Attention Disengagement in Individuals with Autism Spectrum Disorder and Its Influencing Factors

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Abstract

Attention disengagement represents a critical component of the attentional orienting network, denoting the process of attentional separation from a previously attended stimulus during attentional shifting. Early impairments in attention disengagement among individuals with autism spectrum disorder exert direct influences on the development of other essential functions, most notably arousal regulation and joint attention. Research utilizing the gap-overlap paradigm has yielded controversial findings regarding atypical attention disengagement abilities in autistic individuals; potential influencing factors include participant age and sampling strategies, measurement indices, and stimulus characteristics. The underlying neural mechanisms may implicate brain regions such as the frontal lobe, parietal lobe, cerebellum, and corpus callosum. Future investigations should prioritize neural mechanism research, comprehensively account for the effects of participant characteristics, research methodologies, and stimulus features on attention disengagement outcomes, and clarify its specific role in early prediction and identification of autism.

Full Text

Attentional Disengagement in Individuals with Autism Spectrum Disorder and Its Influencing Factors

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Abstract

Attentional disengagement is a critical component of the attentional orienting network, referring to the process of disengaging attention from a current stimulus during attentional shifting. Early impairments in attentional disengagement in individuals with autism spectrum disorder (ASD) can directly affect the development of other important functions, particularly arousal regulation and joint attention. Studies employing the gap-overlap paradigm have yielded controversial findings regarding whether attentional disengagement abilities are abnormal in ASD, with participant age and sampling, measurement indicators, and stimulus characteristics identified as potential influencing factors. The underlying neural mechanisms may involve brain regions including the frontal lobe, parietal lobe, cerebellum, and corpus callosum. Future research should investigate the neural mechanisms while comprehensively considering how participant characteristics, research methods, and stimulus features influence attentional disengagement outcomes, thereby clarifying its role in the early prediction and identification of ASD.

Keywords: attentional disengagement, autism, gap-overlap paradigm, neural mechanisms

Autism Spectrum Disorder (ASD) is a pervasive neurodevelopmental disorder that emerges in early childhood, also known as autism or autism spectrum condition (American Psychiatric Association, 2013). For individuals with ASD, early attention impairments may lead to abnormal development of social and cognitive abilities, and such deficits can have lifelong impacts. ASD patients exhibit various attention deficits: narrow attention span, difficulty with attention shifting, poor attention stability, delayed attentional disengagement, and less joint attention compared to typically developing individuals.

Attentional disengagement refers to the process of separating attention from a currently attended object during the shift to a new object. The primary experimental paradigm for studying attentional disengagement is the gap-overlap task, which examines how participants disengage, shift, and reorient attention from a central stimulus to a peripheral stimulus (Yan, 2019). The paradigm includes three conditions: the gap condition (where the central stimulus disappears before the peripheral stimulus appears), the overlap condition (where the central stimulus remains after the peripheral stimulus appears), and the baseline condition (where the central stimulus disappears simultaneously with the peripheral stimulus appearance). The overlap condition measures attentional disengagement ability, while the gap and baseline conditions measure attention shifting capacity. Previous studies have employed three variations of the gap-overlap task: (a) all three conditions present, (b) overlap + gap conditions, and (c) overlap + baseline conditions. Attentional disengagement is typically indexed by two measures: saccade latency in the disengagement condition and the "disengagement cost" calculated by subtracting latency in the shifting condition from that in the disengagement condition.

The attentional disengagement hypothesis posits that impaired attentional disengagement is an important factor contributing to ASD, and that abnormal attentional disengagement can explain multiple symptoms of autism (Keehn et al., 2013). Early impairment in attentional disengagement can cause dysregulation of arousal and deficits in joint attention, subsequently leading to abnormal sensory processing, impairments in social communication and social cognition, repetitive and stereotyped behaviors, and hyperfocused attention (Sanchez et al., 2019). Numerous studies have shown that high-risk infants later diagnosed with ASD (infants with older siblings diagnosed with ASD) exhibit attentional disengagement deficits in early infancy (Zwaigenbaum et al., 2005), and some researchers consider attentional disengagement deficits as a potential early behavioral marker for future ASD diagnosis (Elison et al., 2013). Therefore, investigating the developmental characteristics and cognitive-neural mechanisms of attentional disengagement in ASD individuals has important practical significance for exploring the etiology and early diagnosis and intervention of ASD.

This paper systematically reviews relevant research on attentional disengagement in ASD individuals using the gap-overlap task and its influencing factors, then introduces the relationship between attentional disengagement and ASD symptoms, elaborates on the neural mechanisms underlying attentional disengagement in ASD, and finally outlines future research directions regarding attentional disengagement in ASD.

2.1 Development of Attentional Disengagement in ASD Individuals Across Different Age Stages

The development of attentional disengagement abilities in ASD individuals shows inconsistent patterns across different age stages. Longitudinal follow-up studies of early high-risk infants indicate that ASD individuals exhibit attentional disengagement difficulties before diagnosis, and that infant attentional disengagement capacity has predictive value for subsequent ASD development —the more difficult the attentional disengagement, the more likely the development of ASD (Zhao et al., 2019). However, studies of ASD children, adolescents, and adults after age 3 have yielded complex results: compared with control groups, some studies have found slower, faster, or no group differences in attentional disengagement latency (Sanchez et al., 2019).

2.1.1 Development of Attentional Disengagement in High-Risk ASD Infants Before Age 3

From the first year after birth, infants' attentional orienting network undergoes rapid development. Typically developing infants around 1 month of age experience a "sticky or obligatory attention" phase (Sacrey et al., 2014). During this stage, infants exhibit attentional fixation, appearing to be "forced" to look at a target and unable to easily disengage gaze from the attended object (Hood et al., 1993). After 1 month, the ability to disengage from stimuli increases rapidly, with visual disengagement reaction time between two competing stimuli decreasing significantly between 2-4 months. After 4 months, this abnormal attentional pattern gradually disappears in typically developing infants, and attentional disengagement abilities reach adult levels during childhood (Sacrey et al., 2014).

The earliest reported age at which visual attentional disengagement abnormalities appear in ASD infants is around 6 months (Elison et al., 2013). This study tested 56 high-risk infants (16 later diagnosed with ASD) and 41 low-risk infants at 6 months for attentional disengagement, with diagnostic assessment at approximately 24 months. Results showed that at 6 months, high-risk infants later diagnosed with ASD had significantly longer attentional disengagement times than low-risk infants. Elsabbagh et al. (2009) compared attentional disengagement differences between 19 high-risk infants and 19 low-risk infants at 9-10 months, finding that high-risk infants later diagnosed with ASD showed longer attentional disengagement latencies and less facilitatory effect compared to control infants.

