

Longitudinal Gaze–Speech Cognitive Decline Biomarkers from Oral Reading

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INTRODUCTION

Importance of Early Diagnosis and Challenges

Benefits: Early Alzheimer’s Disease (AD) diagnosis helps maintain cognitive function, delays nursing home admission, and reduces caregiver burden [1-4]

Limitations of Current Methods: PET imaging and lumbar punctures are expensive, invasive, and lack early-stage sensitivity [1-4]

Need for New Methods: Accessible, non-invasive, cost-effective diagnostics are crucial for early detection and intervention

Speech Biomarkers: Speech and language changes often precede AD symptoms [5-7]. Verbal tests (e.g., 'Cookie Theft' picture description) have proven effective for detecting AD and Mild Cognitive Impairment (MCI) [8-10]

Oculomotor Biomarkers: Eye movement irregularities (e.g., in smooth pursuit and saccades) are linked to early AD stages [11-13]. Recent studies support using eye movement data as indicators [14-16]

Project Goals

- Evaluate the effectiveness of a webcam-based eye tracker as a substitute for Tobii Fusion
- Develop a multimodal AI system combining vocal and oculomotor biomarkers for early AD detection
- Create a practical, mobile assessment tool for clinical and home use

METHODS

Study Design

- Type: 12-month observational cohort study (3 visits, every 6 months)
- Participants: 30 (15 Healthy Control [HC] + 15 Cognitive Decline [CD])

Baseline and Cognitive Testing

- Demographics and Medical History Questionnaire
- Functional Assessment Questionnaire (FAQ)
- Montreal Cognitive Assessment (MoCA)
- Neurocognitive Battery from the Uniform Data Set 3 (UDS3)

Computerized Task

- Fixation and Saccade
 - Visual delayed recall task
- 'Cookie Theft' picture description
 - Story - Delayed recall
- Oral story reading
 - Text eye tracking

Data Collection for Oral Story Reading

Longest Consecutive Fixation Chain: continuous word-by-word fixation

Fixation Sequence Linearity: adherence of fixation order to text order

Gaze-Speech Correlation Metrics: Pearson, Spearman, and cosine similarity between gaze and speech.

Gaze-Speech Error Metrics: standardized Root Mean Square Error and standardized Mean Absolute Error quantifying gaze-speech mismatch

METHODS (cont’d)

