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The Impairment Attention Capture by Topological Change in Children With Autism Spectrum Disorder*

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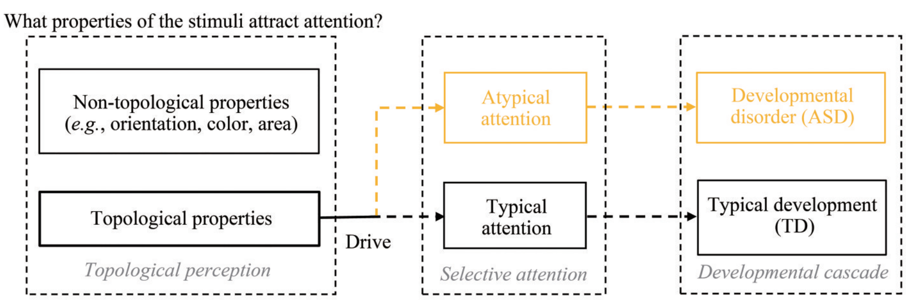
Graphical abstract



Abstract **Objective** Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by difficulties with communication and social interaction, restricted and repetitive behaviors. Previous studies have indicated that individuals with ASD exhibit early and lifelong attention deficits, which are closely related to the core symptoms of ASD. Basic visual attention processes may provide a critical foundation for their social communication and interaction abilities. Therefore, this study explores the behavior of children with ASD in capturing attention to changes in topological properties. **Methods** Our study recruited twenty-seven ASD children diagnosed by professional clinicians according to DSM-5 and twenty-eight typically developing (TD) age-matched controls. In an attention capture task, we recorded the saccadic behaviors of children with ASD and TD in response to topological change (TC) and non-topological change (nTC) stimuli. Saccadic reaction time (SRT), visual search time (VS), and first fixation dwell time (FFDT) were used as indicators of attentional bias. Pearson correlation tests between the clinical assessment scales and attentional bias were conducted. **Results** This study found that TD children had significantly faster SRT ($P<0.05$) and VS ($P<0.05$) for the TC stimuli compared to the nTC stimuli, while the children with ASD did not exhibit significant differences in either measure ($P>0.05$). Additionally, ASD children demonstrated significantly less attention towards the TC targets (measured by FFDT), in comparison to

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TD children (P<0.05). Furthermore, ASD children exhibited a significant negative linear correlation between their attentional bias (measured by VS) and their scores on the compulsive subscale (P<0.05). **Conclusion** The results suggest that children with ASD have difficulty shifting their attention to objects with topological changes during change detection. This atypical attention may affect the child's cognitive and behavioral development, thereby impacting their social communication and interaction. In sum, our findings indicate that difficulties in attentional capture by TC may be a key feature of ASD.

Key words attention, autism spectrum disorder, perceptual object, topological perception

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Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by impairments in social communication, restricted and repetitive behaviors[1]. Attention abnormalities have also been closely linked to the core symptoms of ASD[2-8]. Furthermore, individuals with ASD demonstrate attentional difficulties that are both early-onset and persistent[9-13]. More significantly, researchers discovered that abnormal attention may be used as a preliminary behavioral indicator for identifying infants potentially at risk for autism[9, 13].

Social attention and non-social attention are the two main categories of attentional impairments in ASD research. Disinterest in social stimuli, such as social avoidance[14-15], abnormal face processing[16], and abnormal joint attention[17] is a sign of social attentional disorders in ASD. Individuals with ASD not only have difficulties in the social domain but also show signs of atypical domain-general attention, which include slower attentional disengagement and shifting[18-19] as well as enhanced performance in visual search tasks[20-22]. Earlier non-social information processing may influence the late phases of the cognitive process, particularly during the middle and late stages of individual growth, when higher-level social information processing occurs[20, 23]. Moreover, attention deficits in non-social information processing among individuals with ASD may reduce their interest in social information, which in turn may deteriorate abnormal attention to social interaction[24]. Therefore, investigating the mechanisms of non-social attention in individuals with ASD becomes crucial[25].

Visual attention selects the information most relevant to the current cognitive behavior for further processing. It is considered to be regulated by two different mechanisms: bottom-up attention, which is automatically driven by the properties of the stimuli; and top-down attention, which involves attention assignment based on the current goal or task demands. Visual orientation requires the integration of top-down or bottom-up attention mechanisms[26], which was also true for visual search. Neuroimaging evidence indicates that both visual orientation and visual search, which involve the allocation and shift of attention, engage similar brain activation regions[27-30]. Nonetheless, in these two visual tasks, the attentional effects observed in ASD participants showed contrasting results. On one hand, deficits in attentional disengagement and shifting have been widely reported in ASD individuals[31-34]. On the other hand, the visual search advantage in ASD individuals has also demonstrated by numerous studies[20-22, 35-36]. Thus, reconciling the seemingly incongruous findings of deficits in visual orientation with the superior in visual search remains a challenge. We believe that the application of inconsistent paradigms, along with conflicting theories of attention, may be directly contributing to this discrepancy.