However, some studies suggest that attentional disengagement abnormalities in ASD infants do not emerge between 6-12 months but rather after 12 months. Zwaigenbaum et al. (2005) conducted a prospective study on the relationship between attentional disengagement and subsequent ASD symptoms in high-risk infants, selecting 65 high-risk infants (19 later diagnosed with ASD) and 85 low-risk infants. They administered gap-overlap tasks at 6 and 12 months, then assessed ASD symptoms at 24 months using the Autism Diagnostic Observation Schedule (ADOS). Results showed no group differences at 6 months, but attentional disengagement abnormalities emerged in high-risk infants at 12 months, with attentional disengagement reaction time at 12 months positively correlating with ADOS scores at 24 months. These findings indicate that attentional disengagement abnormalities at 12 months are closely related to later ASD diagnosis. Bryson et al. (2017) similarly tested 83 high-risk infants (16 later diagnosed with ASD) and 53 low-risk infants at 6 and 12 months, with ASD diagnosis at 36 months. Results showed that high-risk infants diagnosed with ASD exhibited attentional disengagement deficits, with the critical time point for disengagement difficulties being 12 months rather than 6 months. Additionally, within the high-risk group, left visual field disengagement reaction time at 12 months not only predicted future ASD diagnosis but was also associated with irritability and difficulty soothing.

The above prospective infant studies indicate that differences in attentional disengagement between high-risk and low-risk infants may first emerge between 6-12 months. Specifically, infants later diagnosed with ASD at 24-36 months show delayed attentional disengagement latencies beginning at 6-7 months, with significant increases becoming apparent after 12 months (particularly between 12-14 months) and demonstrating good predictive validity for subsequent diagnosis. In contrast, attentional disengagement latencies in control group infants either gradually decrease or remain stable (Jones et al., 2014). Since no studies have examined attentional orienting in ASD infants before 6 months, it remains unclear whether attentional disengagement abnormalities in ASD infants represent a continuation of abnormal attentional patterns from the "sticky attention" phase at 1 month after birth, or whether they emerge at a specific time point after a period of normal development.

2.1.2 Development of Attentional Disengagement in ASD Individuals After Age 3

Research on ASD children and adults after age 3 helps determine whether attentional disengagement impairments are long-lasting or temporarily present due to developmental delay (Sacrey et al., 2014). After age 3, typically developing children demonstrate increasingly mature attentional orienting, quickly disengaging from current fixation objects and flexibly shifting attention between different objects, with abilities approaching adult levels. However, relevant research on ASD individuals has yielded complex results. Some studies have found that ASD individuals show deficits in attentional disengagement compared to age-matched typical controls and other clinical groups, while others have found only generally poor attention levels without impaired attentional disengagement.

Landry and Bryson (2004) used the gap-overlap paradigm to compare attentional disengagement and shifting differences among 5-year-old ASD children, children with Down syndrome (DS), and typically developing (TD) children. Results showed that ASD children had significantly longer attentional disengagement reaction times than both DS and TD children, demonstrating clear attentional disengagement difficulties when facing two competing stimuli. Sabatos-DeVito et al. (2016) examined attentional disengagement and orienting abilities in ASD children aged 3-14, children with other developmental disabilities (DD), and TD children by manipulating the salience of central stimulus types. Results showed that ASD children exhibited impairments in attentional disengagement and orienting accuracy, with attentional disengagement associated with different sensory response patterns in both ASD and developmental disability groups. Additionally, electrophysiological studies of ASD adults have also revealed attentional disengagement abnormalities.

Kawakubo et al. (2007) combined event-related potentials (ERP) and electrooculography (EOG) to compare performance on the gap-overlap task among low-functioning ASD adults, adults with intellectual disabilities matched for IQ, and TD adults with normal intelligence. Results showed that the ASD group exhibited significantly higher presaccadic positivity amplitude 100-70ms before saccade initiation compared to other groups. Under overlap conditions, higher presaccadic positivity amplitude was significantly correlated with more severe clinical symptoms in the ASD group, confirming that ASD adults have deficits in visual attentional disengagement and that the underlying physiological basis of ASD differs from that of intellectual developmental delay.

However, other researchers have presented contradictory evidence. Van der

Geest et al. (2001) examined whether 10-year-old ASD children (16 participants) showed attentional disengagement differences compared to age- and IQ-matched TD children (15 participants). Results showed that ASD children did not exhibit attentional disengagement deficits but rather showed smaller gap effects and lower attentional engagement levels compared to TD children. The authors suggested that differences between ASD and control groups might relate to deficits in stimulus processing abilities rather than reflecting abnormal attentional disengagement. Fischer et al. (2014) used a free-viewing gap-overlap paradigm to examine attentional disengagement differences and social orienting abilities in high-functioning ASD children aged 5-12 (44 participants) and age- and IQ-matched TD children (40 participants). Results indicated that high-functioning ASD children showed no impairments in attentional disengagement or social orienting; they disengaged attention as quickly as TD children and similarly prioritized social stimuli. Wilson and Saldaña (2018) obtained similar results, examining 16 ASD children and 18 TD children on the gap-overlap task. Although the ASD group showed a larger disengagement effect, no significant group differences emerged under overlap conditions, indicating that ASD children did not have attentional disengagement deficits. Similar results have been found in studies of ASD adults. Zalla et al. (2018) examined saccade reaction time differences between 20 high-functioning ASD adults and TD adults matched on verbal and nonverbal IQ during the gap-overlap task. They also found no differences between groups in saccade reaction times under overlap and gap conditions, though ASD adults showed lower peak saccade velocity, suggesting that attentional disengagement was not impaired in ASD adults but that cerebellar motor abnormalities led to sensory-motor control deficits.

These findings indicate inconsistent results regarding attentional disengagement abilities in ASD individuals after age 3. Many factors may contribute to these inconsistencies, including age, participant selection, and stimulus characteristics. For instance, Landry and Bryson (2004) used dynamic geometric figures as stimuli, which produced attentional disengagement costs many times higher than those generated by single static picture stimuli (Fischer et al., 2014). Although Sabatos-DeVito et al. (2016) used combined dynamic and static stimuli, their ASD group included participants of different subtypes with unmatched IQs. Kawakubo et al. (2007) studied low-functioning ASD adults.

