A Comparison of Clinician Assessment of Speech Versus Automated Speech Analysis in Mild Cognitive Impairment and Alzheimer’s Dementia

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Background

- Language impairment is a core feature of Alzheimer’s disease (AD) and other neurodegenerative disorders.1
- Prior studies have shown a link between AD symptom severity and declining speech and language capability in picture description tasks.2
- Speech and language changes include alterations in speech rate, utterances, frequency of words, word-finding difficulties, and repetitions.3
- Despite these pervasive language changes, there is no universally accepted system of terminology used to describe language impairment, and large inter-rater variability can also exist between clinicians.4
- In view of current limitations, the role of automated speech analysis is emerging as a novel, and potentially more objective method of assessing language in individuals with neurologic and psychiatric disorders.

We sought to: (1) define a set of speech and language capability ratings that can be used by clinicians with different areas of specialization, (2) determine if these speech and language ratings are applied consistently in a sample of patients including healthy controls, mild cognitive impairment (MCI), and AD, and (3) use automated speech analysis to identify what acoustic and linguistic variables correlate with clinician ratings of speech and language.

Methods

- Speech samples were obtained via the DementiaBank (DB) dataset through the TalkBank Project, with equal numbers of healthy controls, MCI, and probable AD participants.
- Participants provided a recording of a sample speech which comprised a verbal description of the Boston Cookie Theft picture.
- The recordings were rated by 5 clinicians (1 geriatric psychiatrist, 1 neurology resident, 1 speech language pathology resident, 1 neurology resident, and 1 speech language pathology resident) with clinical experience in assessing MCI and AD, according to four characteristics: (1) word-finding difficulty, (2) incoherence, (3) perseveration, and (4) errors in speech; these were rated on a Likert scale (range: 0-3) as being: not present/normal finding, mild, moderate, or severe (Table 1).
- Speech recordings were transcribed, and linguistic and acoustic variables were extracted through automated speech analysis using NodeJS and React. Data processing and feature extraction was performed using Python-based standard acoustic and language processing libraries (e.g., spacy) and custom code.
- The correlation between clinician-identified speech characteristics and the acoustic and linguistic variables were then compared using Spearman correlation.
- Exploratory factor analysis (EFA) was then applied to find common factors between variables for each speech characteristic, using R version 3.6.3 and Python version 3.6.

Table 1: Clinician Consensus Table of Speech Characteristics

<table>
<thead>
<tr>
<th>Speech and Language Characteristic</th>
<th>Clinical Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word-finding difficulty</td>
<td>Reduction in content words, circumlocution, false starts, pauses while searching for words, fluency (rate, phrase length, amount of hesitation), revisions (repetitions of complete words or phrases/elaborations), indefinite terms (fillers)</td>
</tr>
<tr>
<td>Incoherence</td>
<td>Disorganized speech, derailment or sudden topic shifts, tangentiality, flight of ideas, or word salad.</td>
</tr>
<tr>
<td>Perseveration</td>
<td>Repetition of word or phrase even after the stimulus for the behavior (word or phrase) has been taken away; persistence of behavior (word or phrase) despite repeated failure; intrusions (i.e., inappropriate repetition of prior responses)</td>
</tr>
</tbody>
</table>

Results

- The participants demographics/characteristics are described in Table 2.
- Clinician rating agreement was high in three of the four speech characteristics (word-finding difficulty: ICC = 0.92, p < 0.001; incoherence: ICC = 0.91, p < 0.001; perseveration: ICC = 0.88, p < 0.001).
- Speech ratings scores were highest (most impairment) in the probable AD group, followed by MCI and controls. Greater impairments in word-finding difficulty and incoherence were more frequent in AD and MCI.
- For word-finding difficulty, variables with the highest correlations to clinician ratings were related to the rate of speech, word duration and length, and the number of unfilled pauses. Greater severity of word-finding difficulty was associated with slower speech, shorter words and increased pauses.
- For incoherence, the variables with the highest correlations were a mix of syntactic, acoustic and lexical variables, reflecting the use of past tense verb phrases, slower speech rate, and words with higher estimated age of acquisition.
- For perseveration, variables with the highest correlations were related to the complexity of speech and vocabulary. Greater severity of perseveration was associated with increased repetitiveness of speech, decreased vocabulary richness, and decreased semantic similarity. A large number of acoustic variables also correlated with perseveration.
- For errors in speech, the variables with the highest correlations with the consensus clinician ratings included measures relating to the complexity of speech and vocabulary, use of subordinate clauses, and word length.
- EFA showed that between 1 to 4 factors were found to explain each characteristic (data not shown)

Conclusions

- In this exploratory study, variables extracted through automated acoustic and linguistic analysis of MCI and AD speech were strongly correlated to speech and language characteristics rated by clinicians.
- We were able to demonstrate that commonly used clinician-based speech symptoms correlated with speech and language characteristics rated by clinicians, and that these symptoms are common clinical characteristics of AD.
- Strengths of the study include utilizing clinician ratings to provide an objective, understandable, and rational approach to defining speech changes in AD and MCI.
- Limitations include a small sample size and short speech recording sample, and a more comprehensive approach is needed.
- Our work proposes a standardized approach to investigating speech on both a clinical and pathophysiological level. Potential future applications of this method includes the wide scale deployment of speech analysis in resource-limited or remote settings.

References

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9. For incoherence, the variables with the highest correlations were a mix of syntactic, acoustic and lexical variables, reflecting the use of past tense verb phrases, slower speech rate, and words with higher estimated age of acquisition.
10. For perseveration, variables with the highest correlations were related to the complexity of speech and vocabulary. Greater severity of perseveration was associated with increased repetitiveness of speech, decreased vocabulary richness, and decreased semantic similarity. A large number of acoustic variables also correlated with perseveration.
11. For errors in speech, the variables with the highest correlations with the consensus clinician ratings included measures relating to the complexity of speech and vocabulary, use of subordinate clauses, and word length.
12. EFA showed that between 1 to 4 factors were found to explain each characteristic (data not shown).

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