Although there are various theories about attentional capture, it is widely accepted that the abrupt appearance of a new perceptual object typically captures attention[37]. The topological perception theory proposed by Chen *et al.*[38-41] argues that the notion of a perceptual object is its holistic identity preserved over shape-changing transformations. This identity can be characterized precisely as topological invariance[40-41]. Topology, also known as "rubber-sheet geometry", describes the invariant characteristics of geometric shapes across continuous deformations, such as stretching, bending, twisting, and shrinking but disallowing tearing apart or gluing together parts[42]. Under this kind of "rubber-sheet" deformation, the properties that remain unchanged, such as connectivity, the number of holes, and the inside/outside relationship, are topologically invariant properties[41]. According to the topological approach to perceptual object, topological invariant transformation (*e. g.*, orientation, size, and shape) neither creates nor destroys an object. Therefore, one of its implications is that transformation with topological change (*e. g.*, the number of holes) captures attention by introducing a new object or eliminating an existing object. This capability of topological changes to attract attention can be independent of the individual's intent, and can even prioritize over top-down attention[43]. We thus assumed that the lack of sensitivity to detect topological change in children with ASD, leads their difficulties in attention shifting.

We used a change detection task that required participants to identify changes within a stimulus array. The change detection test, combining the overlap task with the simple feature search task, facilitates the examination of attention allocation and shifting within the same activity. To test our hypothesis, we recruited children with ASD and neurological typical age-matched controls to perform the change detection task, with their eye movements being recorded.

1 Materials and methods

1.1 Participants

Two groups of participants were involved in our study: 35 children with ASD, aged 3−13 years old, and 28 typically developing (TD) children, aged 5−6 years old. The ASD children were recruited from the Anhui Disabled Persons' Federation and Hefei Kanghua Hospital in China. Eight ASD children were excluded from the analysis because they were uncooperative during the cognitive assessment or had poor eye movement performance, resulting in a final sample of 27 children with ASD (6 females, 21 males). The TD children were recruited from kindergartens affiliated with Anhui Medical University, China. Detailed participants' characteristics can be found in Table 1.

All children with ASD were diagnosed by professional clinicians according to DSM-5[44], and psychiatric and neurological disease, as well as other comorbid factors were excluded. The two groups of children both had normal or corrected to normal vision. None of the TD children had been diagnosed with a psychiatric or neurological disorder. This study was approved by the Ethics Committee of Anhui Medical University (81220126). We obtained written consent from the parents of all children.

Table 1 Demographic information and clinical measures

	ASD (*n*=27)	TD (*n*=28)	*P* value
Age/years	5.9±2.3	5.4±0.5	0.298
Gender (male/female)	21/6	15/13	0.059
ABC total score	41.3±19.4	–	–
SRS total score	79.5±16.4	–	–
RBS-R total score	14.6±11.6	–	–
Stereotype	3.0±2.6	–	–
Self-injurious	0.6±0.9	–	–
Compulsive	2.1±2.6	–	–
Ritualistic	2.7±2.8	–	–
Repetitive	3.6±3.7	–	–
Restricted	2.5±.2.8	–	–

ABC: Autism Behavior Checklist; SRS: Social Responsiveness Scale; RBS-R: Repetitive Behavior Scale-Revised.

1.2 Stimuli and apparatus

The stimuli consisted of geometric shapes (each 2°×2°) and cartoon pictures (2°×2.6°; Figure S1). The cartoon pictures were used as the central fixation points. The pre-display array included four disks, positioned at the top, bottom, left, and right of the screen (Figure 1). The distance from the center of fixation point to the center of each disk was 8°. The target-display array was identical to the pre-display array, except that a target stimulus could appear in any of the four disks.

In this study, we used iView X high-speed eye-tracking device (Senso Motoric Instruments, Germany) to record participants' eye movements. The stimuli were presented on a 30-inch monitor with a resolution of 1 680×960 pixels and a refresh rate of 250 Hz.

1.3 Procedure

The experiment comprised two phases: an eye-tracking test and a cognitive assessment. In the phase of the eye-tracking test, participants were required to complete a change detection task while sitting in front of the eye tracker monitor at a distance of approximately 65 cm. During the cognitive assessment phase, participants were evaluated for autistic traits.

1.3.1 Change detection task

After a successful 5-points binocular calibration was achieved, the change detection task started (Figure 1). The task consisted of two types of trials: topological change (TC) and non-topological change (nTC) trials. Each trial started with a fixation, which was presented for 800 ms followed by the pre-display array. The presentation of the pre-display array was terminated by the experimenter's keyboard press or after 5 000 ms. When participants' eyes position consistently fell within a circle with a radius of 1.8° from the center of the fixation point for at least 500 ms, the experimenter pressed the keyboard to switch from the pre-display array to the target display array, which was presented for 2 000 ms. The change detection task consisted of 4 practice trials and 16 test trials, with a total experimental duration of about 3 min. The test trials were randomized across participants. The participants were asked to look for the stimulus (target) in the target-display array that was different from the others.

