Attentional atypicalities in autism spectrum disorder and the broader autism phenotype

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Abstract

Although attentional differences are not core symptoms of Autism Spectrum Disorder (ASD), attentional atypicalities are often found amongst children and adults with ASD, and even linked to the development of ASD symptoms. In this theoretical paper, early attentional differences seen in ASD such as attention disengagement will be discussed. Further perceptual differences are also revised, concerning atypical attention allocation and perception of faces and social stimuli, and the processing of global and local features. The theory of executive function in ASD is briefly revised, contrasting to evidence of enhanced performance in visuospatial tasks, bringing a new theoretical framework (Dual Mechanism of Control theory) to explain discrepancies in performance in ASD and the Broader Autism Phenotype. Finally, the concept of attentional training in ASD is also suggested as a viable intervention to bring generalized improvements to children with ASD.

Keywords

Autism Spectrum Disorder. Attention. Perception. Broader Autism Phenotype. Intervention.

INTRODUCTION

Autism Spectrum Disorder (ASD) or autism is a neurodevelopmental condition diagnosed on the basis of two behavioral impairments: 1. impaired social interaction, including difficulties in communication and 2. restricted and repetitive interests and activities. Under these two behavioral impairments, according to the DSM-5 (AMERICAN PSYCHIATRIC ASSOCIATION, 2013) ASD

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involves not only these multiple deficits, but the new diagnostic criteria specify that a person with autism must show problems reciprocating social or emotional interaction, problems maintaining relationships, and non-verbal communication impairments. The individual must also present two of the following deficits: extreme attachment to routines and patterns and resistance to change in routines; repetitive speech or movements; intense and restrictive interests; problems integrating sensory information, hyper or hypo reaction to sensory input or strange interest in sensory aspects of the environment.

Importantly, autism tends to be heterogeneous in its presentation, but various atypical attentional processes are often found amongst individuals with ASD, with accounts of early impairments in attention disengagement linked to the development of ASD symptoms (KEEHN; MÜLLER; TOWNSEND, 2013). In this theoretical review, pertinent issues within the attention and ASD literature will be covered, starting with early deficits on the disengagement of attention, which combined with atypical attention towards socially relevant information in autism, might contribute to symptoms seen in ASD. This review also covers findings regarding global versus local processing and advantage in visual-spatial tasks seen in ASD, linking these findings together, bringing a new theoretical framework (Dual Mechanism of Control theory) to better understand differences in performance of individuals with ASD in visual attention in the literature. Findings regarding attention in the Broader Autism Phenotype (BAP) and the potential impacts of attentional training in children with ASD are also discussed.

AUTISM AND DISENGAGEMENT OF ATTENTION

Attention itself is a broad construct which may involve a variety of processes, but in the context of ASD, previous research highlighted early deficits in switching or shifting attention (which involves disengaging from one item and moving and engaging attention with another) as a source of such atypicality. It was recently argued (SACREY et al., 2014) that toddlers with autism and its broader phenotype show impairments in the disengagement and shifting of attention that are present from the first year of life. Retrospective analysis of home videos of later diagnosed children with ASD and prospective analysis of at-risk infant siblings have shown impairments on disengaging and shifting of attention before the first birthday (KEEHN; MÜLLER; TOWNSEND, 2013). In a longitudinal study involving 65 siblings of older children with a diagnosis of ASD, at-risk infants between 6 and 12 months were tested in a visual orienting task. Once a child was engaged in a central fixation point, another stimulus appeared to the left or right side of the original fixation. Latencies to begin an eye movement to the outer stimuli were measured. High-risk infants demonstrated longer latencies to disengage from the central stimulus compared to a low-risk control group. The high-risk infants who showed longer latencies received an ASD diagnosis later at 24 months (ZWAIGENBAUM et al., 2005). Elsabbagh et al. (2009) also found that 9-10 months old siblings of children with ASD showed longer latencies of attention disengagement and less response to a facilitation cue in comparison to controls. Early deficits in disengaging attention may lead infants to focus on only one aspect of the environment, missing out on top-down visual exploration. In turn, attention could develop to be focused on stimuli of ASD interest (such as non-social information). This might lead to difficulties initiating or responding to joint attention, as joint attention means the child needs to be able to disengage from an object and follow the gaze of the caregiver. This, in turn, could result in deficits related to social interaction seen in ASD (see KEEHN; MÜLLER; TOWNSEND, 2013; SACREY et al., 2014, for a review).

Children, adolescents, and adults with ASD also seem to show slower, less efficient visual disengagement and shifting of attention. Landry and Bryson (2004) measured eye-movements towards a peripheral target following a fixation point. Using a gap-overlap task, they measured the latency to begin an eye movement from a central fixation point to peripheral stimuli. In the gap trials, the initial fixation point disappears at the onset of peripheral stimuli. In the overlap trials, both remain on screen. ASD children took significantly longer to disengage visual attention in the overlap trials compared to controls, while similar response latencies were observed for the gap trials (LANDRY; BRYSON, 2004). The authors suggest the difficulty in disengagement might be due to an over-focused and/or narrowed focus of attention directed to the stimuli. Goldberg et al. (2002) also used a gap-overlap task and found similar results in adolescents with ASD who showed increased reaction times in the overlap condition in comparison to a control group. Finally, Kawakubo et al. (2004, 2007) reported similar findings in adults with ASD as long as more "interesting" figures (vehicles, house objects or animals) were used in the periphery. The authors also found increased pre-saccadic ERP activation, suggesting more resources needed for attention allocation in disengagement in the overlap condition, for the ASD group (KAWAKUBO et al., 2007).