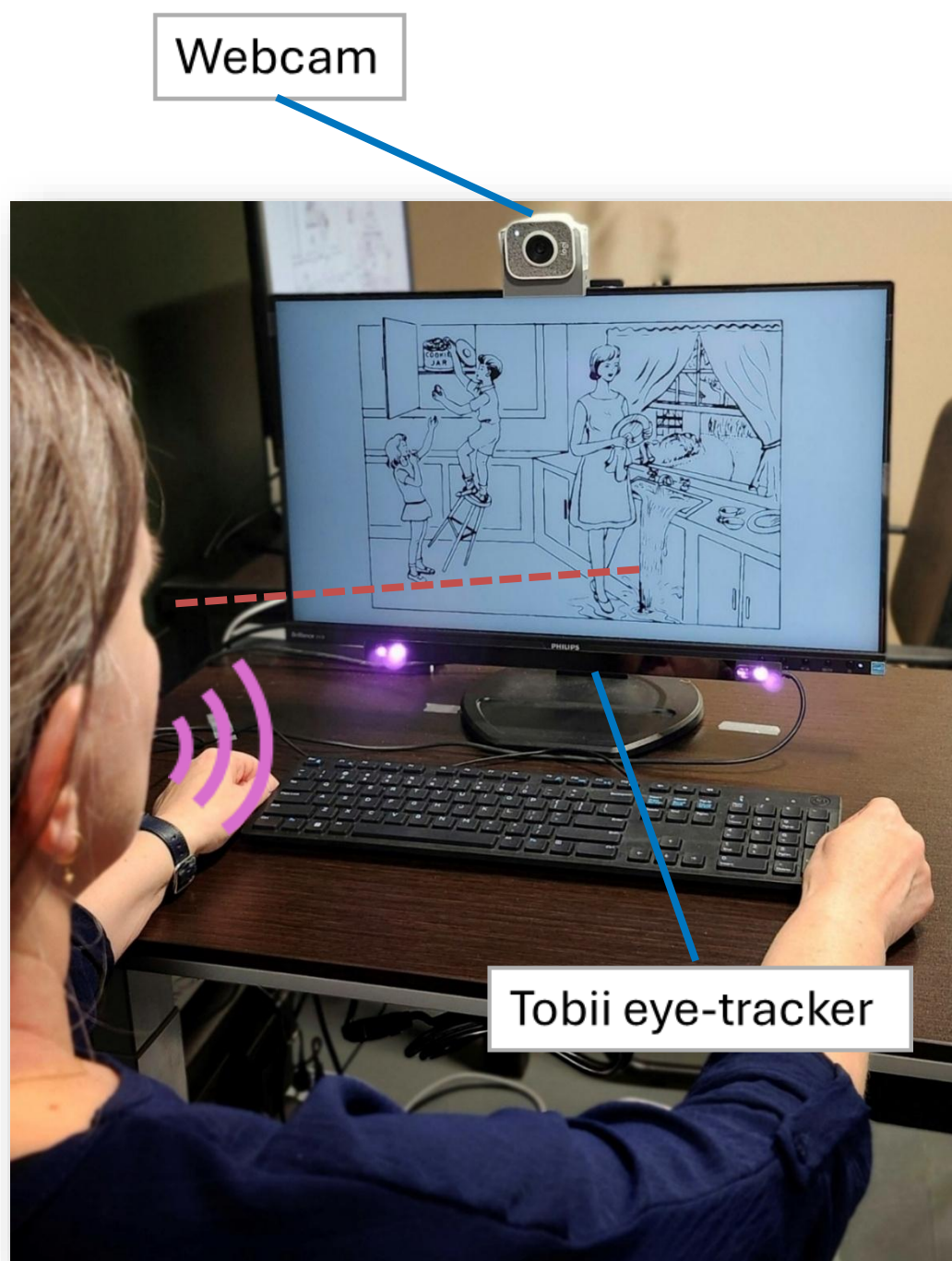


Figure 1: Setup of the System with Tobii and Webcam Eye Trackers

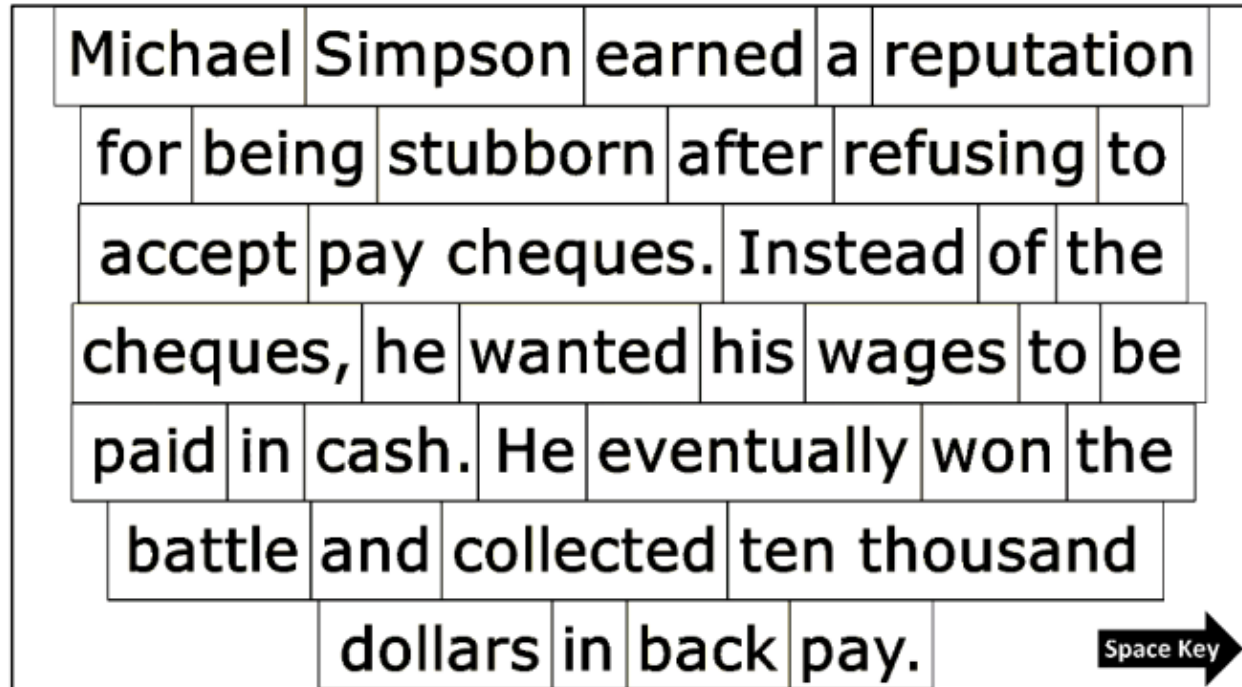


Figure 2: Reading Passage Slide 1 & 2 (Inverted for Visibility) With Word-Level Regions of Interest Outlined

RESULTS

Characteristic	Cognitive Decline (CD)	Healthy Controls (HC)
N (participants)	15	15
Age (years), Mean ± SD	77.0 ± 6.44	71.6 ± 5.2
Education (years), Mean ± SD	16.1 ± 3.52	16.4 ± 2.92
MoCA score (across all visits) Mean ± SD	19.8 ± 4.2	27.4 ± 1.9
Total number of usable visits	41	42
Sex (Male / Female)	11/4	5/10

Table 1. Participant Demographics and Overall Characteristics

During each visit, the Montreal Cognitive Assessment (MoCA) was administered.

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RESULTS (cont’d)

Metric	HC Slope	CD Slope	Δ Slope (CD – HC)
Longest Consecutive Fixation Chain (Words)	−0.438 (n.s.)	+0.964 (p = 0.033)	+1.403 (p = 0.028)
Fixation Sequence Linearity (R ²)	−0.018 (n.s.)	+0.070 (p = 0.022)	+0.088 (p = 0.042)

Table 2. Longitudinal Changes in Fixation-Sequence Linearity

Fixation-sequence linearity increased over time (per 6 months) in CD but not HC. Participants in the CD group showed longer fixation chains and more linear gaze patterns, suggesting a shift toward more ordered, word-by-word reading.

Metric	HC Slope	CD Slope	Δ Slope (CD – HC)