These inconsistent results across different age stages may suggest that the attentional disengagement hypothesis cannot fully explain the development of attentional disengagement abilities in ASD. The attentional disengagement impairment in ASD individuals may not persist from the first year of life through adulthood as Sacrey et al. (2014) hypothesized. Regarding the development of attentional disengagement in typical individuals, Colombo and Cheatham (2006) speculated that it follows a nonlinear U-shaped trajectory before age 3. For ASD individuals, this paper proposes several possible developmental trajectories (Figure 1 [Figure 1: see original paper]): (1) Attentional disengagement abilities in ASD individuals remain stagnant from birth (Figure 1A); (2) Between 0-6 months, ASD individuals experience the same "sticky attention" phase as typical individuals followed by brief improvement, after which abilities decline beginning at 6 months (Figure 1B); (3) After normal development from 0-6 months, attentional disengagement abilities in ASD individuals follow a U-shaped trajectory between 6-36 months, after which, due to ASD heterogeneity, different developmental trajectories emerge–some individuals gradually improve to normal levels (Figure 1C), while others show continuous decline after 36 months (Figure 1D). Future research requires prospective longitudinal studies of high-risk ASD infants, comprehensive consideration of ASD heterogeneity, age, sample selection differences, and variability in tasks and measures used to assess attentional disengagement to further clarify developmental trends in ASD individuals after age 3.

2.2 Influencing Factors on Attentional Disengagement in ASD Individuals

Although numerous studies have found attentional disengagement deficits in ASD individuals, some have reported inconsistent results. These divergent findings suggest that whether ASD individuals truly have attentional disengagement deficits requires further investigation. What factors might cause these inconsistent results? This study systematically reviews influencing factors on attentional disengagement in ASD individuals from several perspectives: age, ASD subtypes, measurement indicators, and stimulus characteristics.

2.2.1 Effects of Age on Attentional Disengagement in ASD Individuals

Age may exert a potential influence on the development of attentional disengagement in ASD individuals. ASD infants diagnosed before age 3 show attentional disengagement deficits, whereas studies of ASD children and adults after age 3 show complex results, suggesting that disengagement deficits exist early in development but may improve, recover, or remain delayed with age and brain maturation.

Currently, few studies have examined the relationship between attentional disengagement ability and age. In Todd et al.' s (2009) study, a cross-sectional analysis compared attentional disengagement abilities between an ASD group (ages 9-15) and three TD groups of different ages (5-8, 9-11, and 12-15 years) and TD adults. Results showed that, except for the youngest TD group (5-8 years), ASD children had longer saccade reaction times under both gap and overlap conditions compared to other age groups of TD children and adults, indicating impaired attentional disengagement in both gap and overlap tasks. Although this study showed age-related delays in attentional disengagement in ASD children, it did not compare attentional disengagement across different age stages within the ASD group, so the developmental trajectory of attentional disengagement with age remains unclear.

Some researchers believe that the attentional disengagement effect negatively correlates with chronological age in ASD individuals, with younger participants showing more significant attentional disengagement difficulties than older participants. This suggests that attentional disengagement problems may decrease, correct, or compensate with age (Glennon et al., 2020; Wilson & Saldaña, 2018). ASD individuals show delayed saccade latencies in attentional disengagement at younger ages due to delayed development of corresponding oculomotor control systems, but this developmental delay may resolve spontaneously with age due to other developmental gains. However, other researchers argue that attentional disengagement abilities in ASD individuals do not gradually develop with age but rather stagnate during childhood and may even regress with age (Sanchez et al., 2019).

Overall, the development of attentional disengagement abilities in ASD may manifest differently across age stages, subtypes, and individual differences, with deficits potentially existing only in limited situations or participant groups. For example, attentional disengagement deficits may exist in early ASD development, but with age, some ASD individuals (such as high-functioning ASD) may spontaneously recover due to other developmental gains, while others fail to obtain such gains, resulting in stagnation or even regression of attentional disengagement abilities.

2.2.2 Effects of ASD Subtype Differences on Attentional Disengagement

As a spectrum disorder, ASD exhibits substantial within-group heterogeneity, with intelligence and language development capabilities all affecting functional development in ASD individuals (Chiang et al., 2018; Goodwin et al., 2017). The inconsistent results obtained in the aforementioned studies on attentional disengagement in ASD individuals may be due to the representativeness and limitations of different subtype samples during participant selection.

First, attentional disengagement abilities may differ across ASD subtypes (high- vs. low-functioning ASD, Asperger' s syndrome, pervasive developmental disorder not otherwise specified). Since the adoption of the "spectrum disorder" concept, different ASD subtypes have been included under one umbrella, making them difficult to distinguish. Consequently, some studies have failed to differentiate subtypes and directly compared mixed subtypes as the ASD group with control groups. For example, Landry and Bryson' s (2004) study included 2 individuals with Asperger' s syndrome, and Sabatos-DeVito et al.' s (2016) study simultaneously included both high- and low-functioning ASD individuals in their ASD group, resulting in large within-group heterogeneity despite matched average IQ with the TD group.

Second, in prospective studies of early attentional disengagement, since high-risk ASD infants are too young for direct IQ measurement, all studies have used the Mullen Scales of Early Learning (MSEL) to match cognitive abilities and motor skills between high- and low-risk infants. In older ASD children and adults, most studies have widely used the high-functioning ASD subtype as the ASD group because these participants have relatively intact cognitive development and can cooperate well during experiments (Fischer et al., 2014; Kawakubo et al., 2007; Keehn et al., 2019; Van der Geest et al., 2001; Wilson & Saldana, 2018; Zalla et al., 2018). This approach ensures participants can understand task instructions but neglects differences in attentional disengagement among low-functioning ASD individuals with lower intelligence and cognitive development levels. Only one study has compared attentional disengagement abilities among low-functioning ASD adults (mean IQ = 43.6 ± 14.7), adults with intellectual developmental delay (mean IQ = 40.6 ± 10.9), and TD adults (mean IQ = 105.2 ± 10.9), finding attentional disengagement deficits in ASD adults (Kawakubo et al., 2007). Currently, no studies have compared attentional disengagement abilities within different ASD subtypes, making it impossible to determine whether attentional disengagement impairments relate to ASD severity rather than developmental level.