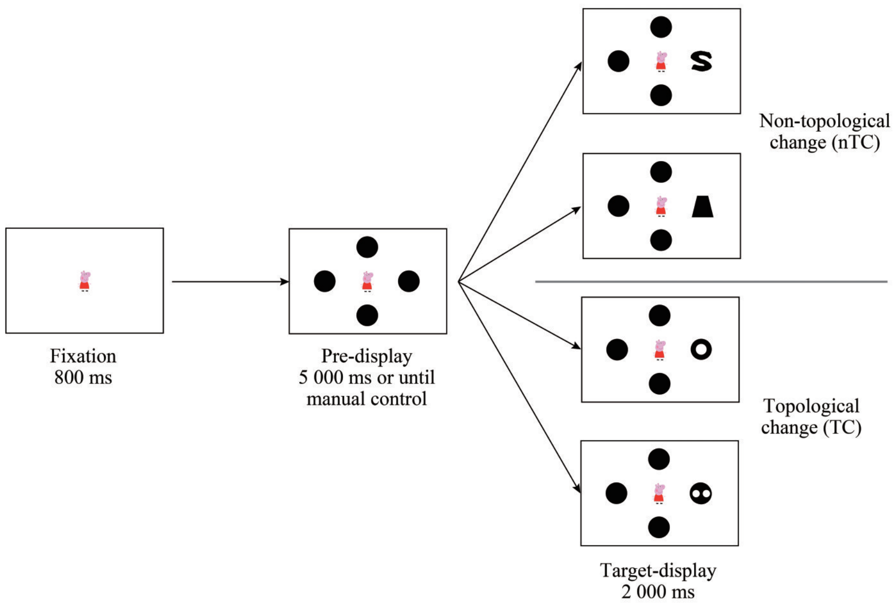

Fig. 1　Stimuli and procedure of change detection task

The presentation of the pre-display array was terminated by experimenter's manual control or after 5 000 ms. Participants were required to look toward the target shape in target-display. The cartoon picture is used as fixation point.

1.3.2　Psychological cognitive assessments

The Chinese version of Autism Behavior Checklist (ABC[45]), Repetitive Behavior Scale-Revised (RBS-R[46]), and Social Responsiveness Scale (SRS[47]) were administered to parents or daily caregivers as a measure of autistic traits. The ABC has 57 items divided into five subscales: sensory (S), social (R), motor (B), verbal communication (L), and social adaptation (S1). The RBS-R is a 43-item parental rating scale in which parents are instructed to rate how well each statement describes their child's behavior using a 4-point Likert scale[48]. The RBS-R contained 6 subscales, including stereotypic behavior, self-injurious behavior, compulsive behavior, ritualistic behavior, repetitive behavior, and restricted interests. The SRS is a widely used parent-report instrument assessing the severity of social impairment, which comprises 5 subscales: social awareness, social cognition, social communication, social motivation, and autistic behavior. A higher score on all these scales indicates more severe symptoms.

1.4　Data analysis

Two areas of interest (AOI) were defined prior to data analysis: the central AOI and the target AOI. The central AOI covered an area with a radius of 1.8°, centered on the fixation point. The target AOI was a trapezoidal area that enclosed the target shape (Figure 2).

Three independent saccadic variables involved in this study are as follows: (1) saccadic reaction time (SRT) is defined as the time difference between the target appeared and the onset of the first correct saccade; (2) visual search time (VS) refers to the interval between the target's appearance and the moment when participants' fixation point fell on the target AOI; (3) first fixation dwell time (FFDT) is calculated as the duration of the first fixation within the target AOI.

We conducted mixed model ANOVAs to analyze the effect of stimulus type (TC and nTC) and group (ASD and TD) on saccadic index (SRT, VS, and FFDT), the saccadic indices for the two groups under topological change and non-topological change conditions were detailed in Table 2. Besides, we performed the Pearson correlation to analyze the relationships between saccadic variables (SRT, VS, and FFDT) and clinical assessment scale (ABC, SRS, and RBS-R). All multiple comparisons were FDR corrected[49].

