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Featured Article

Predicting mild cognitive impairment from spontaneous spoken utterances

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Abstract

Introduction: Trials in Alzheimer's disease are increasingly focusing on prevention in asymptomatic individuals. We hypothesized that indicators of mild cognitive impairment (MCI) may be present in the content of spoken language in older adults and be useful in distinguishing those with MCI from those who are cognitively intact. To test this hypothesis, we performed linguistic analyses of spoken words in participants with MCI and those with intact cognition participating in a clinical trial.

Methods: Data came from a randomized controlled behavioral clinical trial to examine the effect of unstructured conversation on cognitive function among older adults with either normal cognition or MCI (ClinicalTrials.gov: NCT01571427). Unstructured conversations (but with standardized preselected topics across subjects) were recorded between interviewers and interviewees during the intervention sessions of the trial from 14 MCI and 27 cognitively intact participants. From the transcription of interviewees recordings, we grouped spoken words using Linguistic Inquiry and Word Count (LIWC), a structured table of words, which categorizes 2500 words into 68 different word subcategories such as positive and negative words, fillers, and physical states. The number of words in each LIWC word subcategory constructed a vector of 68 dimensions representing the linguistic features of each subject. We used support vector machine and random forest classifiers to distinguish MCI from cognitively intact participants.

Results: MCI participants were distinguished from those with intact cognition using linguistic features obtained by LIWC with 84% classification accuracy which is well above chance 60%.

Discussion: Linguistic analyses of spoken language may be a powerful tool in distinguishing MCI subjects from those with intact cognition. Further studies to assess whether spoken language derived measures could detect changes in cognitive functions in clinical trials are warrented.

Keywords: Biomarkers; Conversational interactions; Early identification; Mild cognitive impairment (MCI); Social markers; Speech characteristics

1. Introduction and motivation

A well-documented literature has identified characteristic early disruption of normative patterns and processing of speech and language in patients with Alzheimer's disease (AD) as well as in prodromal dementia states such as mild cognitive impairment (MCI) [1]. Early foundational clinical studies of language have highlighted changes in verbal fluency and naming [2–4]. More recent studies using automated or semiautomated speech and language analysis approaches have identified linguistic as well as acoustic features that characterize early AD or MCI such as pause frequency and duration, and linguistic complexity measures [5,6].

Almost all of these latter studies have used elicited speech paradigms to generate speech and language samples, for

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example, asking patients to describe what they observe in pictures briefly presented to them or to recall specific stories they are exposed to during a testing session. In addition to analyzing the conversations in these structured, mostly constrained within a clinical setting, there are some studies which have used more spontaneous speech [7,8]. In spite of the potential advantages of capturing spontaneous speech in conversations, major barriers have existed to implementing this approach for persons with MCI or AD in more natural settings. A major impediment has been limitations in the recording technology paradigms that could be deployed. This has been both a problem of practicality such as the form factor of recording devices and power requirements for long-term recording, as well as automated speech and linguistic analysis challenges. Despite these challenges, pioneering early studies using somewhat obtrusive worn or carried recording devices have shown the potential power of this approach in younger populations. For example, Pennebaker and Mehl have illustrated the value of inferring social contexts from audio life logs using a lexicon of salient words, termed Linguistic Inquiry and Word Count (LIWC) 2001 [9]. They demonstrated that social context and other information from audio life logs can be used to quantify participants' social life (interaction and engagement), cognitive function, emotional conditions, and even health status [10]. To the best of our knowledge, LIWC analyses have not been used to examine the cognitive status of older adults. In this study, we use LIWC on a corpus of spontaneous speech samples generated during the course of a 6-week randomized clinical trial of daily online video chats to improve social engagement and cognition in older adults with and without MCI [11,12]. These conversations between the interviewer and the participant provided an opportunity to analyze potential differences in the conversational output of persons with MCI and cognitively intact adults.

1.1. Language and mild cognitive impairment

Although the most typical early cognitive deficit observed in Alzheimer's disease involves the memory domain, linguistic ability is also clearly affected. For example, secondary verbs per utterance, percentage of clauses, percentage of right-branching and left-branching clauses, propositions per utterance, conjunctions per utterance, mean duration of pauses, and standardized phonation time have all been reported to show significant differences between healthy older adults and subjects with MCI or AD [5,13–20]. A major barrier to taking advantage of these language-based discriminators has been the effort required to manually score relevant features from speech samples; the proposed work addresses this through automatic scoring.

1.1.1. Related computational works

Recently, there has been considerable interest in automatically analyzing acoustic and language properties of speech samples to create more sensitive quantitative assessments of patients with cognitive impairment [1,21–23]. For example, Jerrold and colleagues [24] evaluated the ability of machine learning methods to differentiate dementia subtypes, including AD, based on semistructured conversational speech recordings. Their proposed method uses both acoustic features such as duration of consonants, vowels, and pauses, as well as lexical features such as frequency of nouns and verbs derived from automatic transcriptions provided by a speaker-independent automatic speech recognition (ASR) system.

Combining these two profiles of features derived from 48 participants, including nine healthy controls, nine AD patients, and 30 frontotemporal lobar degeneration (FTLD) patients (nine with behavioral variant frontotemporal dementia, 13 with semantic dementia, and eight with progressive nonfluent aphasia), they obtained 61% accuracy in detecting the subjects' FTLD subtype, significantly better than the random diagnosis condition, which had 20% accuracy. In a binary classification setting, they obtained 88% accuracy in distinguishing nine participants with AD from nine healthy controls. Similarly, Lehr et al. [25] developed an automated assessment system and applied it to spoken responses of subjects on a delayed recall test (Wechsler Logical Memory test). First, they automatically transcribed the recordings using an ASR system, then they extracted the story elements using the Berkeley aligner [26], and finally they compared those to the story elements manually identified by the expert examiner. Using a support vector machine (SVM) classifier applied to 72 participants, they showed ASR-derived features can distinguish 35 participants with MCI from 37 healthy controls with a classification accuracy of 81%. More recently, Toth et al. [27] presented an automatic approach for detecting MCI from speech samples in which participants were asked to talk about a 1-minute long animated film. They used an ASR system to transcribe the recordings and extract acoustic biomarkers including articulation rate, speech tempo, length of utterance, duration, and number of silent and filled pauses (hesitation). Their results show that the SVM classifier trained on the aforementioned acoustic features can distinguish 32 participants with MCI from 19 healthy controls with an accuracy of about 80%. Based on this prior work, we sought to improve the ability to extract meaningful markers of cognitive change from the spontaneous speech of individuals with MCI or those at risk for MCI.

2. Methods

2.1. Data collection and corpus

The present study was a part of a larger randomized controlled clinical trial that assessed whether frequent conversations conducted via webcam and Internet-enabled personal computers could improve cognitive function in older persons with either normal cognition