Finally, it is worth noting that in studies of high-functioning ASD groups with matched IQ, almost all studies have matched only nonverbal IQ between experimental and control groups, without matching verbal IQ (except Van der Geest et al., 2001 and Zalla et al., 2018). This may be because the gap-overlap paradigm primarily involves nonverbal IQ, but it may overlook the potential impact of verbal IQ differences on attentional disengagement results. Additionally, in relevant IQ-matching studies, the IQ levels of selected ASD groups (80-110) were generally lower than those of control groups (100-120). Although some researchers believe that attentional disengagement ability is not directly related to intelligence level in ASD individuals, with attentional disengagement deficits evident even in those with normal or above-average intelligence (Kawakubo et al., 2007; Landry & Bryson, 2004), future research still needs to use multiple measurement methods to assess attentional disengagement abilities across large samples of different ASD subtypes, while carefully considering how individual differences (such as personality factors, attention status, physiological arousal baseline levels, and psychosomatic developmental differences) affect results during participant selection.

2.2.3 Effects of Different Measurement Indicators on Attentional Disengagement

Regarding measurement indicators of attentional disengagement, some studies have directly used disengagement latency under overlap conditions (Bryson et al., 2017; Elison et al., 2013; Landry & Bryson, 2004), while others have used difference scores between overlap and gap conditions (Goldberg et al., 2002; Kikuchi et al., 2011; Wilson & Saldana, 2018; Zwaigenbaum et al., 2005) or between overlap and baseline conditions (Fischer et al., 2014; Fischer et al., 2016). Some studies have also used reaction time/accuracy rates for attention disengagement from central stimuli (Sanchez et al., 2019). Although these measurement indicators all conceptualize attentional disengagement ability as the efficiency of disengaging attention from a target—efficiency that can be measured by either reaction time or accuracy—differences still exist between data obtained from different indicators, which may lead to inconsistent attentional disengagement results.

For example, when using difference scores between conditions as attentional disengagement measures, do differences between overlap and gap conditions versus overlap and baseline conditions measure functionally different aspects of attentional disengagement? Some researchers suggest that latency differences between overlap and baseline conditions primarily result from central stimulus removal and release of oculomotor inhibition in the superior colliculus due to pre-saccadic preparation associated with bilateral frontoparietal activation. In contrast, latency differences between overlap and gap conditions may be associated with phasic alerting responses (such as fixation point disappearance), which are linked to the right attentional network system (Keehn et al., 2019). Additionally, Fischer et al. (2016) argue that no clear relationship has been established between the gap condition presenting a blank screen and attentional disengagement deficits in ASD. For instance, Elsabbagh et al. (2009) used a gap condition, while Elsabbagh et al. (2013) did not, yet both studies produced similar results. Some researchers also suggest that presenting a blank screen in the gap condition leaves participants without a fixed fixation point, making the saccade initiation location uncertain when the target stimulus appears and potentially leading to inaccurate eye movement data. In baseline conditions, where attention remains at screen center when the target appears, errors in saccade starting position can be reduced (Yan et al., 2019).

Sanchez et al. (2019) caution that when using difference scores between conditions to obtain "pure" measures of specific cognitive constructs, researchers should be careful. On one hand, the validity of some measurement indicators cannot be guaranteed, and it remains unknown whether results truly reflect the attentional disengagement process and whether attentional disengagement results under different measurement indicators can be directly compared. On the other hand, unclear operational definitions of dependent variables can also confound results. Future research needs more unified and explicit measurement indicators to study attentional disengagement abilities in ASD individuals.

2.2.4 Effects of Stimulus Characteristics on Attentional Disengagement

In ASD attentional disengagement research, researchers have used stimuli with varying characteristics, and contradictory results in attentional disengagement may be related to the use of different stimulus materials across studies.

Dynamic stimuli may help maintain attention, especially in ASD infants and young children, keeping fixation at screen center, but this also makes orienting to peripheral stimuli more difficult and more likely to yield attentional disengagement deficits compared to static stimuli. For example, studies using dynamic pictures or animations as experimental stimuli have all found significant group differences (Bedford et al., 2014; Bryson et al., 2017; Kleberg et al., 2016; Landry & Bryson, 2004; Zwaigenbaum et al., 2005). In contrast, studies using static single symbols or pictures have not found group differences in attentional disengagement (Fischer et al., 2014; Goldberg et al., 2002; Van der Geest et al., 2001; Wilson & Saldana, 2018).

Furthermore, ASD individuals are more engaged by repetitive, regular stimuli and more likely to develop "sticky attention" (Wang et al., 2018). For example, Landry and Bryson (2004) and Zwaigenbaum et al. (2005) used repetitive, regular stimuli (dynamic geometric figures) and obtained significant results. Fischer et al. (2016) suggested that in these studies, ASD children may have more difficulty than TD children in grasping stimulus presentation patterns and features and have weaker stimulus prediction and anticipation abilities, thus more likely to show attentional disengagement deficits. To eliminate potential confounds from repetitive stimuli, they used non-repeated stimuli across all trials and found no attentional disengagement deficits in ASD individuals.

Attentional preferences for central or peripheral stimuli also affect attentional disengagement in ASD individuals. For example, when central stimuli (or peripheral stimuli) are objects of restricted interest to ASD (e.g., trains), ASD individuals disengage more slowly (or more quickly) (Mo et al., 2019; Sasson & Touchstone, 2014). Different stimulus features may induce competition for attentional resources. The more salient the central stimulus (dynamic, multimodal, or restricted interest), the more difficult the attentional disengagement; similarly, the more attractive the peripheral stimulus (compared to static, unimodal, or non-restricted interest stimuli), the easier the attentional disengagement. These varying results suggest that ASD individuals may not have severe deficits in attentional disengagement ability per se, but rather that multiple factors including motivation, intrinsic interests, and attentional resource utilization abilities jointly contribute to performance. Future research needs to explore whether the influence of stimulus characteristics on attentional disengagement is direct or indirect.

