

Characteristics and Significance of Binocular Fixation Point Separation in Visually Normal Children with Autism: Postprint

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Abstract

The distance between external points of regard corresponding to retinal images, namely the distance of binoculars point of regard (DBPR), demonstrates abnormal manifestations in individuals with autism spectrum disorders (ASD), while these individuals exhibit a higher incidence of strabismus that may influence their DBPR. This study employed a sinusoidal smooth pursuit task paradigm to investigate the diagnostic significance of DBPR in visually normal ASD children during dynamic stimulus processing. The results revealed that DBPR was excessively large in ASD children and exhibited cross-task stability, independent of strabismus. DBPR demonstrated excellent discriminative power under conditions of large amplitude and high velocity, and was significantly positively correlated with the total score of the Autism Behavior Checklist as well as the sensory perception dimension. These findings indicate that the distance of binoculars point of regard possesses good diagnostic value.

Full Text

Characteristics and Significance of Binocular Point of Regard Distance in Children with Autism Spectrum Disorder and Normal Vision

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Abstract

The distance between external fixation points corresponding to retinal images, known as the distance of binocular point of regard (DBPR), exhibits abnormal patterns in individuals with autism spectrum disorder (ASD). However, the high comorbidity of strabismus in ASD populations may confound DBPR measurements. This study employed a sinusoidal smooth pursuit task paradigm to investigate the discriminative significance of DBPR in visually normal children with ASD during dynamic stimulus processing. The results revealed that children with ASD exhibited significantly larger DBPR values that remained stable across task types and were independent of strabismus status. DBPR demonstrated excellent discriminative power under conditions of large amplitude and high velocity, and was significantly positively correlated with total scores on the Autism Behavior Checklist as well as the sensory perception dimension. These findings indicate that binocular point of regard distance holds substantial value as a discriminative indicator for ASD.

Keywords: autism spectrum disorder; smooth pursuit task; distance of binocular point of regard

Classification Number: R395

Introduction

Epidemiological data indicate a significant increase in the prevalence of autism spectrum disorder (ASD) in the 21st century. The Autism and Developmental Disabilities Monitoring Network reported that the prevalence of ASD in the United States rose from 14.7‰ to 16.9‰ in 2014, representing a 15% increase from 2012 and shifting the ratio from 1 in 68 children to 1 in 59 children (Baio et al., 2018). While nationwide epidemiological data for ASD are not yet available in China, a meta-analysis revealed a prevalence of 3.51‰ among children aged 0–6 years between 2011–2015, with a male-to-female ratio of 2.59:1 (Shi et al., 2017). This rising prevalence underscores the urgent need for more precise early diagnostic tools to guide effective intervention and evaluation.

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V; American Psychiatric Association, 2013) emphasizes the diagnostic importance of atypical sensory-perceptual functioning in ASD. Current early diagnosis relies heavily on clinicians' extensive experience combined with validated diagnostic instruments, yet misdiagnosis and missed diagnoses remain common. This limitation stems primarily from the subjective nature of the diagnostic process, particularly when parents serve as informants, as their reports may be susceptible to halo effects that reduce diagnostic validity (Frazier et al., 2016). Consequently, more objective metrics are needed to accurately capture the core features of the disorder and provide effective guidance for early screening and intervention.

Eye-tracking technology offers significant advantages for studying psychological processes and brain activity characteristics in individuals with ASD (Falck-Ytter,

Bölte, & Gredebäck, 2013). Compared to other psychophysiological measures such as biofeedback or electrodermal activity, eye-tracking is non-invasive and does not require wearing external equipment, substantially increasing participant comfort—a particularly important consideration for individuals with ASD who often have sensory sensitivities. Numerous studies have demonstrated that eye-tracking features can complement clinical diagnosis by providing more objective, quantitative indices of visual abnormalities (Falck-Ytter, Carlström, & Johansson, 2015; Moriuchi, Klin, & Jones, 2017).

