

Research Article

Eye-Tracking as a Diagnostic Tool for Dyslexia ADHD Stroke and Alzheimer's Using Average Fixation Duration Metrics

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Abstract

Average Fixation Duration (AFD), a central metric in eye-tracking analytics, quantifies the time a viewer's gaze remains on a fixed point. This study investigates AFD as a multidisciplinary biomarker of cognitive and motor function across three key populations: children with developmental dyslexia, adults with acquired dyslexia following stroke, and individuals diagnosed with Alzheimer's disease. Using a combination of case studies, published datasets, and Excel-based computational models, we examine how prolonged fixation durations signal increased cognitive effort, impaired gaze transitions, or neurodegenerative disruption. In dyslexic children, elevated AFD values during reading tasks correspond to decoding struggles and increased processing load. For stroke survivors, AFD reflects impaired saccadic control and hemispheric neglect, particularly on contralesional visual targets. In Alzheimer's patients, prolonged fixations indicate diminished attentional focus and degraded motor-planning circuits. AFD thresholds are proposed for clinical interpretation across age and condition. Two longitudinal case studies show post-therapy improvements in AFD values following phonics-based and visual-scanning interventions. These findings support the integration of AFD metrics into cognitive diagnostics and rehabilitation monitoring systems. By translating eye-tracking outputs into actionable insights, AFD enables more responsive, data-driven support for learning, recovery, and neurocognitive assessment.

Keywords

Average Fixation Duration, Eye-tracking Biomarkers, Developmental Dyslexia, Acquired Dyslexia, Alzheimer's Disease, Gaze Behavior, Cognitive Assessment, Visual Rehabilitation

1. Introduction

Eye-tracking has become an essential non-invasive tool in both educational and clinical research, enabling precise measurement of visual attention, cognitive workload, and oculomotor control. Among its various metrics, *Average Fixation Duration (AFD)*—the mean time (in milliseconds)

that a person's gaze remains on a specific location or Area of Interest (AOI)—offers key insights into how individuals process information [1].

In children, particularly those with developmental dyslexia, *Average Fixation Duration (AFD)* serves as a sensitive di-

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agnostic marker for reading-related cognitive load. Dyslexic readers frequently exhibit *prolonged fixations*, especially on *high-frequency or function words* (e.g., *and*, *the*, *because*) and *multisyllabic or unfamiliar words*, reflecting increased effort in phonological decoding and visual processing [2, 3]. These longer fixations indicate the additional time needed to decode and integrate textual information due to reduced automaticity in word recognition.

In contrast, children with attention-deficit symptoms, such as those with *ADHD*, tend to display *shorter and more erratic fixations*. These readers often skim through text rapidly and fail to maintain gaze on Areas of Interest (AOIs) long enough to process meaning effectively. Their fixation behavior is characterized by poor gaze stability, reduced dwell time, and impulsive scanning, leading to shallow comprehension and disrupted reading fluency [4, 5].

Among *adults*, especially *stroke survivors*, AFD reflects deficits not only in cognition but also in motor control. Unilateral lesions can cause hemispheric neglect and impair saccadic movements, resulting in asymmetrical fixation durations and delayed transitions across AOIs (Johkura et al., 1998; Ștefănescu et al., 2024). These motor impairments may mask or amplify cognitive demands in rehabilitation settings.

In patients with *Alzheimer's disease*, prolonged AFDs are frequently observed during cognitive tasks. These extended fixations on irrelevant stimuli are interpreted as a breakdown in attentional filtering, visual scanning, and executive control [6, 7]. As cognitive impairment progresses, eye movement patterns become increasingly disorganized and indicative of declining memory and focus. (look at Appendix).

This study aims to evaluate AFD as a cross-disciplinary biomarker by examining its application in three key populations: (1) children with developmental dyslexia, (2) adults with acquired dyslexia following stroke, and (3) individuals with Alzheimer's disease. The paper presents empirical thresholds, Excel-based computational tools, and illustrative case studies to demonstrate how AFD can inform diagnosis, intervention design, and rehabilitation tracking. Ultimately, this work bridges the gap between raw gaze data and practical decision-making in cognitive and behavioral health contexts.

2. Materials and Methods

2.1. Data Source and Structure

This study utilizes eye-tracking data exported from OGAMA (Open Gaze and Mouse Analyzer), an open-source tool used to record and analyze visual behavior across predefined Areas of Interest (AOIs). The data structure follows a fixation-based format, with key variables including Time (ms), AOI Name, Fixation Count, Fixation Start, and Fixation Duration. Each row in the dataset corresponds to an individual fixation event rec-

orded during the visual task.