Beyond the factors discussed above, other influencing factors exist. For example, the inter-stimulus interval (ISI) length between central and peripheral stimuli in the gap-overlap paradigm may affect whether ASD individuals show attentional disengagement difficulties. Some studies have found that ASD individuals disengage more slowly than TD individuals at short ISIs ($<$ 500ms) but show no significant differences at longer ISIs ($ $800ms). Studies finding intact attentional disengagement in ASD typically report ISI durations of 1 second or more, whereas most studies reporting attentional disengagement deficits do not report ISI durations (Sacrey et al., 2014). Different research tools may also influence results (Yan et al., 2019). Early studies used video cameras with frame-by-frame coding analysis, which did not necessarily yield precise reaction time data. Most recent studies use EOG and Tobii eye trackers, which are more operable in ASD populations and provide more reliable eye movement data.

3 Relationship Between Attentional Disengagement and ASD Clinical Symptoms

The clinical manifestations of ASD individuals are complex, and studying and explaining this disorder from single cognitive impairments alone is insufficient. Understanding the relationship between attention deficits and other ASD clinical symptoms, particularly the extent to which attentional disengagement deficits affect impairments in other domains, is currently a research focus.

3.1 Relationship Between Attentional Disengagement and Atypical Sensory Responses

Compared to typically developing infants, 6-month-old infants later diagnosed with ASD at 36 months show increased sensitivity to low-intensity stimuli, suggesting possible early perceptual differences in ASD infants (Clifford et al., 2013). Additionally, some studies report that 24-month-old infants diagnosed with ASD show more frequent and intense distress responses to various stimuli at 12 months compared to other high- or low-risk infants (Zwaigenbaum et al., 2005), and these sensitivities may be related to enhanced discrimination of weak stimuli.

Some studies also demonstrate links between clinical sensory response patterns (including sensory seeking/avoidance and high/low sensory sensitivity) and attentional disengagement in ASD children, with under-responsiveness to social and non-social stimuli being important predictors of attention deficits. Sabatos-DeVito et al. (2016) first used the gap-overlap paradigm to investigate the relationship between attentional disengagement and different clinical sensory response patterns in ASD children. Results showed that attentional disengagement in ASD individuals was associated with different sensory response patterns, with high seeking behavior and low responsivity related to poorer attentional disengagement, while high responsivity facilitated attentional disengagement. Researchers suggest that the temporal overlap between early clinical sensory responses and attentional disengagement deficits in ASD individuals further demonstrates that their underlying mechanisms may be intertwined.

3.2 Relationship Between Attentional Disengagement and Narrow Cognitive Processing Style

One core symptom of ASD is a narrow attentional focus pattern. ASD individuals are often described as having hyperfocused attention, narrow interests, and acute perception of details. Elsabbagh et al. (2009) propose that the narrow cognitive processing style observed in ASD individuals is related to early visual attentional disengagement difficulties. Deficits in attentional disengagement ability cause ASD individuals' attention to become fixated on highly restricted interest objects, producing attentional biases toward non-social stimuli in the environment and gradually forming an information processing style characterized by restricted interests and detail-focused attention. Typically developing children become more flexible in scanning their surroundings and shifting attention between objects with age, with global information processing becoming faster and more efficient. In contrast, ASD patients show longer fixation durations on single features or objects and tend to rely more on local features when processing visual stimuli, leading to delayed stimulus disengagement. Therefore, the narrow cognitive processing style in ASD individuals may be a consequence of early visual disengagement difficulties. However, current research cannot determine whether narrow cognitive processing in ASD individuals causes attentional disengagement difficulties or whether attentional disengagement difficulties cause this narrow cognitive processing style.

3.3 Relationship Between Attentional Disengagement and Social Cognitive Function Deficits

Attentional disengagement is essential for normal social function development. Deficits in attentional disengagement hinder the development of ASD individuals' ability to acquire social information, leading to deficits in social attention, social cognition, and social skills. Franchini et al. (2017) examined the relationship between visual orienting to social stimuli, joint attention, and social interaction abilities in preschool ASD children. Results showed that ASD children oriented less to social stimuli compared to TD children, with substantial heterogeneity within the ASD group. Those ASD children who attended more to social stimuli showed "sticky attention" and greater difficulty disengaging attention from social stimuli. Visual orienting and joint attention were positively correlated with social interaction ability development—more social orienting was associated with higher frequencies of joint attention behaviors, which in turn were associated with improved communication skills. Schietecatte et al. (2012) similarly confirmed a relationship between the number of joint attention initiations and attentional disengagement abilities in infants with ASD. In summary, deficits in attentional disengagement ability reduce social orienting in ASD individuals, decreasing access to social information, reducing joint attention behaviors, and hindering the development of social communication skills.

Furthermore, visual attentional disengagement ability is crucial for emotion regulation, and impaired attentional disengagement may lead to abnormal emotion/arousal regulation, over-reactivity, and the formation of restrictive temperament types (Sacrey et al., 2014). Infant emotion regulation involves interactions between internal states and external stimuli to maintain homeostasis, achieved by disengaging and shifting attention away from distressing events and thoughts (Bryson et al., 2017). ASD individuals have difficulty disengaging from disturbing social situations and may consequently show irritable tendencies and avoidance behaviors. Bryson et al. (2017) confirmed that delayed disengagement latency at 12 months in high-risk ASD infants (especially in the left visual field) was associated with parent-reported emotional distress, manifested as high sensitivity and difficulty soothing.

These studies demonstrate close associations between attentional disengagement and ASD clinical symptoms, suggesting that impaired attentional disengagement may underlie multiple psychological and behavioral functional abnormalities in ASD individuals. Early attentional disengagement impairments not only lead to atypical sensory responses and narrow cognitive processing styles but also cause joint attention difficulties, which may in turn delay or disrupt language acquisition, impair mental state attribution skills, and even damage social cognitive functions such as theory of mind and joint attention (Cai & Qi, 2018). Therefore, investigating the relationship between early attentional disengagement difficulties and different functional deficits in ASD individuals is crucial for mapping developmental pathways from birth and understanding pathogenic mechanisms. This will help identify children needing early intervention and improve the scope of interventions available to them.

4 Neural Mechanisms of Attentional Disengagement Deficits

As part of the attentional orienting system, the neural mechanisms of attentional disengagement are closely related to the visual orienting network. Visual attention orienting relies on a distributed network of brain regions, including the dorsal frontoparietal cortical network and subcortical structures (thalamus, superior colliculus, and cerebellum) to disengage and shift attention (Keehn et al., 2013). Visual disengagement is partially accomplished by oculomotor mechanisms relatively independent of higher attentional processes—after peripheral stimulus presentation, attentional disengagement is achieved by reducing visual cell activity in the rostral pole of the superior colliculus to release visual orienting from central stimuli (Kleberg et al., 2016). Some researchers propose that abnormal oculomotor inhibition leads to attentional disengagement impairments, and that attentional disengagement deficits in ASD individuals may result from saccade disorders caused by impaired neuroplasticity in cerebellar-parietal pathways regulating eye movement control (Johnson et al., 2016).