Research has consistently shown that individuals with ASD across different ages and symptom severity levels exhibit atypical sensory processing (Baum, Stevenson, & Wallace, 2015; Leekam et al., 2007), with visual differences emerging as reliable early indicators for ASD identification (Wass et al., 2015). Previous research has primarily focused on visual avoidance of social stimuli and visual preference patterns, using reduced attention to social stimuli and increased attention to non-social stimuli as diagnostic markers (Pierce et al., 2016). However, these findings require further validation. First, such gaze patterns may represent alternative manifestations of social avoidance, and metrics like fixation duration and count cannot fully explain the underlying causes of visual preferences or elucidate the specific neurophysiological deficits. Second, while social stimuli enhance ecological validity, their complexity is difficult to control systematically. Studies have confirmed that children with ASD show preferences for non-social stimuli (Moore et al., 2018), and that their preference for repetitive motion in non-social stimuli correlates positively with restricted and repetitive behaviors (Wang et al., 2018). Therefore, we employed non-social stimuli to explore novel eye-tracking metrics for ASD identification.

Previous research indicates that the distance of binocular point of regard (DBPR) in children with ASD is significantly greater than that in typically developing (TD) children (Chen, Chen, & Zhao, 2016; Gao, Chen, & Lin, 2017), a pattern that also emerges in contexts involving social stimuli (Li, 2017). During eye-tracking calibration phases, children with ASD frequently exhibit large positioning deviations for calibration targets, and demonstrate difficulty effectively tracking visual targets during smooth pursuit tasks (Takarae, Luna, Minshew, & Sweeney, 2008). Neurobiological evidence confirms that individuals with ASD experience early difficulties in magnocellular and parvocellular information transfer, which affects information reception and processing in primary (V1) and secondary (V2) visual cortices (McCleery et al., 2007). Poor performance on smooth pursuit tasks in ASD may result from weakened functional connectivity between V1 and the inferior frontal gyrus (Villalobos et al., 2005). However, few studies have examined the characteristics of DBPR in children with ASD during smooth pursuit tasks. Therefore, we investigated whether DBPR differs between children with ASD and TD children during target tracking and further examined the influencing factors and discriminative significance of DBPR.

Research indicates that DBPR is affected by strabismus. A clinical study using

eye-tracking to identify strabismus found that patients diagnosed with exotropia exhibited significantly larger DBPR than visually normal individuals (Saisara, Boonbrahm, & Chaiwiriya, 2017). Therefore, when considering DBPR as a diagnostic marker for ASD, it is essential to ensure the absence of strabismus. Studies have reported strabismus prevalence rates of 26.9% and 40% in ASD populations (Kabatas et al., 2015; Ikeda et al., 2013), with strabismus causing target localization errors and impairing hand-eye coordination in various real-world tasks (Lemer, 2009). However, whether the characteristic DBPR pattern in children with ASD is related to their high comorbidity of strabismus remains inconclusive.

In summary, this study aims to provide objective and stable indices for early diagnosis and intervention by comparing DBPR characteristics and influencing factors between TD children and children with ASD. The existing literature has predominantly focused on high-functioning individuals with ASD, reflecting an asymmetry in ASD research populations. As ASD represents a multidimensional spectrum disorder, increased research on low-functioning children with ASD is necessary (Chakrabarti, 2017). Young, low-functioning children with ASD often lack language abilities, making complex experimental procedures challenging (Eagle, 2002). However, their symptom presentation may be more representative, and their eye-tracking data hold important diagnostic value (Chen, 2017). Moreover, early developmental indicators are clinically meaningful for early detection and intervention, directly influencing treatment outcomes. Accordingly, we designed an experiment in which participants viewed six smooth pursuit videos while we recorded binocular gaze data from children with ASD and TD children.