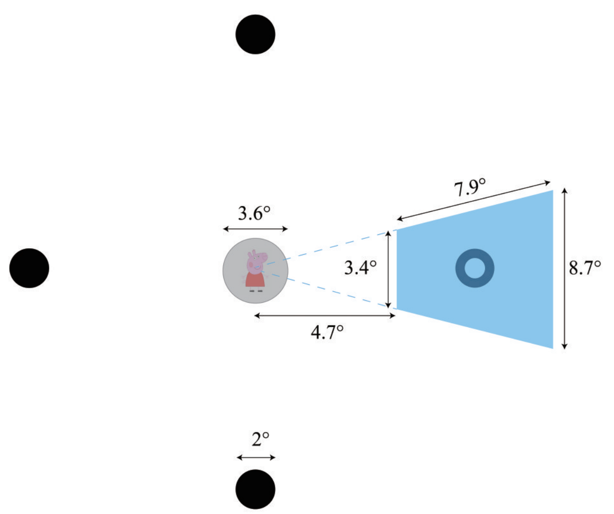

Fig. 2 Two areas of interest (AOI)

The gray circle represents the central AOI, and the blue trapezoid represents the target AOI.

2 Results

2.1 Saccadic reaction time (SRT)

We conducted a 2 (group: ASD, TD)×2 (stimulus type: TC, nTC) mixed-model repeated measures ANOVA on SRT data. The main effect of stimulus type was significant (F (1, 53)=5.486, P=0.023, η^2=0.094), indicating that participants respond faster to TC trials than to nTC trials. The main effect of group (F (1, 53)=0.179, P=0.674) and the interaction between group and stimulus type (F (1, 53)=0.215, P=0.645) were both non-significant. Additionally, a post-hoc paired t-test was performed for each group separately. We found a significant difference between TC and nTC for the TD children (t=−3.450, df=27, P=0.002, cohen's d=0.652), documenting a moderate effect of topological change on capturing participants' attention. This result echoed attentional capture effects in healthy adults[43]. However, we found no significant difference between TC and nTC in the ASD group (t=−1.013, df=26, P=0.320) (Figure 3a, Table 2). These data suggested that children with ASD do not exhibit an attention bias towards topological change compared to TD children.

2.2 Visual search time (VS)

We conducted a 2 (group: ASD, TD)×2 (stimulus type: TC, nTC) mixed-model repeated measures ANOVA on VS data. We found a significant main effect of group (F (1, 53)=5.499, P=0.023, η^2=0.094), indicating that ASD children had significantly slower search time compared to TD children. Besides, there was no significant main effect of stimulus type (F (1, 53)=1.971, P=0.166) or group×stimulus type interaction (F (1, 53)=0.600, P=0.442). Furthermore, we conducted a post-hoc paired t-test separately for each group. We discovered a significant difference between TC and nTC for the TD children (t=−2.123, df=27, P=0.043, cohen's d=0.401), indicating a moderate effect of topological change on capturing participants' attention. Nevertheless, there was no significant difference between TC and nTC in the ASD group (t=−0.362, df=26, P=0.720) (Figure 3b, Table 2). Our findings indicate that children with ASD don't exhibit either superior visual search or a detection advantage for topological changes.

2.3 First fixation dwell time (FFDT)

We conducted a 2 (group: ASD, TD) ×2 (condition: TC, nTC) mixed-model repeated measures ANOVA for FFDT data. The main effect of the group (F (1, 53)=3.565, P=0.065, η^2=0.063) was marginally significant, suggesting that ASD children had shorter fixation dwell times within the target AOI than TD children. Moreover, the interaction between group and stimulus type was significant (F (1, 53)=4.546, P=0.038, η^2=0.079). Post-hoc two-sample t-test showed that ASD children had shorter FFDTs within the TC target than TD children (t=−2.783, P=0.008, cohen's d=0.748) (Figure 3c). Furthermore, we conducted a post-hoc paired t-test separately for each group. We discovered a significant difference between TC and nTC for the TD children (t=2.171, df=27, P=0.039, cohen's d=0.410). However, no significant difference between TC and nTC was observed in the ASD group (t=−0.910, df=26, P=0.371) (Figure 3c, Table 2).

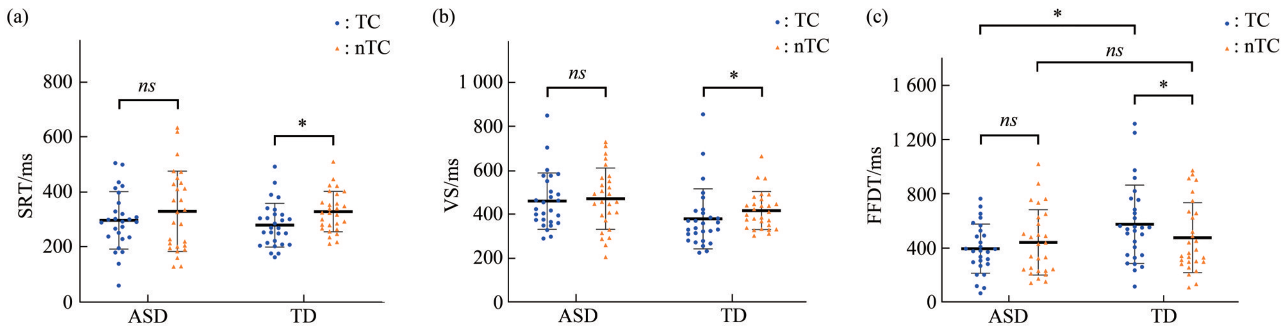

Fig. 3　Saccadic variables indices as a function of group (ASD, TD) and stimulus type (TC, nTC) in change detection task

(a) Scatterplot of saccadic reaction time (SRT) for the ASD and TD groups. (b) Scatterplot of visual search time (VS) for the ASD and TD groups. (c) Scatterplot of first Fixation dwell time (FFDT) for the ASD and TD group. The horizontal line in bold black represents the mean, and the error bar represents the standard deviation. TC: topological change; nTC: non-topological change. *P<0.05; *ns*: no significance.

