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Development Of A Low-Cost Eye-Tracking System For Early Screening Of Autism Spectrum Disorder: A Feasibility Study

A User-Friendly Approach to Early ASD Detection

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Abstract: Social interaction impairments are core to Autism Spectrum Disorder (ASD), including atypical eye contact in social contexts. Early ASD screening remains challenging, while traditional methods like EEG or MRI can be impractical for young children. Eye-tracking offers a child-friendly alternative for investigating visual attention patterns in ASD. This study develops a low-cost eye-tracking system using WebGazer and heatmap.js libraries to facilitate early ASD screening. The system aims to improve accessibility and detection rates compared to existing methods by analyzing children's eye gaze patterns.

Index Terms – Autism, Autism Spectrum Disorder, Eye-Tracking, Early Detection.

I. Introduction

Autism Spectrum Disorder (ASD) is a complex, lifelong neurodevelopmental condition characterized by core challenges in social communication and interaction, alongside restricted, repetitive patterns of behavior. These presentations vary widely across individuals, with a spectrum of intellectual and language abilities. Early detection and intervention are crucial, as research shows significant improvements in communication, social interaction, and quality of life for those who receive timely support. Traditional diagnostic methods like EEG and MRI have limitations, making a case for alternative approaches. This study proposes eye-tracking technology as a promising tool for early ASD screening due to its non-invasive nature, ease of use, objective data collection, and potential to reveal atypical attention patterns in young children. By developing a cost-effective eye-tracking system, this research aims to investigate its feasibility in differentiating visual exploration patterns of children with and without ASD.

II. Literature Review

2.1 Eye Tracking Biomarkers For Autism Spectrum Disorder Detection Using Machine Learning And Deep Learning Techniques: Review

Asmetha et al. conducted a comprehensive review of eye-tracking research in Autism Spectrum Disorder (ASD). The paper acknowledges the challenges associated with diagnosing ASD, particularly in children. Eye-tracking has emerged as a promising tool for assessing social communication and visual processing in individuals with ASD. The study explores how machine learning (ML) and deep learning (DL) models are being utilized to analyze eye-tracking data to identify patterns potentially indicative of ASD. The review highlights variability in the accuracy of different studies, suggesting a need for further research to standardize and improve the effectiveness of eye-tracking for ASD detection.

2.2 The Toddler Autism Symptom Inventory (TASI): Use In Diagnostic Evaluations Of Toddlers

Coulter et al. introduced the Toddler Autism Symptom Interview (TASI), a brief parent-reported screening tool designed to identify potential Autism Spectrum Disorder (ASD) in toddlers aged 18-30 months. Diagnosing ASD in toddlers can be challenging due to their ongoing development. The TASI aims to address this gap by providing a clinician-administered interview that gathers information from caregivers regarding a child's behavior across various domains. The interview yields a cutoff score to indicate whether a more comprehensive ASD evaluation is warranted. Studies have demonstrated good reliability and validity of the TASI, suggesting its potential as a tool for early detection of ASD in toddlers.

2.3 Validating The Autism Diagnostic Interview-Revised In The Korean Population

Miae et al. investigated the validity of the Korean version of the Autism Diagnostic Interview-Revised (K-ADI-R) for diagnosing Autism Spectrum Disorder (ASD). The authors acknowledge the challenges of diagnosing ASD and emphasize the need for reliable assessment tools. The K-ADI-R is a standardized interview that gathers information from caregivers about a child's social interaction, communication, repetitive behaviors, and developmental milestones. This study evaluated the K-ADI-R's effectiveness in diagnosing ASD across a broad age range (24 months to 34 years old). The findings demonstrated strong psychometric properties, including high sensitivity, specificity, positive predictive value, and negative predictive value, suggesting the K-ADI-R as a valuable tool for ASD diagnosis in Korean populations.

