Open Brain AI: automating language analysis

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Abstract

Traditional language assessment methods are time-consuming and labor-intensive. This paper presents a cutting-edge computational platform that utilizes AI to automate language analysis, reduce workload, and optimize healthcare and education processes. It enables rapid and detailed language evaluation, empowering professionals to focus on personalized patient interactions and data-driven insights.

Keywords: language assessment, AI, machine learning, computational platform

Introduction

Speech, language, and communication assessment is crucial in healthcare and education, from diagnosing neurological disorders to evaluating student performance. Traditional assessment methods, however, are often manual, time-consuming, and subjective, limiting their effectiveness and scalability. Computational approaches can address these challenges using machine learning, natural language processing, and advanced signal processing techniques, collectively known as Artificial Intelligence (AI). These AI-powered methods offer automated language assessment with increased robustness, accuracy, and generalizability across different linguistic backgrounds.

Computational language assessment

Previous research by our team and others has demonstrated the effectiveness of AI-based language assessment in identifying patients with Mild Cognitive Impairment (MCI) and Alzheimer's Disease (Themistocleous et al., 2018; Themistocleous, Eckerström, et al., 2020a, 2020b) and subtyping patients with Primary Progressive Aphasia (PPA) into distinct variants (Themistocleous et al., 2021). These AI models have outperformed traditional clinical assessments and expert clinicians' classifications. Furthermore, AI-powered morphological and syntactic analysis using natural language processing (NLP) techniques has provided valuable insights into speech and language patterns in patients with PPA (Themistocleous, Webster, et al., 2020).

AI has also been employed to identify speakers with different dialects based on their speech acoustics, including prosody (Themistocleous, 2016; Themistocleous et al., 2016), vowels (Themistocleous, 2017), and consonants (Themistocleous et al., 2022). Machine learning has further been used to track the linguistic development of learners of the standard language variety in classrooms, demonstrating the potential of AI in diverse populations.

Inspired by these developments, Open Brain AI emerged as a computational platform leveraging AI techniques to automate language assessment. This platform offers a comprehensive suite of tools for analyzing spoken and written language productions, providing clinicians and researchers with an easy, quick, and inexpensive assessment method. Open Brain AI's capabilities include automated speech-to-text transcription, automatic morphosyntactic and linguistic analysis of transcripts, and machine learning-based diagnosis and subtyping of language disorders.

Methods

Open Brain AI's core lies in a speech-to-text component that enables multilingual transcription of speech recordings into text. The transcribed text undergoes further processing through various analytical tools, including large language models, morphological taggers, parsers, and semantic analysis tools. These tools analyze language, providing quantitative measures across various linguistic domains: phonology, morphology, syntax, semantics, and lexicon. Additionally, IPA transcription and acoustic analysis tools are integrated to capture the nuances of spoken language.

Open Brain AI incorporates language-specific Natural Language Processing (NLP) tools that dissect written and spoken texts to achieve this comprehensive language analysis. These tools include tokenizers, stemmers, lemmatizers, part-of-speech (POS) taggers, named entity recognizers (NERs), parsers, semantic role labelers, and coreference resolvers. Each tool is crucial in extracting meaningful measures from the language data.

Results

Open Brain AI offers a range of computational tools for analyzing and assessing spoken and written language productions. It provides automated transcription linguistic, and acoustic analysis for text and speech recordings. Additionally, it offers a clinical toolkit for evaluating individuals with language disorders, including a picture description task, automatic conversion to the International Phonetic Alphabet, spelling scoring, phonological scoring, and semantic scoring.

Open Brain AI supports a variety of languages and language varieties. These include English, French, Greek, Swedish, Norwegian, and many other languages. Open Brain AI incorporates more languages to provide truly multilingual and multidialectal support. The core of Open Brain AI is the speech-to-text module, which enables multilingual transcription of speech recordings into text. This transcribed text is further analyzed using various tools, including morphological taggers, parsers, and semantic analysis tools.

These tools provide quantitative measures across different linguistic domains: phonology, morphology, syntax, semantics, and lexicon (Figure 1).

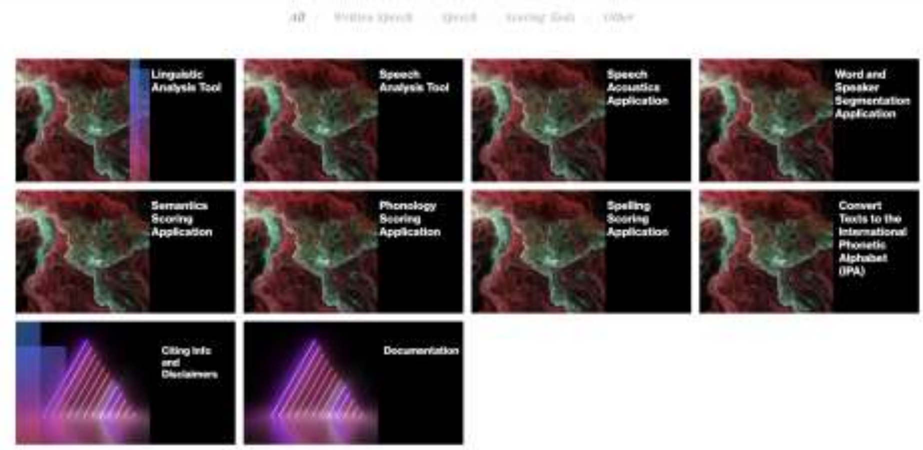

Figure 1. The current interface of Open Brain AI.

In addition to linguistic analysis, Open Brain AI provides acoustic analysis tools. These tools enable the segmentation of speech into words and speakers and the extraction of acoustic measures such as prosody and voice quality.
The clinical toolkit provided by Open Brain AI includes four primary tools:

1. *The Picture Description Tool* assesses the ability of individuals with aphasia or other language disorders to produce spontaneous speech.
2. *The automatic Conversion to the International Phonetic Alphabet (IPA)* converts words written in standard orthography into the IPA, allowing for a more detailed pronunciation analysis.
3. *The Spelling Scoring App* evaluates spelling accuracy by comparing the words spelled by patients to the target words using the Levenshtein Distance algorithm (Themistocleous, Neophytou, et al., 2020).
4. *The Phonological Scoring Tool* quantifies phonological errors by comparing the target and response words in the IPA and using the Levenshtein Distance algorithm.
5. *The Semantics Scoring Tool* employs word embeddings to score naming tasks involving semantic memory access.

Discussion

Open Brain AI further extends its capabilities with acoustic analysis, enabling the transcription of speech recordings. The sound input is processed to segment speech into words and speakers, extracting acoustic measures such as prosody and voice quality. Specialized tools provide graphical representations of the speech signals, including waveforms, spectrograms, and *F0*.

Open Brain AI leverages machine learning and statistical models, particularly deep neural network architectures, to comprehensively characterize language impairment. These sophisticated algorithms identify patterns from linguistic and acoustic data, enabling the platform to distinguish between typical language production and various language disorders.

The computational power of Open Brain AI extends to multimodal and multilingual data integration, offering a rich source of information for research, clinical, and educational applications. By combining language data with other relevant modalities, such as medical imaging or behavioral data, Open Brain AI can provide deeper insights into the underlying mechanisms of language impairment.

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