Table 2　Saccadic indices as a function of group (ASD, TD) and stimulus type (TC, nTC)

	ASD (n=27)		TD (n=28)	
	TC (M±SD)	nTC (M±SD)	TC (M±SD)	nTC (M±SD)
SRT/ms	296.0±104.7	329.1±146.4	278.4±79.8	328.0±73.9
VS/ms	461.8±128.9	472.7±140.2	380.7±136.7	418.5±86.3
FFDT/ms	396.3±181.3	442.6±241.2	576.6±288.7	477.1±258.0

SRT: saccadic reaction time; VS: visual search time; FFDT: first fixation dwell time. TC: topological change; nTC: non-topological change.

2.4　Correlations between the saccadic variables and autistic measurements

To better understand the relationship between clinical symptoms and impaired visual attention, we conducted Pearson correlation tests between the clinical assessment scales and attention bias, as reflected by saccadic variables (SRT, VS, and FFDT). No significant correlation was found between the saccadic variables and ABC or SRS (P>0.05). The VS was negatively correlated with the compulsive subscale scores (P<0.05), and the correlation between SRT and the compulsive subscale scores was marginally significant (P=0.054), as indicated in Table 3. Our findings suggest that an increase in compulsive symptom is associated with a reduced attention bias to topological change.

Table 3　Correlations of the SRT, VS, and FFDT with the autistic measurements

	$SRT_{nTC}-SRT_{TC}$	$VS_{nTC}-VS_{TC}$	$FFDT_{TC}$
ABC	−0.163	−0.131	−0.065
SRS	−0.033	−0.027	−0.459
RBS-R total score	−0.447	−0.370	0.096
Stereotype	−0.365	−0.331	−0.099
Self-injurious	0.117	0.421	0.239
Compulsive	−0.519#	−0.533*	0.103
Ritualistic	−0.359	−0.403	0.045
Repetitive	−0.315	−0.272	<−0.001
Restricted	−0.267	−0.089	0.292

Multiple correlation tests were corrected using FDR. ABC: Autism Behavior Checklist; SRS: Social Responsiveness Scale; RBS-R: Repetitive Behavior Scale-Revised. SRT: saccadic reaction time; VS: visual search time; FFDT: first fixation dwell time. TC: topological change; nTC: non-topological change. * indicates that the correlation between VS and Compulsive is significant after FDR correction (P<0.05); # indicates that the correlation between SRT and Compulsive is marginally significant after FDR correction (P=0.054).

3 Discussion

Atypical attention has been considered one of the earliest characteristics that identify infants who are at risk for autism[8, 12]. In this study, we used the change detection task to test attention capture by topological change in children with ASD. Our study revealed that ASD children failed to orient toward a new object defined by topological change. First, we discovered no significant difference in SRT and VS for TC trials compared to nTC trials in ASD children, which contrasted with the results observed in TD children. Furthermore, the FFDT of ASD children towards TC was significantly shorter than that of TD children. Second, we found that ASD children’s VS was associated with their level of autistic trait, as measured by the compulsive subscale, demonstrating that severer compulsive behaviors were linked to a weaker attentional bias to TC. We interpreted these findings as suggesting that an impaired ability in topological perception may underlie the atypical attention observed in children with ASD.

The topological account was supported by comparing the differences between topological and non-topological changes. One might argue that topological changes can be explained by the area and spatial frequency of the stimuli or the specificity of the holes. However, the stimuli we used are derived from Chen *et al.*’s study[39], where factors such as area, spatial frequency, and the specificity of the holes have been well controlled. According to Chen *et al.*’s theory[38], the detection of the topological properties of stimuli is the fundamental function of the visual system, occurring at the earliest stages of the visual processing. The prioritization of topological perception has been supported by numerous studies, including those involving honey bees[50], mice[51], and human neonates[52]. Therefore, using topological changes as a detection variable to test the attention capture process in children with ASD has paved the way to understanding the inconsistent findings of attention deficit.