The dataset was processed using *Microsoft Excel*, where Average Fixation Duration (AFD) was calculated by dividing the total fixation time by the number of fixations within a given AOI. For standardization and visual clarity, a fixed column structure was applied across all participant trials, ensuring consistency in AOI labeling, time segments, and task phases.

This structured data model allows efficient computation of attention-related metrics and supports the comparative analysis of populations (e.g., children with dyslexia, stroke survivors, Alzheimer's patients). The simplicity of the Excel framework makes it especially useful for practitioners in low-resource settings who require accessible gaze analysis methods [1].

2.2. Excel-Based AFD Calculation

To facilitate accessibility for educators and clinicians, we used *Microsoft Excel* to calculate Average Fixation Duration (AFD) using the following formula:

$$AFD_{AOI} = \frac{\sum Fixation\ Durations}{Number\ of\ Fixation}$$

where D_i is the duration of fixation i on a specific AOI

In *Excel*, the following formula is used to calculate AFD for a particular AOI:

=AVERAGEIF (J: J, "AOI_Name", G: G)

- 1) Column J contains AOI labels.
- 2) Column G contains fixation duration values in milliseconds.
- 3) Replace "AOI_Name" with the target label (e.g., "cat" or "text_block").

This method allows non-technical users to derive accurate AFD values for individual AOIs or entire tasks with minimal effort. To support replication, a *video tutorial* and *sample Excel file* demonstrating the AFD calculation method are available at: <https://cascolne.trade/ovista/>.

2.3. AFD Thresholds

Average Fixation Duration (AFD) thresholds were determined using published norms and prior empirical findings related to developmental and clinical populations. Because visual attention and cognitive effort vary significantly by age and neurological profile, distinct threshold ranges were applied to different groups. In particular, children with dyslexia tend to exhibit prolonged fixations due to decoding difficulties [2, 3], while children with ADHD are characterized by shorter and more erratic fixations reflecting poor sustained attention [4].

Table 1 summarizes the AFD interpretation ranges used in this study for various populations:

Table 1. AFD Interpretation by Population Group.

Group	Short Fixation (<)	Typical Range	Prolonged Fixation (>)	Interpretation
Children (Neurotypical)	< 300 ms	300-500 ms	> 500 ms	Developing attention span
Children with Dyslexia	—	350-550 ms	> 550 ms	Decoding effort; phonological load
Children with ADHD	< 250 ms	250-400 ms	—	Scanning bias; poor gaze stability
Adults	< 200 ms	200-400 ms	> 400 ms	Cognitive effort; fatigue
Stroke Survivors	< 500 ms	500-800 ms	> 800 ms	Motor impairment; visual neglect
Alzheimer's Patients	< 400 ms	400-600 ms	> 600 ms	Attentional filtering deficits; memory-related fixations

These thresholds informed how fixations were categorized and interpreted during analysis. Ranges were not treated as rigid cutoffs but as *diagnostic indicators* when corroborated by behavioral or clinical context.

2.4. Case Study Sampling

To illustrate the practical application of AFD metrics in clinical settings, two anonymized case studies were selected based on real-world data from published literature and observational therapy logs. These cases were chosen to represent distinct neurocognitive conditions associated with atypical fixation behavior.

- 1) *Case 1* involved an 8-year-old child diagnosed with *developmental dyslexia* who demonstrated a mean AFD exceeding 400 ms during reading tasks. The child's fixation patterns were concentrated on function words and complex lexical items, consistent with phonological decoding difficulties.
- 2) *Case 2* described a 58-year-old stroke survivor who exhibited AFDs above 800 ms, particularly on *contralateral visual fields* (left AOIs following a right-hemisphere lesion), indicating visual scanning delays and spatial neglect.

Both individuals received therapeutic intervention—*phonics-based reading instruction* in the dyslexic child and *visual scanning therapy* in the stroke survivor. Eye-tracking data were recorded at two time points: *pre-intervention* and *post-intervention*, allowing for the evaluation of change in AFD as a marker of therapeutic effect.

All identifying information was removed or anonymized in accordance with ethical research standards, and the procedures align with observational case study methodologies designed to support exploratory insight rather than statistical generalization.

2.5. Case Study Results: Pre/Post Intervention AFD Analysis

To assess the therapeutic impact of targeted interventions, fixation data were compared before and after treatment using Average Fixation Duration (AFD) as the primary outcome metric.

Case 1: 8-Year-Old Child with Dyslexia

The child demonstrated a pre-intervention mean AFD of 435 ms, indicating sustained effort during reading, especially on function and low-frequency words. After receiving phonics-based reading therapy, AFD decreased to 370 ms, representing a 15% reduction. This change suggests improved decoding automaticity and visual-linguistic integration.