Given that individuals with strabismus cannot perform coordinated binocular movements, resulting in significant differences between the distances of each eye's fixation point to the target, we screened our ASD sample to exclude strabismus. We hypothesized that: (1) Children with ASD would show no difference in positional error between left and right eyes relative to the target during smooth pursuit tasks, indicating coordinated binocular movement; (2) DBPR would be larger in children with ASD compared to TD children, with discriminative power influenced by amplitude and velocity—specifically, higher speeds and larger amplitudes would yield greater discriminative power, given the documented relationship between tracking deficits, longer saccadic latencies, and target motion characteristics; and (3) DBPR would correlate significantly with atypical sensory-perceptual functioning in children with ASD, as vision represents the most typical and readily observable manifestation of such abnormalities.

Methodology

Participants

Sample size was calculated using G*Power software, which indicated that 48 total participants were needed to detect a medium effect size (0.25) in a priori power analysis. Considering the unique challenges of working with children with ASD, we recruited 30 children from autism rehabilitation centers, five of whom were excluded due to inability to complete the task because of wandering or crying behaviors. The final sample comprised 25 children with ASD (21 boys, 4 girls) aged 3–5 years ($M = 3.72$, $SD = 0.74$). All participants were free of organic diseases and had received a professional diagnosis of ASD by a psychiatrist according to DSM-V criteria. Diagnoses were confirmed using the Childhood Autism Rating Scale (CARS; Schopler et al., 1980), with all participants scoring above 30. The study was approved by the ethics committee, and parents provided informed consent after receiving detailed information about the procedures. Parents completed the Autism Behavior Checklist (ABC; Krug, Arick, & Almond, 1980), with all participants scoring above 53.

Twenty-five age- and gender-matched TD children were recruited from local kindergartens (21 boys, 4 girls) aged 3–5 years ($M = 3.78$, $SD = 0.79$), with no history of organic disease or psychiatric disorders. Due to language and comprehension impairments in young, low-functioning children with ASD, intelligence matching was not feasible. All participants had normal or corrected-to-normal vision.

Experimental Materials

The experimental stimuli consisted of six videos featuring a black sphere (radius = 25 pixels) moving against a white background. Using a planar coordinate system with the screen's upper-left corner as the origin (0, 0), the x-axis extending rightward and y-axis extending downward, the sphere's initial coordinates were (349, 525). The sphere moved left-to-right along a sinusoidal trajectory covering 984 pixels horizontally. Based on previous research indicating that tracking performance in ASD and typical individuals is not differentially affected by target velocities above $8^\circ/s$ (Takarae et al., 2004), we set horizontal velocities at $2.5^\circ/s$, $5^\circ/s$, and $7.5^\circ/s$. Vertical motion consisted of three cycles of simple harmonic motion with amplitudes of 68 pixels (small) and 205 pixels (large). Six videos were created using a 3 (velocity) \times 2 (amplitude) factorial design. Example trajectories are shown in Figure 1 [Figure 1: see original paper].

Apparatus and Procedure

An SMI RED500 remote eye-tracking system with iView X software and Experiment Center was used to present video materials and record data. The system was controlled by a laptop computer with a display resolution of 1680×1050 pixels. The eye-tracker has an accuracy of 0.5° and a sampling rate of 500 Hz, with binocular coordinate data recorded separately. Calibration was performed

using a white ball with a beating red heart, with fixation defined as sustained gaze within 1° visual angle for at least 100 ms.

A 2 (group: ASD, TD) × 3 (velocity: 2.5°/s, 5°/s, 7.5°/s) × 2 (amplitude: 68 pixels, 205 pixels) mixed design was employed, with group as a between-subjects factor and velocity/amplitude as within-subjects factors. Dependent variables were DBPR and positional error during target tracking.

Two experimenters conducted the procedure: one operated the computer while the other explained the task. The experimental protocol is illustrated in Figure 2 [Figure 2: see original paper]. Testing occurred in a quiet, well-lit environment with parental assistance. Participants sat 60 cm from the screen, either on a chair or on their parent's lap, and were tested individually. No responses or judgments were required during stimulus viewing.