Bottom-up and top-down attention determines the way we experience and perceive the world[5]. These two attention mechanisms are not mutually exclusive and are usually concurrently involved in the selective attention process. For instance, the shift of attention (*e. g.*, looking toward target peripheral stimuli) of a child is contingent upon pre-existing goal-directed attention setting (*e. g.*, searching a specific target in an array of distractors), which integrates both top-down and bottom-up processes[26]. In the present study, stimulus-driven attention occurs more quickly than goal-directed attention, although these two attention mechanisms are indissociable under the current experimental setting. To further consolidate our findings, future research needs to dissociate the top-down process from the bottom-up process.

Many studies have demonstrated that individuals with ASD outperform controls on the task of visual search. This “ASD advantage” has been reviewed by Kaldy *et al.* [20]. Although most studies have documented a visual search advantage in ASD individuals, some researchers argued that the ASD advantage is derived from non-search processes, such as enhanced attention to the target feature before the presentation of a stimulus[36, 53]. Our research results also reveal that children with ASD did not exhibit an advantage in visual search, which is difficult to explain by enhanced attention to target features, as there was no difference in search time between topological and non-topological changes. Task difficulty and perceptual load may be one of the reasons. Therefore, enhanced visual search ability is not a stable feature of ASD and may not be demonstrated in the change detection task.

There are several limitations in the present study. Firstly, the gender difference in our study doesn’t match up very well (*Chi-square* test, P=0.059). However, this is unlikely to be the main influencing factor, since topological properties are the fundamental units of visual perception processing[38-39], are not influenced by gender. Secondly, although the number of trials here is comparable to a recent eye-tracking study in preschoolers with ASD[54], it remains relatively small compared to the sample sizes typically investigated in visual attention research[55]. The insufficient number of trials may lead to an unbalanced number of valid trials. However, a similar number of trials were retained in each condition, ensuring that the results were not confounded by the inclusion of different trial types. Finally, the applicability of the assessments devised in our study to other groups on the autism spectrum remains a challenge, which needs further investigation in the future.

4 Conclusion

Despite these limitations, our findings provide a new perspective on the problem of attention mechanisms in children with ASD. That is, children with ASD fail to redirect their attention to topological change objects during novelty detection as compared to TD children. These findings may help us better understand attentional anomalies and impaired social attention in children with ASD.

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Data Availability The associated data for this paper (DOI: 10.57760/sciencedb.09651, CSTR: 31253.11.sciencedb.09651) can be accessed and obtained from the Science Data Bank database (https://www.scidb.cn/en).

References

[1] Li T, Li Y, Hu Y, *et al*. Heterogeneity of visual preferences for biological and repetitive movements in children with autism spectrum disorder. Autism Res, 2021, **14**(1): 102-111

[2] Belmonte M K, Gomot M, Baron-Cohen S. Visual attention in autism families: ‘unaffected’ sibs share atypical frontal activation. J Child Psychol Psychiatry, 2010, **51**(3): 259-276

[3] Falck-Ytter T, Nyström P, Gredebäck G, *et al*. Reduced orienting to audiovisual synchrony in infancy predicts autism diagnosis at 3 years of age. J Child Psychol Psychiatry, 2018, **59**(8): 872-880

[4] Keehn B, Joseph R M. Impaired prioritization of novel onset stimuli in autism spectrum disorder. J Child Psychol Psychiatry, 2008, **49**(12): 1296-1303

[5] Keehn B, Müller R A, Townsend J. Atypical attentional networks and the emergence of autism. Neurosci Biobehav Rev, 2013, **37**(2): 164-183

[6] Mundy P, Block J, Delgado C, *et al*. Individual differences and the development of joint attention in infancy. Child Dev, 2007, **78**(3): 938-954

[7] Robertson C E, Baron-Cohen S. Sensory perception in autism. Nat Rev Neurosci, 2017, **18**(11): 671-684

[8] Schietecatte I, Roeyers H, Warreyn P. Exploring the nature of joint attention impairments in young children with autism spectrum disorder: associated social and cognitive skills. J Autism Dev Disord, 2012, **42**(1): 1-12

[9] Elsabbagh M, Volein A, Holmboe K, *et al*. Visual orienting in the early broader autism phenotype: disengagement and facilitation. J Child Psychol Psychiatry, 2009, **50**(5): 637-642

[10] Farrant K, Uddin L Q. Atypical developmental of dorsal and ventral attention networks in autism. Dev Sci, 2016, **19**(4): 550-563

[11] Osterling J A, Dawson G, Munson J A. Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. Dev Psychopathol, 2002, **14**(2): 239-251

[12] Sacrey L A R, Armstrong V L, Bryson S E, *et al*. Impairments to visual disengagement in autism spectrum disorder: a review of experimental studies from infancy to adulthood. Neurosci Biobehav Rev, 2014, **47**: 559-577

[13] Zwaigenbaum L, Bryson S, Rogers T, *et al*. Behavioral manifestations of autism in the first year of life. Int J Dev Neurosci, 2005, **23**(2/3): 143-152

[14] Chita-Tegmark M. Social attention in ASD: a review and meta-analysis of eye-tracking studies. Res Dev Disabil, 2016, **48**: 79-93