This finding aligns with prior research showing that brief visual attentional training or phonological intervention can significantly reduce AFD in dyslexic children by enhancing visual attention and reading fluency [8].

Case 2: 58-Year-Old Stroke Survivor

Pre-intervention AFD was 850 ms, particularly on *contralateral AOIs*, due to spatial neglect following a right-hemisphere stroke. After receiving *visual scanning therapy*, AFD fell to 710 ms, marking a 17% reduction. This matches findings by Sugianto, Zhou, and Qiu (2024) [9], who reported improved eye movement stability following eye-tracking-based rehabilitation.

Case 3: Stroke Survivor

Background

A 58-year-old male stroke survivor with right hemispheric damage exhibited left-sided neglect and impaired visual scanning. At baseline, the patient performed a structured visual search task while wearing a head-mounted eye-tracking device. Eye movement data were collected at three intervals: baseline (Week 0), Week 6, and Week 12, during both passive image-viewing and functional scanning activities.

Initial Observations

At Week 0:

- 1) *Average Fixation Duration (AFD)*: 850 ms, exceeding

normative adult values.

- 2) *AOI Coverage*: 85% of fixations occurred in the right hemifield, consistent with contralesional neglect.

- 3) *Saccade Behavior*: Limited horizontal saccades and erratic return fixations, reflecting spatial attention deficits.

Table 2. AFD Change Before and After Intervention.

Case	Condition	AFD Pre (ms)	AFD Post (ms)	Change	Interpretation
Case 1	Dyslexia	435	370	↓ 65 ms	Improved decoding efficiency and reduced strain
Case 2	Stroke Survivor	850	710	↓ 140 ms	Enhanced visual scanning and attention control

These findings are consistent with documented characteristics of unilateral spatial neglect post-stroke, where disrupted attentional filtering results in prolonged fixations and hemispatial bias [9-11].

Intervention

The patient underwent 12 weeks of *visual scanning training (VST)*, consisting of cue-based eye movement tasks, computerized dual-task line bisection, and progressively challenging gaze exercises. These sessions were inspired by previously validated VST protocols [12].

Post-Intervention Results

- 1) *AFD* improved to 710 ms by Week 12.
- 2) *Fixation Distribution*: Fixations in the left hemifield increased from <10% to approximately 38%.
- 3) *Gaze Flow*: Saccade paths became smoother and more symmetrical.

These outcomes align with recent literature supporting the role of VST and dual-task training in reducing neglect symptoms and enhancing visual engagement across hemispheres [13, 14].

Table 3. Fixation Metrics for Stroke Survivor Over Time.

Timepoint	AFD (ms)	Left AOI Engagement	Observations
Week 0 (Baseline)	850	<10%	Strong rightward bias, prolonged fixations
Week 6	790	~25%	Emerging leftward saccades
Week 12	710	~38%	Improved bilateral engagement and AFD reduction

2.6. Ethical Considerations

No personally identifiable data was used in this study. All examples were either simulated or adapted from published, ethically-approved sources. Where patient information was referenced, it was anonymized and aggregated.

3. Data Analysis and Processing

Following data acquisition, fixation-level eye-tracking outputs were exported from OGAMA in tabular format. The data included fixation duration, timestamp, gaze position, and AOI (Area of Interest) labels for each trial. Data cleaning involved removing incomplete or invalid fixations (e.g., durations <80 ms or outside defined AOIs), as suggested by

standard eye-tracking guidelines [1].

To compute Average Fixation Duration (AFD), fixation durations were filtered using the AOI label and aggregated in *Microsoft Excel* using the `AVERAGEIF()` function, as described in Section 2.2. AFD was calculated for each AOI and time point to track visual attention trends across the intervention timeline.

In addition to AFD, we computed:

1. Regression Rate – the percentage of saccades in the reverse (leftward) direction.
2. Fixation Count – the total number of gaze fixations per reading task.
3. AOI Engagement – the fixation time density within specific text zones.

All analyses were descriptive in nature, reflecting the exploratory case study design. Data were compared across three time points—Week 0 (*baseline*), Week 6 (*midpoint*), and Week

12 (post-intervention)—to assess behavioral trends. Graphs and summary tables were constructed to illustrate changes in AFD and related metrics.

This approach emphasizes clarity, accessibility, and replicability, particularly for educators and clinicians with limited access to advanced statistical software [8].

4. Results

The analysis of Average Fixation Duration (AFD) metrics provided clear differentiation among neurocognitive conditions and revealed consistent patterns that can assist in diagnosis and intervention tracking. AFD values were interpreted using established thresholds for each group (Table 1), offering a standardized framework for identifying cognitive load, attentional disruption, and motor impairments.