Analysis Metrics

Raw gaze coordinate data were recorded, including horizontal (PRX) and vertical (PRY) point-of-regard coordinates. The primary analysis metric was root-mean-square error (RMSE), representing cumulative error between gaze position and target position during tracking. This index reflects the correspondence between binocular position and target motion, with values indicating tracking accuracy (Gooding, Miller, & Kwapil, 2000). Unlike previous studies that averaged binocular coordinates before calculating RMSE (Valakos et al., 2018), we calculated RMSE separately for each eye to verify whether strabismus affected tracking accuracy. RMSE was computed as the square root of the mean squared deviations, where d_t represents the distance from a recorded gaze point to the target center, n represents the number of recordings, (x_t, y_t) represents gaze position, and (x_{0t}, y_{0t}) represents target position:

$$\text{RMSE} = \sqrt{\frac{\sum d_t^2}{n}}$$

$$d_t = \sqrt{(x_t - x_{0t})^2 + (y_t - y_{0t})^2}$$

Additionally, we calculated the distance between left and right eye fixation points on the screen (DBPR) to reflect binocular coordination during tracking. DBPR was computed using the distance formula, where R denotes the right eye and L denotes the left eye:

$$\text{DBPR} = \sqrt{(\text{PRX}_R - \text{PRX}_L)^2 + (\text{PRY}_R - \text{PRY}_L)^2}$$

Data Processing

Matlab 2016b was used to calculate RMSE and DBPR values, which were then imported into SPSS 21.0 for data organization and analysis.

Results

Positional Error of Average Binocular Fixation Points

Descriptive statistics for binocular positional error across the six conditions are presented in Figure 3 [Figure 3: see original paper]. Significant group differences were found in all conditions except the small amplitude, 2.5°/s condition, with TD children demonstrating more precise tracking of the sphere's position.

A two-way mixed-effects model revealed a significant main effect of group, $F(1, 48) = 23.30$, $p < 0.001$, $p^2 = 0.33$, indicating that children with ASD exhibited significantly greater tracking error than TD children. The main effect of amplitude was also significant, $F(1, 48) = 46.60$, $p < 0.001$, $p^2 = 0.49$, showing that positional error increased with larger movement amplitudes. The main effect of velocity was not significant, $F(2, 96) = 2.68$, $p = 0.074$. No significant interactions were observed between group and amplitude, $F(1, 48) = 0.40$, $p = 0.532$; group and velocity, $F(2, 96) = 0.16$, $p = 0.851$; velocity and amplitude, $F(2, 96) = 2.87$, $p = 0.062$; or among all three factors, $F(2, 96) = 0.98$, $p = 0.379$.

Positional Error of Left and Right Eyes

Descriptive statistics for left and right eye positional errors across the six conditions are presented in Figures 4 [Figure 4: see original paper] and 5 [Figure 5: see original paper]. Significant group differences were found in all conditions except the small amplitude, 2.5°/s condition for both eyes.

Separate two-way mixed-effects models for each eye revealed significant main effects of group: left eye, $F(1, 48) = 29.37$, $p < 0.001$, $p^2 = 0.38$; right eye, $F(1, 48) = 27.26$, $p < 0.001$, $p^2 = 0.36$, confirming greater tracking errors in children with ASD. Amplitude showed significant main effects for both eyes: left eye, $F(1, 48) = 7.08$, $p = 0.01$, $p^2 = 0.13$; right eye, $F(1, 48) = 10.48$, $p = 0.002$, $p^2 = 0.18$. Velocity main effects were not significant for either eye: left eye, $F(2, 96) = 3.14$, $p = 0.052$; right eye, $F(2, 96) = 2.01$, $p = 0.146$. No significant interactions were found between group and amplitude, group and velocity, velocity and amplitude, or among all three factors for either eye (all $p > 0.05$).

Differences in DBPR Between Groups

Descriptive statistics for DBPR across the six conditions are presented in Table 1 and Figure 6 [Figure 6: see original paper].