[15] Riby D M, Hancock P J B. Viewing it differently: social scene perception in Williams syndrome and Autism. Neuropsychologia, 2008, **46**(11): 2855-2860

[16] Griffin J W, Bauer R, Scherf K S. A quantitative meta-analysis of face recognition deficits in autism: 40 years of research. Psychol Bull, 2021, **147**(3): 268-292

[17] Jones E J, Gliga T, Bedford R, *et al*. Developmental pathways to autism: a review of prospective studies of infants at risk. Neurosci Biobehav Rev, 2014, **39**(100): 1-33

[18] Kawakubo Y, Kasai K, Okazaki S, *et al*. Electrophysiological abnormalities of spatial attention in adults with autism during the gap overlap task. Clin Neurophysiol, 2007, **118**(7): 1464-1471

[19] Landry R, Bryson S E. Impaired disengagement of attention in young children with autism. J Child Psychol Psychiatry, 2004, **45**(6): 1115-1122

[20] Kaldy Z, Giserman I, Carter A S, *et al*. The mechanisms underlying the ASD advantage in visual search. J Autism Dev Disord, 2016, **46**(5): 1513-1527

[21] O'riordan M A. Superior visual search in adults with autism. Autism, 2004, **8**(3): 229-248

[22] O'Riordan M A, Plaisted K C, Driver J, *et al*. Superior visual search in autism. J Exp Psychol Hum Percept Perform, 2001, **27**(3): 719-730

[23] Elison J T, Sasson N J, Turner-Brown L M, *et al*. Age trends in visual exploration of social and nonsocial information in children with autism. Res Autism Spectr Disord, 2012, **6**(2):

842-851

[24] Sasson N J, Touchstone E W. Visual attention to competing social and object images by preschool children with autism spectrum disorder. J Autism Dev Disord, 2014, **44**(3): 584-592

[25] 陈晓雯, 蔡文淑, 谢桐, 等. 孤独症谱系障碍者视觉定向与视觉搜索的特点及神经机制. 心理科学进展, 2020, **28**(1): 98-110
Chen X W, Cai W S, Xie T, *et al*. Adv Psychol Sci, 2020, **28**(1): 98-110

[26] Keehn B, Westerfield M, Müller R A, *et al*. Autism, attention, and alpha oscillations: an electrophysiological study of attentional capture. Biol Psychiatry Cogn Neurosci Neuroimaging, 2017, **2**(6): 528-536

[27] Coull J T, Walsh V, Frith C D, *et al*. Distinct neural substrates for visual search amongst spatial versus temporal distractors. Cogn Brain Res, 2003, **17**(2): 368-379

[28] Donner T, Kettermann A, Diesch E, *et al*. Involvement of the human frontal eye field and multiple parietal areas in covert visual selection during conjunction search. Eur J Neurosci, 2000, **12**(9): 3407-3414

[29] Donner T H, Kettermann A, Diesch E, *et al*. Visual feature and conjunction searches of equal difficulty engage only partially overlapping frontoparietal networks. NeuroImage, 2002, **15**(1): 16-25

[30] Posner M I, Rothbart M K, Voelker P. Developing brain networks of attention. Curr Opin Pediatr, 2016, **28**(6): 720-724

[31] Bryson S, Garon N, McMullen T, *et al*. Impaired disengagement of attention and its relationship to emotional distress in infants at high-risk for autism spectrum disorder. J Clin Exp Neuropsychol, 2018, **40**(5): 487-501

[32] Goldberg M C, Lasker A G, Zee D S, *et al*. Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. Neuropsychologia, 2002, **40**(12): 2039-2049

[33] Harris N S, Courchesne E, Townsend J, *et al*. Neuroanatomic contributions to slowed orienting of attention in children with autism. Brain Res Cogn Brain Res, 1999, **8**(1): 61-71

[34] Rinehart N J, Bradshaw J L, Moss S A, *et al*. A deficit in shifting attention present in high-functioning autism but not Asperger's disorder. Autism, 2001, **5**(1): 67-80

[35] Hessels R S, Hooge I T C, Snijders T M, *et al*. Is there a limit to the superiority of individuals with ASD in visual search?. J Autism Dev Disord, 2014, **44**(2): 443-451

[36] Joseph R M, Keehn B, Connolly C, *et al*. Why is visual search superior in autism spectrum disorder?. Dev Sci, 2009, **12**(6): 1083-1096

[37] Rauschenberger R, Yantis S. Attentional capture by globally defined objects. Percept Psychophys, 2001, **63**(7): 1250-1261

[38] Chen L. Topological structure in visual perception. Science, 1982, **218**(4573): 699-700

[39] Chen L. The topological approach to perceptual organization. Vis Cogn, 2005, **12**(4): 553-637