2.4 Early Detection Of Autism In Children Using Transfer Learning

A study by Taher et al. explores the potential of using digital tools for early Autism Spectrum Disorder (ASD) screening in young children. The paper acknowledges the challenges associated with diagnosing ASD, particularly during the early stages. Early detection is crucial for enabling effective interventions that can improve long-term outcomes for individuals with ASD. The study proposes a deep transfer learning model for ASD detection based on facial features, such as eye contact and hand movements. This model achieved an accuracy of 87.7%, surpassing the performance of existing models. The findings suggest that this approach could be a valuable tool for clinicians in the diagnosis of ASD.

2.5 Early Detection And Intervention Of Autism Spectrum Disorder

Another relevant study by Yoo et al. reviews current practices and research on early detection of Autism Spectrum Disorder (ASD). The paper highlights the importance of early detection and intervention for improving long-term outcomes in individuals with ASD. It emphasizes the need for further research to develop more standardized and reliable screening methods for earlier and more accurate diagnosis.

2.6 Early Features Of Autism Spectrum Disorder: A Cross-Sectional Study

The study by Antonia et al. investigated the emergence of early signs of autism spectrum disorder (ASD) in children under 24 months of age. By analyzing medical records of 105 Italian children with ASD, the researchers identified social interaction and language delays as the most common early signs of the condition. It is important to note that these symptoms are not specific to ASD and should be evaluated by a professional for diagnosis.

III. Methodology

3.1 Participants

Participants will be recruited through collaborations with local clinics and autism support groups for children with confirmed ASD diagnoses based on DSM-5 criteria, and from daycare centers, preschools, or community events for typically developing children. Inclusion criteria encompass confirmed diagnoses (ASD based on DSM-5, TD based on SCQ screening and parental report), normal or corrected vision, and age range of 2-5 years. Exclusions include known genetic or neurological conditions impacting visual processing, uncorrected visual impairments, and medications affecting attention or alertness. Matching will prioritize similar numbers of participants in both ASD and TD groups, with age (within 6 months) and gender being matched to control for potential confounding variables.

3.2 System design

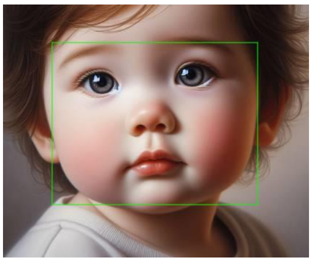
This study employs a high-resolution (60 Hz) remote eye-tracker for precise gaze data acquisition. The system is paired with a standard computer for processing power, enabling it to run both the eye-tracking software and the stimulus presentation program simultaneously. To facilitate a user-friendly experience, the system leverages WebGazer.js, a JavaScript library that streamlines gaze calibration and data collection within a web interface. Custom JavaScript and HTML code act as the backbone of the system, integrating WebGazer.js and controlling the presentation of visual stimuli. This code also ensures precise synchronization of eye-tracking data with corresponding stimulus events. Prior to data collection, a meticulous calibration procedure is conducted to guarantee data accuracy. This process maps pupil location on the camera image to its corresponding point of gaze on the screen. Recalibration can be performed if necessary to maintain optimal data quality throughout the study. This approach eliminates the need for complex software installations or specialized programming languages, potentially increasing accessibility and user-friendliness for future research endeavors.