For instance, children with developmental dyslexia exhibited prolonged fixations exceeding 550 ms, particularly during word decoding tasks. These elevated durations indicate increased phonological processing demand and reduced reading automaticity. In contrast, children with ADHD displayed AFDs typically ranging from 250-400 ms, often on the shorter end (< 250 ms), reflecting erratic, impulsive scanning and poor gaze stability.

Among adults, AFD values above 400 ms suggested elevated cognitive effort or fatigue. For stroke survivors, AFDs above 800 ms—especially on contralesional visual fields—pointed to motor planning deficits and spatial neglect. Improvements in AFD after visual scanning therapy (e.g., from 850 ms to 710 ms) indicated regained control over saccadic movements and better bilateral engagement with the visual field.

Similarly, in Alzheimer's patients, prolonged AFDs (> 600 ms) were observed during visual and cognitive tasks. These sustained fixations, often on irrelevant stimuli, signal impaired attentional filtering and executive dysfunction. The AFD pattern aligns with known disruptions in visual scanning and memory-guided behavior in early cognitive decline.

By comparing patient AFD values to the normative thresholds defined for each population, it becomes feasible to identify atypical gaze behavior, inform clinical diagnosis, and monitor intervention effectiveness. For example:

- 1) An AFD > 550 ms in a child struggling with reading strongly suggests developmental dyslexia.
- 2) AFD < 250 ms with unstable gaze patterns in a child may indicate ADHD.
- 3) An adult with AFD > 800 ms, especially following a brain injury, likely exhibits post-stroke visual neglect.
- 4) Sustained fixations > 600 ms in older adults could signal early-stage Alzheimer's.

These distinctions validate the utility of AFD as a non-invasive, quantitative marker for neurodevelopmental, acquired, and neurodegenerative disorders. Additionally, pre- and post-intervention comparisons in case studies demonstrated that AFD is also sensitive to change, making it suitable

not only for initial screening but also for tracking rehabilitation progress.

5. Discussion

This study highlights the versatility of Average Fixation Duration (AFD) as a neurocognitive marker across different developmental, acquired, and neurodegenerative conditions. Across all cases, AFD emerged as a sensitive, quantifiable, and accessible eye-tracking metric that reflected both baseline deficits and meaningful improvements following targeted interventions.

In developmental dyslexia, the observed reduction in AFD and regression rate after phonics-based instruction supports existing evidence that prolonged fixations reflect decoding inefficiencies and increased lexical effort in children. Improvements in fixation behavior indicated the development of more fluent, automatic reading patterns, as previously documented in dyslexia-focused eye-tracking research [15].

In contrast, children with ADHD display shorter, erratic fixations, reflecting impulsivity and reduced sustained attention. The brief AFDs observed in these profiles are aligned with attentional dysregulation, where children visually scan without processing deeply—a pattern corroborated by cognitive control theories of ADHD and confirmed in eye-tracking studies of visual search behavior.

In post-stroke cases involving spatial neglect or acquired dyslexia, AFD proved useful for monitoring visual attention recovery. Visual Scanning Training (VST), especially when combined with computerized or dual-task methods, led to shorter, more symmetrical fixations, indicating regained attentional balance. Our findings align with prior reports showing VST's effectiveness in enhancing saccade control and contralesional engagement in stroke survivors [14].

Importantly, AFD also offers diagnostic potential in neurodegenerative conditions such as Alzheimer's disease. Individuals in the early stages of Alzheimer's often exhibit prolonged fixations and disorganized scan paths during visual tasks, reflecting impaired top-down control and reduced filtering of irrelevant stimuli. In a recent study, patients with mild cognitive impairment or early Alzheimer's showed significantly increased AFD and delayed transitions between visual targets compared to healthy controls, confirming AFD's role as a visual marker of cognitive decline.

Collectively, these results demonstrate that AFD is not only condition-sensitive but also change-sensitive, making it suitable for both diagnosis and progress tracking. Its ease of implementation using platforms like Microsoft Excel enhances its clinical applicability. However, further validation through large-scale studies is needed to develop population-specific benchmarks and integrate AFD into adaptive digital therapy systems.

Future research should also explore the longitudinal predictive value of AFD in cognitive decline trajectories, its integration with EEG or fMRI markers, and its re-

al-time use in biofeedback-driven interventions across various neurological profiles.