[40] Zhou K, Luo H, Zhou T, *et al*. Topological change disturbs object continuity in attentive tracking. Proc Natl Acad Sci USA, 2010, **107**(50): 21920-21924

[41] Wu R, Wang B, Zhuo Y, *et al*. Topological dominance in peripheral vision. J Vis, 2021, **21**(10): 19

[42] Wang W, Zhou T, Chen L, *et al*. A subcortical magnocellular pathway is responsible for the fast processing of topological properties of objects: a transcranial magnetic stimulation study. Hum Brain Mapp, 2023, **44**(4): 1617-1628

[43] Huang Y, Zhou T, Chen L. The precedence of topological change over top-down attention in masked priming. J Vis, 2011, **11**(12): 9

[44] American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders (5th ed.). Washington, DC: American Psychiatric Association, 2013

[45] Rellini E, Tortolani D, Trillo S, *et al*. Childhood autism rating scale (CARS) and autism behavior checklist (ABC) correspondence and conflicts with DSM-IV criteria in diagnosis of autism. J Autism Dev Disord, 2004, **34**(6): 703-708

[46] Bodfish J W, Symons F J, Parker D E, *et al*. Varieties of repetitive behavior in autism: comparisons to mental retardation. J Autism Dev Disord, 2000, **30**(3): 237-243

[47] Pearl A M, Murray M J, Smith L A, *et al*. Assessing adolescent social competence using the Social Responsiveness Scale: should we ask both parents or will just one do?. Autism, 2013, **17**(6): 736-742

[48] Wang Q, Hu Y, Shi D, *et al*. Children with autism spectrum disorder prefer looking at repetitive movements in a preferential looking paradigm. J Autism Dev Disord, 2018, **48**(8): 2821-2831

[49] Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. J R Stat Soc Ser B Stat Methodol, 1995, **57**(1): 289-300

[50] Chen L, Zhang S, Srinivasan M V. Global perception in small brains: topological pattern recognition in honey bees. Proc Natl Acad Sci USA, 2003, **100**(11): 6884-6889

[51] Huang Y, Li L, Dong K, *et al*. Topological shape changes weaken the innate defensive response to visual threat in mice. Neurosci Bull, 2020, **36**(4): 427-431

[52] Lin Y L, Hui-Lin Chien S, Hu S F. An early sensitivity for detecting differences in visual topological property in 0-to 4-day-old human neonates. Pediatr Dimensions, 2016, **1**(2): 29-33

[53] Keehn B, Joseph R M. Slowed search in the context of unimpaired grouping in autism: evidence from multiple conjunction search. Autism Res, 2016, **9**(3): 333-339

[54] Mo S, Liang L, Bardikoff N, *et al*. Shifting visual attention to social and non-social stimuli in Autism Spectrum Disorders. Res Autism Spectr Disord, 2019, **65**: 56-64

[55] Wilson C E, Saldaña D. No evidence of atypical attentional disengagement in autism: a study across the spectrum. Autism, 2019, **23**(3): 677-688

自闭症谱系障碍儿童拓扑变化捕获注意的缺陷*

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摘要 目的 自闭症谱系障碍（ASD）是一种神经发育疾病，其核心特征是交流和社会互动困难，限制性和重复行为。以往研究表明，ASD患者表现出早期和终身的注意力缺陷，这些缺陷与ASD的核心症状密切相关。基本的视觉注意加工可能为其社会交流和互动能力提供关键的基础。因此，本研究探索了ASD儿童对拓扑性质变化捕获注意的行为。**方法** 招募27名由专业医生根据美国精神障碍诊断与统计手册第5版（DSM-5）诊断的ASD儿童和28名年龄匹配的正常发展（TD）对照儿童。在一项注意捕获任务中，记录ASD儿童和TD儿童对拓扑变化和非拓扑变化刺激的眼跳行为。眼跳反应时间（SRT）、视觉搜索时间（VS）和首次注视停留时间（FFDT）被用作注意偏向的指标。本研究还进行了注意偏向与临床评估量表之间的皮尔逊相关性检验。**结果** 与非拓扑变化刺激相比，TD儿童对拓扑变化刺激有更快的SRT（$P<0.05$）和VS（$P<0.05$），而ASD儿童在两种指标上均没有表现出显著性差异（$P>0.05$）。此外，ASD儿童对拓扑变化目标的注意力（由FFDT测得）显著少于TD儿童（$P<0.05$）。而且，ASD儿童的注意偏向（由VS测得）与其强迫行为分量表得分之间存在显著负相关（$P<0.05$）。**结论** 在变化检测过程中ASD儿童难以将注意转移到发生拓扑变化的物体上。这种非典型注意可能影响儿童的认知和行为发展，从而影响其社会沟通和互动。本研究表明，对拓扑变化刺激捕获注意的缺陷可能是自闭症儿童注意缺陷的一个关键特征。

关键词 注意，自闭症谱系障碍，知觉物体，拓扑知觉

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