Novel Digital Voice Biomarkers of Dementia from the Framingham Study

D. Stück[1], A. Signorini[1], T. Alhanai[2], M. Sandoval[1], C. Lemke[1], J. Glass[2], S. Hardy[3,4], M. Lavallee[3,4], B. Wasserman[3,4], T. Ang[3,5], C. Nowak[3,4] and R. Au[3,4,5,6]

(1) Evidation Health, (2) Massachusetts Institute of Technology, (3) Framingham Heart Study, (4) Boston University School of Medicine, (5) Boston University School of Public Health, (6) Boston University Alzheimer's Disease Center

Introduction

Alzheimer's Disease affects 10% of people over 65 and is the 6th leading cause of death in the US. Earlier detection is needed but current screening methodologies are not always clinically practical. Here we show a non-invasive digital voice biomarker that can be used for early detection of dementia.

Methods

Subjects.

Subset of Framingham Heart Study (FHS) participants whose spoken responses were digitally recorded between 2005-2016 and transcribed using IBM Watson Speech-to-Text translator (n= 200); 127 of these recordings were also manually transcribed.

Demographics.

Sample Demographics	N	% Men	Ave. Age (s.d.)	Education^
No Dementia (ND)	35	60.0	83±8	2.0
Cognitively Impaired-ND (CIND)	58	40.4	83±8	1.5
Dementia*	107	37.5	83±6	1.7

***Dementia diagnosis determined by consensus panel review; ^Education levels: 0= High school (HS), did not graduate; 1= HS graduate; 2= Some college, did not graduate; 3 = College graduate+**

Data Used for Analysis:

1. Demographic Information
2. Health Data (e.g., serum labs values, weight)
3. Cognitive Status
4. Recorded Audio

Analysis

We used audio analysis, speech transcription, and language processing to automatically reduce voice segments from participants into a set of digital biomarkers for the early detection and diagnosis of dementia:

- **Input**: Acoustic, quantitative and linguistic features
- **Target**: Participant's cognitive status
- **Machine Learning**: Random Forest classifier
- **Performance Metric**: Area Under the Curve (AUC)
- **Validation Strategy**: 10-fold cross validation

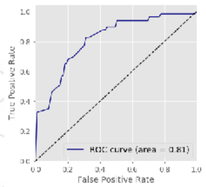
Audio Features

A. **Acoustic Features**
e.g., pitch, Harmonic-to-Noise ratio, jitter

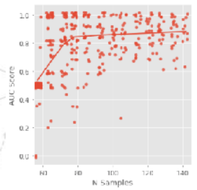
B. **Quantitative Audio Features**
e.g., #fillers, speed, pauses length, answer delay

C. **Linguistic Features**
e.g., part of speech tags, tree depth, frequency

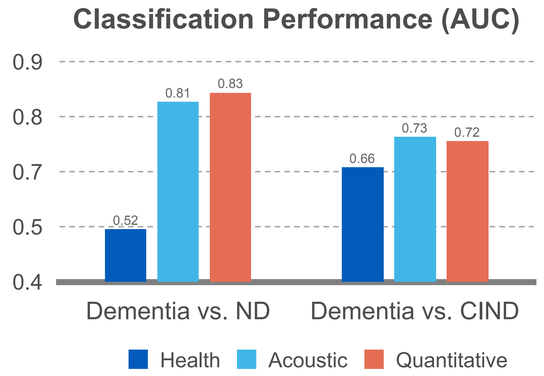
Results



Dementia vs. ND
ROC curve, Audio features



Dementia vs. ND
AUC scores, each fold w/ jitter



In predicting dementia, **context agnostic features** (A,B) are 55% more accurate than health data [See Figure Above]. **Linguistic features** (C) have the highest predicting power even in mixed age population [See Table Below].

MANUALLY TRANSCRIBED DATASET

Limited to 127 participants:
Dementia (n=45, mean age=83±7)
ND (n=82; mean age=65±17)

Dementia vs. ND	
All	0.91 [0.85, 0.97]
Linguistic Features	0.9 [0.82, 0.98]
Audio + Linguistic	0.89 [0.82, 0.97]
Audio Features Only	0.76 [0.66, 0.86]
Health & Demographic	0.82 [0.71, 0.93]

Mean AUC Scores and 95th CI

Conclusion

While these results are preliminary, simple acoustic and language features computed over speech segments show promise for the development of accurate digital biomarkers of cognitive impairment.

- **Strengths:** Audio features performed well even if original input were lossy old recordings.
- **Limitations:** Results obtained on limited dataset, manual transcriptions were necessary.
- **Future Developments:** Increase sample size, obtain better audio recordings, supplement data with other data sources.

Acknowledgments

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Collaborators

- **Evidation** https://evidation.com/research
- **MIT** https://csail.mit.edu/research
- **FHS** http://www.framinghamheartstudy.org

asignorini@evidation.com