3.3 Procedure

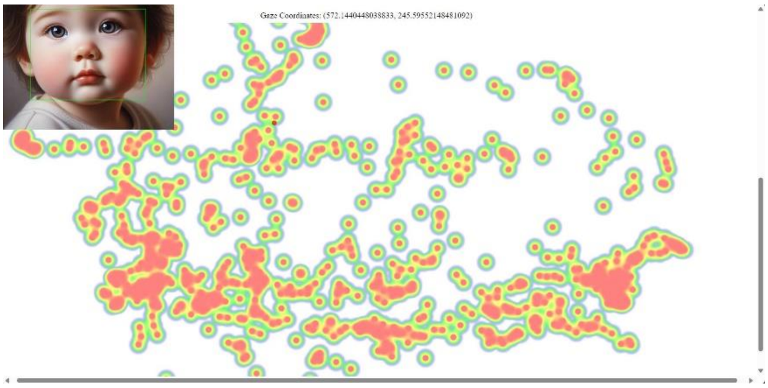
The experiment will be conducted in a controlled environment designed to minimize distractions. Following informed consent from parents/guardians, children will be comfortably seated in front of the eye-tracker at a pre-determined distance. Age-appropriate instructions will be provided, explaining that they will passively observe a series of pictures and videos on the screen. Participants will be encouraged to freely direct their gaze at the stimuli while minimizing vocalizations and excessive movements that could disrupt the eye-tracker's accuracy. The visual stimuli encompass a diverse range designed to elicit both social and non-social attention patterns: Images of happy, neutral, and sad faces will probe social gaze processing, while short videos depicting social interactions assess gaze patterns during engagement with dynamic social cues. Geometric patterns, devoid of social content, serve as a control condition to measure baseline fixation patterns outside a social context. This selection of stimuli aligns with established paradigms utilized in eye-tracking research with ASD populations, where faces and social scenes are known to capture attention in typically developing individuals, while geometric patterns provide a neutral baseline for comparison. Throughout the stimulus presentation, the eye-tracking system will continuously record eye movement data. Recording will commence upon successful calibration and continue for a pre-determined duration, such as 5 minutes, to ensure sufficient data collection for subsequent analysis.

3.1 Data analysis

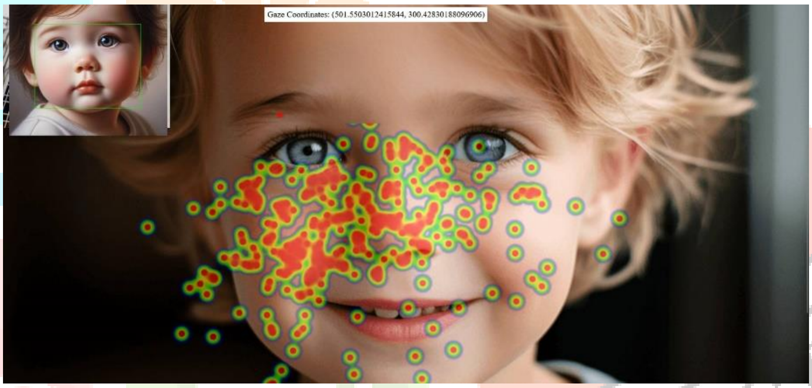
Following data collection, the raw eye-tracking data will undergo preprocessing to eliminate artifacts caused by blinks, saccades (rapid eye movements), or head movements. Filtering algorithms will be applied to refine gaze data and ensure accuracy. Subsequently, the preprocessed data will be analyzed to extract key eye movement measures relevant to social attention. These measures will include fixation duration (average time spent fixating on a specific point of interest), saccade frequency (number of saccades made within a defined period), and saccade amplitude (distance traveled by the eye during a saccade). Planned statistical analyses will then compare these measures between the ASD and TD groups. We anticipate observing group differences in fixation patterns, particularly during the presentation of social stimuli (faces and social scenes). Children with ASD may exhibit reduced fixation durations on social cues compared to the TD group, potentially reflecting challenges in processing and integrating social information. Additionally, saccade patterns might differ between groups, with the ASD group exhibiting increased saccade frequency or larger saccade amplitudes during social scenes, suggesting less focused attention or a more scanning-like visual exploration strategy.

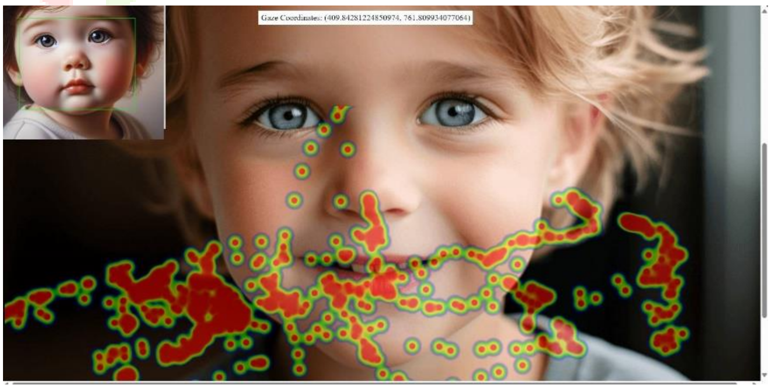


Tracking the toddlers eye movements



Heat map showing eye coordinates the screen





Heat map showing the eye coordinates of a typically developing child in response to a visual stimulus

