools can reveal language markers that distinguish AD from HC.
- Reduced MMSE was related to short, early-acquired and familiar content words. Lower MMSE also correlated with fewer prepositions, more adverbs, short speech segments, and frequent pauses.

References: [1] Goodglass, H., Kaplan, E., & Weintraub, S. (1983). Boston Diagnostic Aphasia Examination. Philadelphia, PA: Lea & Febiger. [2] Cho, S., Nevler, N., Shellikeri, S., Parjane, N., Irwin, D., Ryant, N., Ash, S., Cieri, C., Liberman, M., and Grossman, M. Lexical and acoustic characteristics of young and older healthy adults. (in press) *Journal of Speech, Language, and Hearing Research*. [3] Honnibal, M., & Johnson, M. (2015). An improved non-monotonic transition system for dependency parsing. *EMNLP 2015: Conference on empirical methods in natural language processing*, 1373–1378. [4] Bird, S., Loper, E., and Klein, E. (2009). *Natural Language Processing with Python*. O'Reilly Media Inc.. [5] Nevler, N., Ash, S., Irwin, D. J., Liberman, M., & Grossman, M. (2019). Validated automatic speech biomarkers in primary progressive aphasia. *Annals of Clinical and Translational Neurology*, *6*(1), 4–14.

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