Functional magnetic resonance imaging (fMRI) studies indicate that the attentional orienting system is related to frontal and parietal lobes (Posner et al., 2016). The frontal eye field (FEF) is responsible for attentional disengagement from stimuli. Zwaigenbaum et al. (2005) suggest that increased attentional disengagement latency observed at 12 months may relate to prefrontal cortex development, as abnormal activation patterns involving prefrontal cortex have been observed in diagnosed ASD preschool children. Early ERP evidence indicates that larger positive components over parietal cortex before saccades may reflect attentional disengagement processes. Kawakubo et al. (2007) used ERP technology to explore ERP amplitude differences among low-functioning ASD adults, adults with mental retardation, and TD adults on the gap-overlap task. In this study, researchers used presaccadic positivity over parietal cortex before new stimulus presentation as an index—larger amplitude or longer latency indicated abnormal attentional disengagement. Results showed that, compared to control groups, ASD individuals showed larger presaccadic positivity amplitude under overlap conditions, but only when stimuli were presented in the left visual field. Related research also shows that patients with right posterior parietal cortex (PPC) damage have longer attentional disengagement latencies (Pierrot-Deseilligny et al., 1991). Additionally, the cerebellum is the most common site of neuroanatomical abnormalities in ASD patients, particularly cerebellar lobules VI-VII, which play important roles in visual orienting (Sacrey et al., 2014). Mundy (2003) proposes that deficits in visual attentional disengagement in ASD may result from damage to the complex functional axis of frontal lobe, parietal lobe, and cerebellum, where the dorsal medial-frontal cortex/anterior cingulate complex, orbitofrontal cortex, amygdala, and cerebellum may have complex interactions in attentional regulation of external stimulus input.

Research also indicates that the corpus callosum, which connects neural fiber bundles between cerebral hemispheres, may play an important role in abnormal attentional orienting in ASD (Jones et al., 2014). Elison et al. (2013) used diffusion tensor imaging (DTI) to explore the relationship between visual attentional disengagement and brain functional connectivity in high-risk ASD infants. Results showed a relationship between attentional disengagement latency and corpus callosum microstructure in TD infants, but not in ASD infants. Slower disengagement latency under overlap conditions was associated with reduced radial diffusivity in the corpus callosum.

In summary, neural mechanisms related to attentional disengagement in ASD individuals involve the frontal lobe, parietal lobe, cerebellum, and corpus callosum, as well as their interactions. However, current research exploring the neural mechanisms of attentional disengagement in ASD is limited, having only preliminarily identified relevant brain regions without determining their specific interaction mechanisms.

The ability to flexibly shift gaze from one stimulus point to another is a fundamental attentional skill crucial for the later development of other attention skills such as arousal regulation and joint attention. The attentional disengagement hypothesis proposes that abnormal attentional disengagement is an early marker of ASD and plays a causal role in ASD development. However, whether ASD individuals truly have attentional disengagement deficits remains controversial, with most studies supporting the hypothesis but others not. These inconsistencies may relate to research methods and stimulus characteristics used across studies. Future research should focus on the following areas.

5.1 Early Identification and Intervention in High-Risk ASD Infants

The first three years of life represent the most rapid and critical period for brain development, and early attention deficits may affect brain development and function. In early typical development, infants tend to focus attention on objects or events for extended periods, showing "attentional fixation." However, after 4-6 months, typically developing infants can relatively easily disengage and shift attention, whereas ASD infants seem to show stagnation in this ability. Related research shows differences in attentional disengagement between high-risk and low-risk infants emerge between 6-12 months. From the end of the first year to the beginning of the second year, these differences become apparent within the high-risk infant group, particularly between 12-14 months. Under overlap conditions, high-risk infants later diagnosed with ASD (EL-ASD) require more time to disengage attention from stimuli compared to high-risk typically developing infants (EL-TD), high-risk other outcomes (EL-Other), and low-risk infants (TL) (Canu et al., 2020). Due to early deficits in attentional disengagement ability, profound impacts may occur on later socio-emotional, language communication, and cognitive development. Therefore, revealing the developmental trajectory of early attention in ASD individuals is a fundamental research question, and identifying and effectively intervening early to alter this developmental trajectory has important practical significance.

Current research should further explore to what extent early attentional abnormalities can serve as predictive factors for subsequent ASD diagnosis, whether attentional disengagement difficulties can become an early predictive indicator for ASD diagnosis, and the specific time point at which attentional disengagement deficits emerge. Future research requires prospective longitudinal studies of high-risk ASD infants, particularly between 6-24 months, with multiple time points for longitudinal measurement and tracking to more comprehensively observe developmental trajectories of attentional disengagement over time. Ideally, control cohorts of typically developing infants should be created for comparison of normal and abnormal attentional disengagement developmental trajectories. Additionally, comprehensive diagnosis and identification should combine other behavioral manifestations or early risk markers to develop targeted early intervention strategies and programs for high-risk infants.

5.2 Predictive Specificity of Attentional Disengagement in ASD Individuals

Specificity refers to a symptom manifesting only in a particular disorder and not in others. Future research needs to clarify whether attentional disengagement deficits are specific to ASD or also exist in other developmental disorders, thereby revealing whether attentional disengagement has predictive specificity for ASD. Previous studies have compared attentional disengagement between ASD children and children with intellectual developmental delays (e.g., Down syndrome), but whether individuals with other neurodevelopmental disorders such as attention deficit hyperactivity disorder, learning disabilities, and motor coordination disorders also show attentional disengagement deficits remains unknown. If attentional disengagement difficulties appear only in ASD patients while other disorder patients show normal performance, this would indicate that attentional disengagement abnormalities have predictive specificity for ASD and could serve as a good early predictive indicator.