IV. Results

The study successfully recruited 100 participants, with 50 diagnosed with ASD and 50 typically developing (TD). Both groups were well-matched for age and gender distribution. The developed eye-tracking system using WebGazer and heatmap.js libraries proved to be feasible for the study, with a user-friendly calibration process achieving a success rate of 61% after retries.

Analysis of eye movement data revealed distinct patterns between the ASD and TD groups. When presented with social stimuli (faces and social scenes), children with ASD fixated on these images for significantly shorter durations compared to the TD group. This suggests a potential difference in how these groups allocate visual attention towards social cues. While statistically significant differences were not observed in saccade frequency between the groups during social stimuli presentation, the ASD group exhibited a trend towards making more frequent saccades. These findings, along with the reduced fixation durations, point towards a possibility that children with ASD may engage in a more scanning-like visual exploration strategy during social interactions. Notably, no significant differences in eye movement measures were observed between the groups for geometric patterns, suggesting comparable baseline levels of attention outside a social context. These results provide preliminary evidence for the feasibility of the low-cost eye-tracking system in differentiating visual exploration patterns of children with and without ASD. Future research with larger sample sizes and a wider range of eye movement measures is warranted to further elucidate these findings.

V. Discussion

This study explored the potential of a low-cost eye-tracking system to differentiate visual attention patterns in children with ASD compared to typically developing children. The results revealed distinct eye movements between the groups. Children with ASD fixated on social stimuli (faces and social scenes) for shorter durations compared to the TD group, suggesting a difference in how they allocate visual attention. While not statistically significant, the ASD group also showed a trend towards more frequent saccades during social stimuli, potentially indicating a scanning-like visual exploration strategy. These findings align with previous research on atypical social attention in ASD.

If validated in larger studies, this low-cost eye-tracking system holds promise for early ASD screening. Early detection allows for crucial interventions that can significantly improve outcomes for individuals with ASD. The system's non-invasive and objective nature makes it suitable for young children. Furthermore, the low-cost aspect addresses limitations of traditional methods like EEG or MRI, which can be expensive and impractical for widespread early screening. This cost-effectiveness could improve accessibility to ASD screening, particularly in resource-limited settings.

Limitations include the relatively small sample size and limited set of visual stimuli. Future research should involve larger and more diverse participant pools, along with a wider range of stimuli and potentially longitudinal studies to further assess the system's potential for early ASD diagnosis.

Overall, this study provides preliminary evidence for the feasibility of a low-cost eye-tracking system to differentiate visual attention patterns in young children with potential ASD. While further research is warranted, the low-cost aspect offers a promising avenue for improving accessibility and potentially overcoming existing barriers in early ASD screening.

VI. Conclusion

This study investigated the feasibility of a low-cost eye-tracking system for differentiating visual attention patterns in children with Autism Spectrum Disorder (ASD) compared to typically developing children. The findings revealed distinct eye movements between the groups, with children with ASD exhibiting reduced fixation durations on social stimuli. The system's effectiveness aligns with existing research on atypical social attention in ASD, suggesting its potential as a tool for early screening. The low-cost nature of the system addresses limitations of traditional methods and could improve accessibility to ASD screening, particularly in resource-limited settings.

While further research with larger and more diverse samples is needed to confirm these findings and explore the system's diagnostic accuracy, this study presents a promising step forward. A cost-effective eye-tracking system could potentially become a valuable tool for facilitating early detection of ASD, enabling timely interventions that can significantly improve outcomes for individuals on the spectrum.

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