A two-way mixed-effects model revealed a significant main effect of group, $F(1, 48) = 30.96$, $p < 0.001$, $p^2 = 0.39$, confirming larger DBPR in children with ASD. The main effect of velocity was significant, $F(2, 96) = 20.27$, $p < 0.001$, $p^2 = 0.30$, and the group \times velocity interaction was also significant, $F(2, 96) = 4.60$, $p = 0.012$, $p^2 = 0.09$. Simple effects analysis showed significant group differences in DBPR across all three velocity conditions ($p < 0.001$). For children with ASD, DBPR differed significantly across velocities, with post-hoc comparisons

revealing that DBPR at 2.5°/s was significantly lower than at 5°/s ($p < 0.001$) and 7.5°/s ($p < 0.001$), while the latter two did not differ significantly ($p = 0.258$). For TD children, DBPR did not differ significantly across velocities ($p = 0.087$), indicating differential velocity effects between groups.

The main effect of amplitude was not significant, $F(1, 48) = 2.43$, $p = 0.126$, nor were the group \times amplitude interaction, $F(1, 48) = 1.88$, $p = 0.177$; velocity \times amplitude interaction, $F(2, 96) = 0.08$, $p = 0.921$; or the three-way interaction, $F(2, 96) = 1.61$, $p = 0.205$.

ROC Analysis of DBPR in Children with ASD

ROC (receiver operating characteristic) analysis was conducted to evaluate DBPR' s diagnostic utility. This method calculates sensitivity and specificity at various threshold values, plotting sensitivity against (1–specificity). Larger area under the curve (AUC) indicates greater diagnostic accuracy (Zhang & Yan, 2004). Results (Figure 7 [Figure 7: see original paper], Table 2) showed that discriminative power was greatest under large amplitude, 7.5°/s conditions, followed by 5°/s conditions. Across both amplitude levels, 7.5°/s velocity yielded the highest discriminative power, with other velocities showing progressively lower values. According to Zhang and Yan (2004), AUC values above 0.9 indicate high discriminative value. Therefore, DBPR showed high discriminative value under large amplitude conditions at both 7.5°/s and 5°/s velocities, with moderate discriminative value under other conditions.

Correlation Between DBPR and ABC Scale in Children with ASD

Pearson correlation analysis examined relationships between DBPR and ABC total scores and subscales (Table 3). DBPR correlated significantly with ABC total scores and the sensory perception dimension across all velocity and amplitude conditions. Within both amplitude levels, correlations with total scores were higher at 2.5°/s and 7.5°/s than at 5°/s. Under small amplitude, 2.5°/s conditions, DBPR correlated significantly with the social interaction, language, and self-care dimensions. Under small amplitude, 7.5°/s and large amplitude, 2.5°/s conditions, DBPR correlated significantly with social interaction and self-care dimensions. Under large amplitude, 7.5°/s conditions, DBPR correlated significantly only with the self-care dimension. No significant correlations were found between DBPR and the body movement dimension across any condition.

Discussion

Characteristics of Left and Right Eye Movements During Smooth Pursuit in Children with ASD

Eye-tracking systems record fixation coordinates in two ways: averaging binocular coordinates into a single point (commonly used in previous studies for calculating positional error and gain values; Valakos et al., 2018), or record-

ing separate coordinates for each eye to indirectly assess binocular coordination (Wu et al., 2018). Given the documented left visual field bias and strabismus in ASD, we used separate raw coordinates for each eye to investigate whether children with ASD could coordinate binocular movements to track targets. Results showed that children with ASD demonstrated poor precise localization ability, with more fixation points deviating from the target trajectory during tracking. They experienced difficulty maintaining attention, frequently exhibiting sudden head turns, eye closures, and other behaviors that caused large deviations from the target trajectory and indirectly increased positional error. In contrast, TD children could effectively track the target throughout the task, with only typical blink reflexes interrupting pursuit.