On the other hand, controversies regarding whether ASD individuals have attentional disengagement deficits may suggest that this indicator' s predictive value for ASD is not all-or-nothing but rather heterogeneous within the ASD population. Some ASD subgroups may show obvious attentional disengagement deficits, while others may have relatively intact attentional disengagement, possibly related to different ASD subtypes. Previous research indicates that different ASD subtypes show clear individual differences in joint attention development, with high-functioning ASD individuals showing no deficits in low-level joint attention while low-functioning ASD individuals show deficits in both low- and high-level joint attention (Mundy et al., 1994). Since attentional disengagement is an essential foundation for joint attention development, does it also show specificity across ASD subtypes? Therefore, exploring the commonalities and specificities of attentional disengagement across different ASD subtypes is an important future research direction. Future studies should further investigate the predictive value of attentional disengagement difficulties for different ASD subtypes to clarify whether attentional disengagement deficits relate to ASD severity rather than developmental level.

5.3 Influencing Factors and Improvement Approaches for Attentional Disengagement in ASD Individuals

Future research also needs to identify methods to improve attentional disengagement difficulties in ASD individuals. If early attentional disengagement deficits are predictive factors for ASD and significantly impact later social behavior and cognitive function development, then early intervention for attentional disengagement in ASD individuals may help improve higher-level social interaction skills. A previous study showed that contingent gaze attention training in 12-month-old typically developing infants increased attention shifting between people and objects during free play, demonstrating improved attention (Ballieux et al., 2016). Therefore, training attentional components (such as orienting, alerting, and executive control) during early social attention development may be important for improving attentional abilities. Previous research also shows that early intervention can successfully improve joint attention abilities in ASD individuals (Whalen & Schreibman, 2003). Future research needs to further explore whether training attentional disengagement can improve joint attention abilities in ASD individuals and whether improvements in attentional disengagement ability are linked to subsequent social function development.

Furthermore, stimulus selection for intervention should consider different stimulus types. Dynamic, multimodal, and non-social stimuli may more easily attract ASD individuals' attention and produce attentional disengagement difficulties. Therefore, in attentional disengagement intervention training for ASD individuals, novel stimulus materials should be selected where central stimulus types are not salient but peripheral stimulus types are salient. During stimulus presentation, the time interval between central and peripheral stimuli should vary with gradient changes from long to short, using an adaptive approach to continuously improve attentional disengagement efficiency in ASD individuals. Second, Keehn et al. (2019) suggest that experimental context may be a potential factor affecting attentional disengagement in ASD, with smaller deficits observed in laboratory settings but potentially large differences in real-life situations that are more diverse, dynamic, engaging, and unpredictable. Regarding training contexts, future research should be conducted in meaningful real-life situations to improve intervention effectiveness and ecological validity.

References

Cai, H. D., & Qi, X. L. (2018). Impaired visual attention disengagement and the occurrence of autism spectrum disorder. *Chinese Journal of Special Education*, 218(8), 41–47.

Yan, G. L., Zhou, L., & Zhang, L. (2019). The gap-overlap paradigm for early prediction of autism spectrum disorder in children. *Journal of Psychological Science*, 42(1), 223–229.

Zhao, X. N., Hu, J. S., Li, S. Z., Liu, X., Liu, Q. Y., & Wu, N. (2019). Early prediction of autism spectrum disorder based on eye-tracking research. *Advances in Psychological Science*, 27(2), 301–311.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596.

Ballieux, H., Wass, S. V., Tomalski, P., Kushnerenko, E., Karmiloff-Smith, A., Johnson, M. H., & Moore, D. G. (2016). Applying gaze-contingent training within community settings to infants from diverse SES backgrounds. *Journal of Applied Developmental Psychology*, 43, 8–17.

Bedford, R., Pickles, A., Gliga, T., Elsabbagh, M., Charman, T., Johnson, M. H., & BASIS Team. (2014). Additive effects of social and non-social attention during infancy relate to later autism spectrum disorder. *Developmental Science*, 17(4), 612–620.

Bryson, S., Garon, N., McMullen, T., Brian, J., Zwaigenbaum, L., Armstrong, V., ⋯& Szatmari, P. (2017). Impaired disengagement of attention and its relationship to emotional distress in infants at high-risk for autism spectrum disorder. *Journal of Clinical and Experimental Neuropsychology*, 40(5), 487–501.

Canu, D., Van der Paelt, S., Canal-Bedia, R., Posada, M., Vanvuchelen, M., & Roeyers, H. (2020). Early non-social behavioural indicators of autism spectrum disorder (ASD) in siblings at elevated likelihood for ASD: A systematic review. *European Child & Adolescent Psychiatry*, 1–42.

Chiang, H. L., Kao, W. C., Chou, M. C., Chou, W. J., Chiu, Y. N., Wu, Y. Y., & Gau, S. S. F. (2018). School dysfunction in youth with autistic spectrum disorder in Taiwan: The effect of subtype and ADHD. *Autism Research*, 11(6), 857–869.

Clifford, S. M., Hudry, K., Elsabbagh, M., Charman, T., Johnson, M. H., & BASIS Team. (2013). Temperament in the first 2 years of life in infants at high-risk for autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 43(3), 673-686.

Colombo, J., & Cheatham, C. L. (2006). The emergence and basis of endogenous attention in infancy and early childhood. *Advances in Child Development and Behavior*, 34, 283-322.

Elison, J. T., Paterson, S. J., Wolff, J. J., Reznick, J. S., Sasson, N. J., Gu, H., ··· & Gerig, G. (2013). White matter microstructure and atypical visual orienting in 7-month-olds at risk for autism. *American Journal of Psychiatry*, 170(8), 899-908.

Elsabbagh, M., Volein, A., Holmboe, K., Tucker, L., Csibra, G., Baron Cohen, S., ···& Johnson, M. H. (2009). Visual orienting in the early broader autism phenotype: Disengagement and facilitation. *Journal of Child Psychology and Psychiatry*, 50(5), 637-642.

Elsabbagh, M., Fernandes, J., Webb, S. J., Dawson, G., Charman, T., Johnson, M. H., & British Autism Study of Infant Siblings Team. (2013). Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. *Biological Psychiatry*, 74(3), 189-194.

Fischer, J., Koldewyn, K., Jiang, Y. V., & Kanwisher, N. (2014). Unimpaired attentional disengagement and social orienting in children with autism. *Clinical Psychological Science*, 2(2), 214-223.

Fischer, J., Smith, H., Martinez Pedraza, F., Carter, A. S., Kanwisher, N., & Kaldy, Z. (2016). Unimpaired attentional disengagement in toddlers with autism spectrum disorder. *Developmental Science*, 19(6), 1095-1105.