Contrary to other reports of difficulties in disengaging attention in ASD, a null effect in attentional disengagement and social orienting in children with ASD was also reported in a recent study (FISCHER et al., 2014) using an eye-tracking task. In this task, a face or object appeared in the center or periphery of the screen, and children had to disengage attention from the first central stimuli to shift it to the periphery while the central object remained (disengage trials) or disappeared (shift trials). Children were instructed to look at the objects on the screen, and attention disengagement was measured in saccadic reaction time (time from the onset of peripheral stimuli to first eye movement towards it). The authors reported no group difference in disengaging attention or in orienting attention to social images or objects, between ASD and IQ matched controls (FISCHER et al., 2014).

Studies show that ASD participants are quicker (or similar to typically developing controls; TD) to disengage when social stimuli are employed, possibly because faces and social features are less engaging to individuals with ASD (see SACREY et al., 2014 for a review paper). In a gap overlap task, Kikuchi et al. (2011) investigated disengagement using faces and objects with children and adolescents with autism and a matching TD group. The ASD group showed no differences in disengaging between objects or faces (measured in saccadic reaction time) whereas the TD group showed a more significant gap effect for faces, linked to an attentional engagement that was not found in the ASD participants. Interestingly, in a follow-up study in which fixation to the eyes was instructed, this elicited a more substantial gap effect for faces in children with ASD, and instructed fixation to the mouth in TD participants elicited a smaller gap effect for faces in that group, reversing the previous findings according to task instructions (KIKUCHI et al., 2011). This indicates that when following clear task instructions (e.g., fixation to the eyes or mouth), performance in ASD and TD children can be reversed. One attempt to explain these supposedly opposing effects was proposed by Sacrey et al. (2014), who suggested that successful disengagement of attention in ASD might depend on sufficiently long ISIs (inter-stimulus-interval). Thus, with enough time people with ASD can better regulate top-down processes.

Although the results are mixed when it comes to the disengagement of attention in ASD, there is evidence that endogenous, as well as exogenous spatial attention, seem to be intact in high functioning adults with ASD. Exogenous attention is involuntary, stimuli-driven and activated by a sudden appearance of stimuli in the visual field, while endogenous attention involves top-down, self-directed and voluntary attentional guidance. Grubb et al. (2013a) conducted a study using three different visuospatial tasks measuring contrast sensitivity using a peripheral precue to manipulate exogenous attention with a 1. valid, invalid or neutral cue; 2. reduction of distractor crowding in the visual periphery; and 3. improvements in visual search. High-functioning adults with autism performed as well as the control group showing enhancement of performance when provided with a peripheral precue (GRUBB et al., 2013a). Using an orientation discrimination task with Gabor patches, Grubb et al. (2013b) investigated endogenous attention in high functioning adults with autism and controls. The tasks had three different versions with varying ISI (650 ms or 50 ms), valid and neutral precues and a response cue. The stimuli placeholder boxes were manipulated in size to control for high or low spatial uncertainty. Although overall there were no differences in reaction time or accuracy between the ASD and control group, pointing to intact endogenous spatial attention in autism, ASD participants showed slower reaction time with spatial uncertainty. This finding might indicate that people with autism need more time to process and react to stimuli under conditions of uncertainty (GRUBB et al., 2013b).

Overall, findings in disengagement of attention in ASD point towards difficulties disengaging from stimuli since an early age, which might only be present in adults with the disorder under certain conditions, such as uncertainty. Differences in disengagement might also be apparent when allocating attention towards social content and faces.

ATTENTION ALLOCATION IN THE CONTEXT OF FACES

In addition to difficulties in attention disengagement seen in ASD, attention atypicalities have been particularly evident in people with autism in the context of face processing, often with less attention directed to faces (e.g., BEHRMANN; THOMAS; HUMPHREYS, 2006; RIBY; HANCOCK, 2009). Many studies have documented reduced eye movements towards faces in people with autism, showing increased eye gaze towards the mouth and less to the eye area (PELPHREY et al., 2002; KLIN et al., 2002). Bird et al. (2006) conducted a fMRI study investigating the modulation of attention in participants with ASD towards houses and faces. ASD participants showed diminished attention modulation towards social stimuli, but not houses. These results indicate a lack of salience for social stimuli, such as faces, in individuals with autism (BIRD et al., 2006). Riby and Hancock (2009) used an eye-tracking experiment measuring spontaneous eye gaze towards faces embedded in scenes and found that participants with ASD showed reduced gaze towards faces (measured in fixation length) in comparison to TD controls, which the authors linked to a lack of interest in the social information. In this task, an "incongruent" face was inserted in a typical image of a scene (incongruent here meaning a face being inserted in a manner that does not typically occur). ASD participants were not captured by the incongruent-social element as controlled, suggesting an underlying atypical attentional mechanism in how participants with autism responded to images including faces when these are also distracting incongruent elements. In a review of the neural and cognitive mechanisms involved in face processing in autism, Behrmann et al. (2006; BEHRMANN; THOMAS; HUMPHREYS, 2006), argued that face processing impairments occur due to core perceptual alterations, possibly due to an atypical attentional bias to local features of stimuli that could be combined with the social disinclination seen in ASD.