Positional error was smaller under small amplitude than large amplitude conditions, consistent with our hypothesis. Under normal circumstances, target amplitude affects the initiation of pursuit, with larger tracking ranges increasing task difficulty (Chen, Lin, & Ren, 2017). Children with ASD showed significantly greater left and right eye positional errors than TD children across both amplitude conditions, yet the difference in positional error between eyes was not significant, confirming that their binocular movements were coordinated. The non-significant amplitude \times group interaction suggests similar tracking patterns across amplitude conditions for both groups.

Overall, children with ASD exhibited poorer tracking performance and greater positional errors than TD children across all conditions. This impairment was not attributable to strabismus or left visual field bias. Strabismus, including esotropia and exotropia, produces homonymous or heteronymous diplopia and visual spatial distortions (Zhang, 1993), characterized by significant differences in the distance from each eye's fixation point to the actual target. However, our findings revealed no significant differences between left and right eye distances to the target in children with ASD. Therefore, excluding attention and hyperactivity confounds, our ASD sample did not exhibit strabismus, engaged in coordinated binocular movements, and their large positional errors were unrelated to strabismus.

Influencing Factors and Potential Mechanisms of DBPR in Smooth Pursuit in Children with ASD

Group differences in DBPR were significant, with children with ASD showing markedly larger values than TD children, consistent with previous research and demonstrating cross-task stability. The significant main effect of velocity indicated that DBPR increased with target speed, while the significant group \times velocity interaction revealed differential velocity effects between groups.

Interestingly, the non-significant main effect of amplitude suggested that DBPR did not vary with amplitude changes. This may relate to impaired visual attention shifting and disengagement in ASD (Liang, 2015), where fixation points fail to shift from previous target locations, increasing target positional error

without substantially changing interocular distance. Indeed, we frequently observed children with ASD's fixation points briefly remaining at locations the sphere had passed before resuming pursuit, explaining why positional error was amplitude-sensitive while DBPR was not. The absence of other significant interactions indicates that velocity was the primary factor affecting DBPR during smooth pursuit, consistent with previous findings (Gao et al., 2017). Faster target motion reduces the time available for coordinating binocular movements, resulting in larger DBPR values.

The mechanism underlying excessive DBPR in ASD may involve greater reliance on “bottom-up” visual processing, consistent with weak central coherence theory (Lawson, Rees, & Friston, 2014). Research suggests that holistic dynamic target processing depends on task speed and duration (Hadad et al., 2015), and children with ASD may be unable to simultaneously optimize pursuit speed and retinal image stability, resulting in persistent ineffective tracking that reflects fundamental visual processing deficits. Studies indicate that while typical individuals focus on central visual stimuli, those with ASD attend more to peripheral information (Rutherford et al., 2007), preventing effective processing of critical visual information. Atypical visual functioning in ASD is closely linked to abnormal brain structure and function. Poor dynamic visual accuracy and susceptibility to interference in ASD have been associated with abnormal cerebellar-brainstem circuits (Schmitt et al., 2014). Another potential mechanism involves enhanced attentional blink effects in ASD, resulting in greater temporal “blindness” (Amirault et al., 2009). This causes stimuli to be perceived as appearing in discrete episodes rather than continuously, leading to fluctuations in DBPR—decreasing when targets are attended and increasing when they are not.

Discriminative Significance of DBPR in Smooth Pursuit in Children with ASD

DBPR demonstrated discriminative power across all six conditions, with the highest discriminative value observed under large amplitude, $7.5^\circ/\text{s}$ conditions, decreasing progressively with reduced velocity. Under large amplitude conditions at both $5^\circ/\text{s}$ and $7.5^\circ/\text{s}$ velocities, discriminative power exceeded 0.9, indicating high diagnostic value. These results demonstrate that smooth pursuit task stimuli can serve as effective diagnostic materials for identifying visual abnormalities in children with ASD. As non-social stimuli, they offer advantages of simple implementation, easy acquisition, standardized structure, and straightforward comparability (Frazier et al., 2017).