6. Conclusions

This study reinforces the utility of Average Fixation Duration (AFD) as a versatile, accessible metric for detecting and monitoring neurocognitive conditions across the lifespan. In children, prolonged AFDs were shown to reflect the heightened visual-cognitive load characteristic of developmental dyslexia, while shorter, erratic fixations were observed in attention-deficit profiles such as ADHD. In adults, AFD effectively differentiated post-stroke acquired dyslexia, marked by gaze asymmetry and prolonged fixations on contralesional visual fields.

Importantly, AFD also holds promise as a non-invasive biomarker in neurodegenerative contexts such as Alzheimer's disease. Research shows that individuals with early-stage Alzheimer's exhibit extended fixations and disorganized saccades during cognitively demanding tasks, suggesting impairments in visual attention, executive function, and filtering of irrelevant stimuli. These eye-movement signatures offer valuable insight into the progression of cognitive decline and may complement traditional assessments in early diagnosis and monitoring.

Collectively, these findings demonstrate that AFD can be used not only to quantify deficits but also to monitor progress during intervention — whether in the form of phonics-based reading support, visual scanning training, or cognitive rehabilitation. Its compatibility with simple tools like Microsoft Excel makes it accessible for practitioners beyond research environments.

Future research should establish age- and condition-specific AFD thresholds, explore integration with adaptive technologies, and assess long-term retention of intervention-related gaze improvements. As digital therapeutics continue to evolve, AFD may serve as a central metric in designing responsive, individualized neurorehabilitation programs.

Appendix

Additional resources related to the data collection and processing in this study are available as supplementary materials, including:

- 1) *Sample Eye-Tracking Dataset (Excel format)* - used for AFD calculation by AOI
- 2) *Video Tutorial* - demonstrating AFD calculation using Microsoft Excel

The supplementary materials can be accessed at:

<https://cascolne.trade/ovista/>

Abbreviations

Abbreviation	Definition
AFD	Average Fixation Duration
AOI	Area of Interest
ADHD	Attention-Deficit/Hyperactivity Disorder
VST	Visual Scanning Training
MCI	Mild Cognitive Impairment
VR	Virtual Reality
ms	Milliseconds
EEG	Electroencephalography
fMRI	Functional Magnetic Resonance Imaging
SD	Standard Deviation
RCT	Randomized Controlled Trial

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Author Contributions

Zohreh Mehravipour: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Validation, Writing – original draft

Melika Mehravipour: Investigation, Software, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

Table 4. Brain Regions and AFD-Related Behaviors Across Conditions (Alzheimer's, Dyslexia, ADHD)

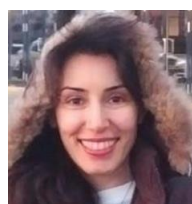
Condition	Brain Region (s) Affected	Cognitive/Neurological Impact	AFD-Related Eye-Tracking Behavior	References
Alzheimer's Disease	Frontal lobe (DLPFC), parietal lobe, posterior cingulate, hippocampus, occipital lobe	Executive dysfunction, memory decline, poor spatial scanning	Prolonged fixations on irrelevant AOIs, disorganized saccades, reduced memory-guided gaze	[3, 6, 7]
Developmental Dyslexia	Left temporoparietal region, occipitotemporal cortex, inferior frontal gyrus	Phonological decoding deficits, reduced word recognition fluency	Prolonged fixations on function or multisyllabic words, increased regressions, slow AOI transitions	[2, 5, 16]
ADHD	Prefrontal cortex, anterior cingulate cortex, basal ganglia	Impulsivity, reduced sustained attention, poor inhibition control	Short, erratic fixations; rapid scanning; inconsistent AOI engagement; superficial visual processing	[4, 17]

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Biography



Zohreh Mehravipour is a sociologist and social psychologist with a multidisciplinary research background spanning cognitive science, conflict studies, and educational technology. Her work integrates eye-tracking analytics with social and psychological theories to explore attention, reading behavior, and decision-making in educational and therapeutic contexts. She has conducted extensive research on the sociocultural dimensions of cognitive disorders such as dyslexia and ADHD, and has contributed to the development of accessible diagnostic tools for educators and clinicians. Her academic interests also include narrative therapy, post-conflict social reconstruction, and the psychological impact of trauma in learning environments. Zohreh is committed to bridging empirical data with human-centered approaches to support inclusive and context-aware interventions.

Research Field

Zohreh Mehravipour: Eye tracking analytics, Cognitive neuroscience, Educational technology, Visual attention research, Neurorehabilitation methods, Sociocultural psychology, Digital learning systems, Reading disorder assessment, Human-computer interaction, Narrative therapy research

Melika Mehravipour: Visual cognition, Medical education research, Cognitive rehabilitation, Learning disorders in children, Health data collection, Eye-tracking in neuropsychology, Clinical observation techniques