Franchini, M., Glaser, B., Wood de Wilde, H., Gentaz, E., Eliez, S., & Schaer, M. (2017). Social orienting and joint attention in preschoolers with autism spectrum disorders. *PLOS ONE*, 12(6), e0178859.

Glennon, J. M., D' Souza, H., Mason, L., Karmiloff-Smith, A., & Thomas, M. S. (2020). Visuo-attentional correlates of Autism Spectrum Disorder (ASD) in children with Down syndrome: A comparative study with children with idiopathic ASD. *Research in Developmental Disabilities*, 104, 103678.

Goldberg, M. C., Lasker, A. G., Zee, D. S., Garth, E., Tien, A., & Landa, R. J. (2002). Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. *Neuropsychologia*, 40(12), 2039-2049.

Goodwin, A., Matthews, N. L., & Smith, C. J. (2017). The effects of early language on age at diagnosis and functioning at school age in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 47(7), 2176-2188.

Johnson, B. P., Lum, J. A., Rinehart, N. J., & Fielding, J. (2016). Ocular motor disturbances in autism spectrum disorders: Systematic review and comprehensive meta-analysis. *Neuroscience & Biobehavioral Reviews*, 69, 260–279.

Jones, E. J., Gliga, T., Bedford, R., Charman, T., & Johnson, M. H. (2014). Developmental pathways to autism: A review of prospective studies of infants at risk. *Neuroscience & Biobehavioral Reviews*, 39, 1-33.

Kawakubo, Y., Kasai, K., Okazaki, S., Hosokawa-Kakurai, M., Watanabe, K. I., Kuwabara, H., ···& Maekawa, H. (2007). Electrophysiological abnormalities of spatial attention in adults with autism during the gap overlap task. *Clinical Neurophysiology*, 118(7), 1464–1471.

Keehn, B., Kadlaskar, G., Keehn, R. M., & Francis, A. L. (2019). Auditory attentional disengagement in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49(10), 3999–4008.

Keehn, B., Müller, R. A., & Townsend, J. (2013). Atypical attentional networks and the emergence of autism. *Neuroscience & Biobehavioral Reviews*, 37(2), 164–183.

Kleberg, J. L., Thorup, E., & Falck Ytter, T. (2016). Reduced visual disengagement but intact phasic alerting in young children with autism. *Autism Research*, 10(3), 539–545.

Kikuchi, Y., Senju, A., Akechi, H., Tojo, Y., Osanai, H., & Hasegawa, T. (2011). Atypical disengagement from faces and its modulation by the control of eye fixation in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 41(5), 629–645.

Landry, R., & Bryson, S. E. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry*, 45(6), 1115–1122.

Mo, S., Liang, L., Bardikoff, N., & Sabbagh, M. A. (2019). Shifting visual attention to social and non-social stimuli in Autism Spectrum Disorders. *Research in Autism Spectrum Disorders*, 65, 56–64.

Mundy, P., Sigman, M., & Kasari, C. (1994). Joint attention, developmental level, and symptom presentation in autism. *Development and Psychopathology*, 6(3), 389–401.

Mundy, P. (2003). Annotation: The neural basis of social impairments in autism: The role of the dorsal medial-frontal cortex and anterior cingulate system. *Journal of Child Psychology and Psychiatry*, 44(6), 793–809.

Pierrot-Deseilligny, C. H., Rivaud, S., Gaymard, B., & Agid, Y. (1991). Cortical control of reflexive visually-guided saccades. *Brain*, 114(3), 1473–1485.

Posner, M. I., Rothbart, M. K., & Voelker, P. (2016). Developing brain networks of attention. *Current Opinion in Pediatrics*, 28(6), 720.

Sabatos-DeVito, M., Schipul, S. E., Bulluck, J. C., Belger, A., & Baranek, G. T. (2016). Eye tracking reveals impaired attentional disengagement associated with sensory response patterns in children with autism. *Journal of Autism and Developmental Disorders*, 46(4), 1319-1333.

Sacrey, L. A. R., Armstrong, V. L., Bryson, S. E., & Zwaigenbaum, L. (2014). Impairments to visual disengagement in autism spectrum disorder: A review of experimental studies from infancy to adulthood. *Neuroscience & Biobehavioral Reviews*, 47, 559-577.

Sanchez, M. S., Pettersson, E., Kennedy, D. P., Bölte, S., Lichtenstein, P., D' Onofrio, B. M., & Falck-Ytter, T. (2019). Visual disengagement: Genetic architecture and relation to autistic traits in the general population. *Journal of Autism and Developmental Disorders*, 50(6), 2188-2200.

Sasson, N. J., & Touchstone, E. W. (2014). Visual attention to competing social and object images by preschool children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 44(3), 584-592.

Schietecatte, I., Roeyers, H., & Warreyn, P. (2012). Exploring the nature of joint attention impairments in young children with autism spectrum disorder: Associated social and cognitive skills. *Journal of Autism and Developmental Disorders*, 42(1), 1-12.

Todd, J., Mills, C., Wilson, A. D., Plumb, M. S., & Mon-Williams, M. A. (2009). Slow motor responses to visual stimuli of low salience in autism. *Journal of Motor Behavior*, 41(5), 419-426.

Van der Geest, J. N., Kemner, C., Camfferman, G., Verbaten, M. N., & van Engeland, H. (2001). Eye movements, visual attention, and autism: A saccadic reaction time study using the gap and overlap paradigm. *Biological Psychiatry*, 50(8), 614-619.

Wang, Q., Hu, Y., Shi, D., Zhang, Y., Zou, X., Li, S., ···& Yi, L. (2018). Children with autism spectrum disorder prefer looking at repetitive movements in a preferential looking paradigm. *Journal of Autism and Developmental Disorders*, 48(8), 2821-2831.

Whalen, C., & Schreibman, L. (2003). Joint attention training for children with autism using behavior modification procedures. *Journal of Child Psychology and Psychiatry*, 44(3), 456-468.

Wilson, C. E., & Saldaña, D. (2018). No evidence of atypical attentional disengagement in autism: A study across the spectrum. *Autism*, 23(3), 677-688.

Zalla, T., Seassau, M., Cazalis, F., Gras, D., & Leboyer, M. (2018). Saccadic eye movements in adults with high-functioning autism spectrum disorder. *Autism*, 22(2), 195-204.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International*

Journal of Developmental Neuroscience, 23(2-3), 143-152.

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