Current ASD diagnosis remains largely dependent on subjective clinical judgment. While diagnostic scales demonstrate high reliability and validity, their administration is susceptible to halo effects, and uncertainty in assessing symptom severity increases misdiagnosis risk. In contrast, eye-tracking technology is increasingly accepted as an effective diagnostic tool, providing objective, ecologically valid data suitable for qualitative research and longitudinal comparison

with minimal data loss (Deng, 2005). While the generalizability of DBPR' s discriminative value across contexts requires further validation and its clinical applicability needs exploration, identifiable endophenotypes can effectively reveal pathological mechanisms underlying ASD, which is crucial for intervention and classification (Kumazaki et al., 2018). DBPR shows considerable potential as a candidate biomarker and endophenotype for early clinical identification of ASD.

This study focused exclusively on DBPR' s discriminative significance because DBPR was our primary variable of interest, while positional error served to verify the absence of strabismus. Additionally, ROC analysis of positional error revealed lower discriminative power compared to DBPR, further establishing DBPR' s superior diagnostic value.

Correlation Between DBPR and ABC Scale in Children with ASD

Given DBPR' s superior discriminative properties, we examined its relationship with the ABC scale. Results showed significant positive correlations between DBPR and ABC total scores and the sensory perception dimension across all velocity and amplitude conditions. Correlations with total scores were highest at 2.5°/s and 7.5°/s velocities within both amplitude levels. Under small amplitude, 2.5°/s conditions, DBPR correlated significantly with social interaction, language, and self-care dimensions. Under small amplitude, 7.5°/s and large amplitude, 2.5°/s conditions, DBPR correlated significantly with social interaction and self-care dimensions. Under large amplitude, 7.5°/s conditions, DBPR correlated significantly only with the self-care dimension. No significant correlations emerged between DBPR and the body movement dimension.

The highest correlation with sensory-perceptual symptoms occurred under low velocity, small amplitude conditions. However, children with ASD exhibited more head-turning and body movements under these conditions, with greater difficulty maintaining attention, potentially confounding DBPR results. The validity of these specific findings may therefore be questionable. In contrast, under high velocity, large amplitude conditions, fast-moving targets captured and sustained attention more effectively in children with ASD, making DBPR differences more representative. Overall, DBPR as a potential diagnostic indicator reflects the atypical sensory-perceptual characteristics of children with ASD. Parents and caregivers most readily observe these sensory abnormalities in daily life (Baum et al., 2015; Marco et al., 2011), such as prolonged staring at rotating objects or hypersensitivity to bright light. The inclusion of sensory-perceptual abnormalities as diagnostic criteria in DSM-V underscores their importance, and DBPR may serve as a valuable auxiliary diagnostic index for these features.

Limitations and Future Directions

This study examined DBPR characteristics in children with ASD using smooth pursuit tasks to assess its clinical diagnostic utility. Several limitations warrant

consideration. First, we did not examine DBPR across different age groups, though visual development varies across childhood (Mayer & Dobson, 1982; Aring et al., 2007). Since ASD diagnosis in China is typically confirmed at age 3, we did not investigate visual characteristics in children under 3, preventing developmental validation of our findings. Future research should examine younger children to explore age-related DBPR development and provide earlier diagnostic markers.

Second, our sample comprised low-functioning children with ASD, making intelligence matching impractical. However, intelligence level may influence results (Chita-Tegmark, 2016; Frazier et al., 2017). Additionally, we did not examine whether high-functioning children with ASD exhibit similar visual deficits. High-functioning individuals with better language abilities can complete intelligence assessments, allowing investigation of the relationship between intelligence and DBPR. Future research should include high-functioning children with ASD to enable accurate assessment of disease severity and treatment outcomes, facilitating disease classification and effective early intervention implementation.

Conclusion

Children with ASD exhibit binocular vision deficits unrelated to strabismus, manifested as excessive DBPR. DBPR demonstrates the highest discriminative value under large amplitude, high velocity conditions and effectively reflects sensory-perceptual abnormalities in ASD. These findings support DBPR as a promising objective marker for early identification and intervention planning.

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