Fluency in Spontaneous Speech Predicts Individual Variance in Executive Function among Seniors

P-53070

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KEY TAKEAWAY: Our results suggest that speech is a rich measure of cognitive function in healthy older adults. Furthermore, automated speech analysis may serve as an inexpensive and repeatable measure to track cognitive status over time in older adults who are at risk of dementia.

INTRODUCTION

- Executive function (EF) is a family of cognitive processes that allows one to execute purposeful action (Diamond, 2013; Jurado & Rosselli, 2007)[1, 2].
- Some studies have found executive function to be a significant protective factor against the development of Mild Cognitive Impairment and Alzheimer's Disease (Farias et al., 2006; Roy et al., 2016)[3, 4].
- Given the projected increase of dementia cases and the desirability of early diagnosis at affordable costs, better methods of detecting cognitive decline are needed (Alzheimer's Disease International, 2020; Balagopalan, Novikova, Rudzicz, & Ghassemi, 2018)[5, 6].
- Speech is a rich source of information about someone's cognitive status.
- Relationships between spontaneous speech characteristics and Executive Function are currently unknown.
- **Research question:** Are there any significant relationships between quantitative aspects of speech and measures of executive function?
- **We hypothesize** that differences in executive function are predictive of differences in these natural speech measures

METHODS

- We measured the EF of 76 cognitively healthy older adults aged 65-75, using an extensive test battery.
- Speech samples from picture description tasks were collected and analyzed using prototype commercial software from Winterlight Labs.
- Due to technical difficulties, six participants were excluded from statistical analysis creating a total of n=70.

Theory-Driven Approach

- Subsets of 526 features automatically derived from speech samples were grouped into eight composites based on theoretical constructs[7]: Discourse, Local Coherence, Global Coherence, Lexical Complexity, Word Finding Difficulty, Semantics, Syntactic Complexity, and Information units.
- We conducted a 5-fold cross-validated Partial least squares regression (PLS) on this data and the neuropsychological test data.

Data-Driven Approach

- Using an internal normative dataset of 887 audio samples, from 224 cognitively healthy older adults (526 linguistic features), factor analysis was conducted to find feature combinations that pattern together. We used these factors to derive composites of the linguistic features measured in our sample of 70 adults.
- We conducted a PLS on this data and the neuropsychological test data.

Composites[8]

- **Discourse:** Measures speech repetition.
- **Lexical Complexity:** Measures speech complexity and vocabulary richness.
- **Word-Finding Difficulty:** Measure's word-finding ability based on hesitation, pauses, etc.
- **Information Units:** Measures how informative picture descriptions were.
- **Sentiment:** Relates to the valence of spoken words.
- **Global Coherence:** Uses the cosine metrics based on the GloVe model to compare utterances with predefined content units in the pictures[7].
- **Local Coherence**: Measures relatedness between immediately preceding utterances.
- **Syntactic Complexity:** Measures structural complexity i.e. utterance length of the picture description.

RESULTS

- An exploratory factor analysis found one underlying factor that accounted for most of the variance in the executive function data (known as Factor 1) See Figure A

Figure A.

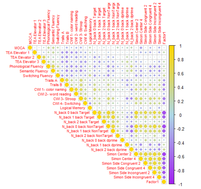

Figure A: Factor loadings i.e. Pearson's correlation between the neuropsychological test scores and the extracted Factor 1. N-back and Simon tasks showed the strongest correlation with Factor 1. Higher scores on Factor 1 reflect better executive function shown by faster (lower) times on reaction time tests; Simon and N-back, and higher scores on fluency tasks.

Figure B.

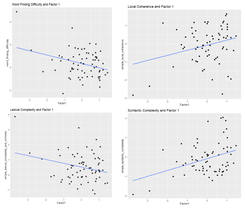

Figure B: Significant correlations of the theory-driven composites with Factor 1. **Top Left:** Word-Finding Difficulty (p = 0.001029**), **Top Right:** Local-Coherence (p = 0.01151*), **Bottom Left:** Lexical Complexity and Richness (p = 0.01344*), **Bottom Right:** Syntactic Complexity (p = 0.01529*)

Figure C.

	Loading Weight
Edges for Each Node/Total Number of Nodes	-0.697135740044983
Number of edges/Total Number of Nodes^2	-0.686028633664004
Mean length of shortest path between nodes	-0.193192726975312
Type to Token Ratio	-0.049432015611597
Number of Unique Tokens	0.0440118589322936
Shortest Path Between All Node Pairs	-0.038608094999136
mber of Nodes in the Largest Connected subgraph	-0.009274381408772 4
Number of Contentful Words	-0.009274381408772 4

	Loading Weight
Simon Congruent Side 2 colored Squares	-0.685522174671223
Simon Incongruent Side 4 colored Squares	-0.674198593916148
N-back 0-back Target	-0.245433768240352
Simon Center 4 colored Squares	-0.123603678759441

Figure C: Loading weights of the data-driven PLS model. **Top:** explanatory power of the linguistic variables on the neuropsychological test variables. **Bottom:** explanatory power of the neuropsychological tests variables on the linguistic variables.

Figure D.

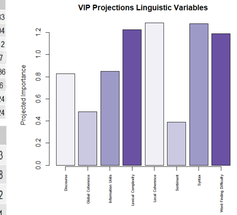

Figure D: Variable of Importance (VIP) coefficients of the theory-driven composites. The variables that are most relevant in explaining the executive function data are syntactic complexity, local coherence, lexical complexity and richness, and word-finding difficulty.

PLS RESULTS

Data Driven PLS

Q^2 = -0.003531596 Averaged Mean Squared Error Prediction (MSEP) = 1.019165

Average R^2 = 0.02373372 Average Predicted Residual Error for Sum of Squares (PRESS) = 67.23662

- According to the data-driven PLS model: linguistic features most relevant for explaining the neuropsychological data comprised of structural metrics. See Figure C.

Theory Driven PLS

Q^2 = 0.009716846 Averaged Mean Squared Error Prediction (MSEP) = 1.003195

Average R^2= 0.04144109 Average Predicted Residual Error for Sum of Squares (PRESS): 66.34897

- The theory-driven PLS model showed that syntactic complexity was the most relevant for explaining the neuropsychological variables; the N-back and Simon tasks were the most relevant in explaining the linguistic variables.

Overall, our theory-driven PLS model performed better than our data driven PLS.

CONCLUSIONS/FUTURE DIRECTIONS

- Our results indicate that older adults who scored higher on executive function, exhibit more fluent speech as quantified by automated linguistic analysis.
- Higher syntactic complexity and local coherence were associated with better executive function scores.
- Greater lexical complexity and word-finding difficulty were associated with worse executive function scores.
- These results are in support of Fisk and Sharp's (2004)[9] findings which suggest that access to long-term memory is a significant component of executive function.
- Word finding difficulties may reflect an overall slowing of cognitive process and access to long-term memory.
- However, picture description tasks do not reflect conversational speech.

Future Directions

- Future studies should use scripted and timed interviews.
- Future multivariate models should include those with healthy age-matched controls and those with MCI for more sensitivity.

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