Pearson Correlation	−0.018 (n.s.)	+0.039 (p = 0.008)	+0.057 (p = 0.006)
Spearman Correlation	−0.024 (n.s.)	+0.042 (p = 0.036)	+0.066 (p = 0.021)
Cosine Similarity	−0.007 (n.s.)	+0.010 (p = 0.037)	+0.017 (p = 0.012)
zRMSE (Error)	+0.026 (n.s.)	−0.073 (p = 0.005)	−0.100 (p = 0.007)
zMAE (Error)	+0.020 (n.s.)	−0.058 (p = 0.016)	−0.078 (p = 0.021)

Table 3. Longitudinal Changes in Gaze–Speech Coupling

Gaze–speech coupling strengthened longitudinally (per 6 months) in the CD group but not in the HC. In CD, coupling correlations increased while coupling error metrics decreased, indicating progressively tighter synchronization between word fixation and the word being spoken. Significant CD–HC slope differences, alongside non-significant HC trends, suggest CD-specific increases in gaze–speech alignment rather than general practice or retest effects.

CONCLUSION

Our results show that, over repeated visits, individuals with cognitive decline exhibit a CD-specific shift toward more sequential, word-by-word visual reading and tighter gaze–speech synchronization, while healthy controls remain stable. This demonstrates that a brief, naturalistic oral-reading task can provide interpretable longitudinal biomarkers of cognitive decline, supporting the development of accessible, scalable tools for remote screening and monitoring.



References