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Computer-based evaluation of AD and MCI patients during a picture description task

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Abstract

Introduction: We present a methodology to automatically evaluate the performance of patients during picture description tasks.

Methods: Transcriptions and audio recordings of the Cookie Theft picture description task were used. With 25 healthy elderly control (HC) samples and an information coverage measure, we automatically generated a population-specific referent. We then assessed 517 transcriptions (257 Alzheimer's disease [AD], 217 HC, and 43 mild cognitively impaired samples) according to their informativeness and pertinence against this referent. We extracted linguistic and phonetic metrics which previous literature correlated to early-stage AD. We trained two learners to distinguish HCs from cognitively impaired individuals.

Results: Our measures significantly ($P < .001$) correlated with the severity of the cognitive impairment and the Mini–Mental State Examination score. The classification sensitivity was 81% (area under the curve of receiver operating characteristics = 0.79) and 85% (area under the curve of receiver operating characteristics = 0.76) between HCs and AD and between HCs and AD and mild cognitively impaired, respectively.

Dicussion: An automated assessment of a picture description task could assist clinicians in the detection of early signs of cognitive impairment and AD.

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Keywords: Alzheimer's disease (AD); Mild cognitive impairment (MCI); Picture description task; Automatic assessment; Information coverage; Linguistic analysis; Phonetic features; Machine learning

1. Introduction and motivation

Multiple studies have assessed language functions as early markers of Alzheimer's disease (AD) [1]. Consequently, language is now widely accepted to be one of the first cognitive abilities affected by this dementia. Some of the most commonly used tests in clinical practice are Verbal Fluency by categories, Picture Description, the Boston Naming Test [2], and the Token Test [3], which measure expository speech, oral expression, and comprehension of commands, respectively [4].

This exploration of the changes in language functions derived from AD has attracted significant attention among scientists outside the field of medicine [5]. Researchers, especially those working in natural language processing, have proposed computer-based approaches for automatic and semiautomatic analysis of language in patients suffering from AD [6–13].

In this work, we propose a methodology to automatically describe patients' performance during a picture description task [14]. We selected this type of test because it elicits spontaneous speech from patients, allowing us to describe not only patients' ability to retrieve information from a visual stimulus but also some of their

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linguistic characteristics. Our evaluation describes three aspects: the informativeness and pertinence of the description provided by the patient, some linguistic characteristics, such as vocabulary richness and general use of part-of-speech categories, and a phonetic overview.

1.1. Information coverage

One of the key objectives of a picture description task is to measure the amount and quality of the information that a patient can provide from a visual stimulus. Even early in the course of the disease, AD patients have been shown to provide less informative descriptions than cognitively intact elderly adults [15]. This measure is generally made by comparing the description provided by the patient to a list containing the main information content units (ICUs) of the image, namely, actors, objects, actions, and places. Over the years, several authors have come up with predefined lists of ICUs for the Cookie Theft picture description task [16–21]. However, one of the disadvantages of using predefined lists to evaluate elderly patients is that the list author does not necessarily have a similar education level, age, focus, cultural background, and interests as the target population. Also, different authors may come up with different lists, depending on their idiosyncrasies, their own observations, and what they may consider "important" from the picture.

1.1.1. Related computational works

Hakkani-Tür et al. [22] used a manually predefined list as a referent to automatically compare descriptions of the Western Aphasia Battery's Picnic Picture. The authors found a high correlation between the traditional manual assessment and their automated approach. However, the computer-based evaluation had trouble handling ICUs expressed in multiple ways.

Pakhomov et al. [23] used manual transcriptions of descriptions of the Cookie Theft picture to assess the performance of patients with frontotemporal lobar degeneration. They compiled a list of predefined ICUs based on Yorkston and Beukelman's study [16] and manually extended it to include lexical and morphological variants of words and phrases. One drawback of this method is that it entails the manual creation of a list that considers as many variants as possible for each ICU.

Fraser et al. [24] used a semiautomatic approach to automatically classify Alzheimer's patients and healthy elderly controls (HCs) by analyzing manual transcriptions of descriptions of the Cookie Theft picture in the Pitt Corpus [25]. As a referent, the authors used the predefined list proposed by Croisile et al. [19] and evaluated the frequency of key words used to name the ICUs in different ways. As in Pakhomov et al.'s work [23], manually considering all the ICUs and their linguistic variations is a time-consuming task.

Yancheva and Rudzicz [26] automatically extracted the main ICUs retrieved by elderly adults in the Pitt Corpus. The authors contrasted automatically extracted ICUs to a combination of several predefined lists of ICUs. They retrieved most of the human-selected ICUs. In addition, they found that some participants mentioned the object *apron*, a new ICU that none of the specialists had perceived before. They also observed that HCs were more prone than AD patients to mention this object in their descriptions.

The appreciation of the fact that a woman is wearing an apron while doing housework could be attributed to a generational and cultural perception of what the object *apron* represented to elderly participants taking the test back in the 1980s. Different remarks may be attributable to cultural differences. For example, a non-Caucasian-predominant population may remark on the fact that all the subjects in the Cookie Theft picture are blond. Hence, we consider that a fairer referent for comparison in this task should be constructed by healthy participants of the target population. As such, it would be possible to create referents that are adapted to specific populations from different generations, cultures, and educational and general socioeconomic backgrounds.

1.1.2. The coverage measure

We identify three important tasks for performing a computer-based evaluation of a picture description task:

1. Creating a population-adapted referent.
2. Evaluating the *informativeness* of descriptions: estimate how much of the information in the referent is being covered by the participant.
3. Evaluating the *pertinence* of utterances: determine how much of what the participant is saying is covered by the referent. Some participants, particularly those with AD, can drift off-topic. Although this situation is easily detected when performing a manual evaluation, it is a challenging task for an automated analysis.

With these tasks in mind, we selected the information coverage measure proposed by Velazquez [27]. He originally proposed the method for comparing the coverage of information in news articles, although it could be used in different contexts.

Velazquez proposes a methodology for creating a referent for evaluating the information coverage. One distinguishing feature of his measure is that it uses linguistic patterns that allow the consideration of the context. In addition, the measure allows a two-way analysis of the information coverage, from the referent by the subject of comparison and vice versa. These two measures would allow the estimation of informativeness and pertinence, respectively.

1.2. Linguistic characteristics

There is extensive literature covering the analysis of the linguistic characteristics of AD patients [6,7,24,28–34]. As part of our evaluation, we selected those that most authors

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