



Dynamical Eye Movement Analysis for the Detection of Mild Cognitive Impairment

P1-08

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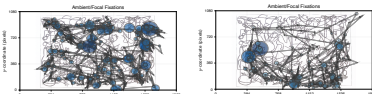
Dynamical analysis of eye gaze demonstrates efficacy of evaluating the temporal nature of ET indicators for MCI detection. Results are relative, implying their best utility might be in a longitudinal sense, i.e., gaze metrics compared to baseline over time.

INTRODUCTION

Mild Cognitive Impairment (MCI) is a significant risk factor for the progression of dementia. Early identification is essential, as timely interventions may delay progression, preserve autonomy, and improve patients' quality of life. However, substantial study heterogeneity and poor reproducibility persist, particularly in digital biomarker development of Eye Tracking (ET). Traditional metrics analyze gaze data made in the aggregate following trial completion. We discuss the more effectual analysis of gaze data as a time series.

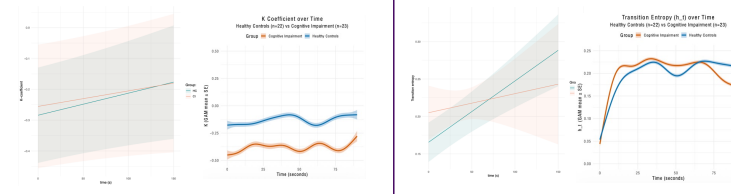
METHODS

60 nursing home residents were assessed: 30 healthy controls and 30 participants with MCI. The protocol consisted of a 30-minute ET battery including visual search of Rey's Figure Aggrovigiate among other tasks. Gaze analysis compared the ambient/focal K coefficient and gaze transition entropy.



RESULTS

	HC	CI
No.	30	30
Age, years	74.50 (69.00; 81.00)	88.00 (82.00; 92.00)
Education, years	8.00 (5.00; 13.00)	5.00 (5.00; 8.00)
Female gender, n (%)	15/30 (50.00%)	23/30 (76.67%)
MMSE (adjusted)	28.00 (27.20; 28.40)	21.85 (18.40; 24.20)
RBANS total (age-adjusted)	88.00 (76.00; 105.00)	60.00 (53.00; 69.00)
FAB (adjusted)	15.51 (1.68)	11.01 (2.84)
GDS	4.00 (1.00; 6.00)	8.50 (6.00; 14.00)
Barthel Index	100.00 (98.00; 100.00)	54.00 (28.00; 85.00)
CRIq	102.97 (19.57)	80.17 (12.83)



After eye-tracking quality control, gaze data were analyzed using complementary GLMM and GAM approaches. GLMMs tested adjusted effects of group, time, and Group $\times$ Time interactions, controlling for gender, age, education, depressive symptoms, functional status, and cognitive reserve, with FDR correction. GAMs modeled nonlinear temporal trajectories of gaze behavior. For transition gaze entropy, GLMMs showed a significant time effect and Group $\times$ Time interaction, with a trend toward higher entropy in cognitively impaired participants. GAMs confirmed significant temporal group differences, $F(2,19301) = 66.32$, $p < 0.01$, suggesting less predictable gaze behavior early in the trial. For the K coefficient, the main group effect was not significant, but time and Group $\times$ Time were significant. GAMs showed significant time-course differences, $F(2,19301) = 159.98$, $p < 0.01$. Fixation duration was higher in cognitively impaired participants, whereas saccade amplitude showed no significant main group effect. Together, these findings suggest that dynamic eye-tracking metrics may capture subtle alterations in visual exploration and represent candidate digital biomarkers of cognitive impairment.

CONCLUSIONS

Aggregate Metrics (Traditional)



Aggregate Metrics vs. Dynamical Analysis: Traditional aggregate metrics lacked efficacy, failing to distinguish between groups.

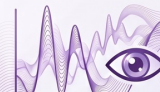
The Study Protocol



Defining the Study Groups: Comparisons are drawn between Healthy Controls (HC) and those labeled Cognitively Impaired (CI).

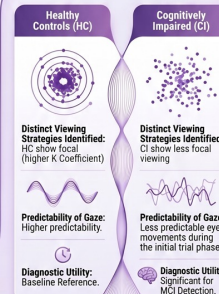


Dynamical Analysis (Time-Series)



Dynamical Analysis: Successfully identified distinct viewing strategies, outperforming traditional methods.

Key Findings & Clinical Conclusion



The Value of Longitudinal Monitoring

Temporal indicators are most effective when monitored against an individual's baseline over time.

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