It has been suggested that people with ASD show a bias towards local processing, which could also explain the intact discrimination of faces. Deruelle et al. (2008) investigated face processing strategies where participants had to match a set of different faces according to gender, emotion, and identity. While children with ASD did not differ from the control group for gender identity (which relies on a holistic approach), they seemed to rely on local facial elements to differentiate between identity and emotion. This is in accordance with theories suggesting that people with autism utilize atypical local-oriented strategies when processing faces (DERUELLE et al., 2004). In accordance with this approach, participants with autism show less activation in the fusiform gyrus when presented with faces (SCHULTZ et al., 2000). In TD individuals, this area is activated when processing faces as a whole. This suggests that ASD participants may rely on a local, rather than a holistic approach to process faces.

Furthermore, there is evidence of intact face discrimination and deficits in performance in ASD participants only appear when there is a need to recognize emotions or attribute mental states to faces. Adolphs, Sears, and Piven (2006) carried out a study with eight high functioning adults with autism, using tasks involving recognition of emotional and social stimuli. They found that the ASD group showed atypical social judgments regarding faces, similar to patients with amygdala damage, but intact expressed ability to physically discriminate between the stimuli, pointing to a deficit in social comprehension but not low-level face processing. Humphreys et al. (2007) conducted a study showing different faces and emotion labels, and participants had to identify the equivalent emotion corresponding to the facial expression. ASD participants performed as well as the control group at identifying the correspondent emotion to the face (except for the emotion of "fear") and differentiating between the faces. As no deficits were differentiating the facial expressions, it was suggested that the impairment might be linguistic (associating the emotion label, e.g. "fear" to the face expression). Also, as suggested in the previous paragraphs, the findings might be linked to a local bias, where ASD participants would focus on a particular part of the faces, in this case, the authors argued that they would avoid the eye area (found to be involved in recognition of the emotion "fear"), and focus on the mouth in order to differentiate between varied face expressions.

There is a body of research on the neural correlates of face processing in autism and, although it is agreed that faces elicit atypical responses in ASD, findings point to different possible brain abnormalities, with different neural correlates being active in participants with autism in comparison to TD when responding to faces and social stimuli. In neurotypical individuals, the recognition of familiar objects and social stimuli comprises neural correlates such as the inferotemporal cortex, superior temporal sulcus or the amygdala. It is suggested that this correlates modulate early visual areas and feed into the control of spatial attention and eye movements in the prefrontal cortex (TREUE, 2003). Differently, in autism, the cerebral cortex (inferior frontal cortex, inferior parietal lobe, superior temporal gyrus) has been found to be thinner in areas involving social cognition. Hypoactivation was also found in face-processing areas (right amygdala, inferior frontal cortex, superior temporal sulcus, and face-related somatosensory and premotor cortex (HADJIKHANI et al., 2006, 2007; PELPHREY; MORRIS; MCCARTHY, 2005). Although the fusiform gyrus shows hypoactivation in participants with ASD when responding to faces (HALL; SZECHTMAN; NAHMIAS, 2003; HUBL et al., 2003; PIGGOT et al., 2004; WANG et al., 2004), it has been demonstrated that when viewing highly familiar faces, the fusiform gyrus is activated in autism (AYLWARD et al., 2004; PIERCE et al., 2004). This suggests that individuals with ASD respond differently when viewing familiar *versus unfamiliar faces, showing relatively "typical" responses to highly familiar faces (*GILLESPIE-SMITH et al., 2014) but impairments when responding to unfamiliar faces (RIBY; DOHERTY-SNEDDON; BRUCE, 2009). This shows that brain and behavioral differences are present in ASD compared to TD only when processing socially relevant information from unfamiliar faces.

Another neural correlate related to differences in face processing in autism is the amygdala. The amygdala seems to be involved in core social impairments found in autism, due to its atypical function and structural abnormalities seen in people with ASD (e.g., ADOLPHS; SEARS; PIVEN, 2006; KLEINHANS et al., 2009; LOMBARDO; CHAKRABARTI; BARON-COHEN, 2009). The amygdala encompasses processes related to emotion, memory and decision making and in the context of autism and face processing, it might be related to a deficit in extracting the emotional information from faces. Indeed, anatomical abnormalities in the amygdala were documented in ASD with evidence of reduced volume and activation in a functional MRI study investigating the perception of faces in ASD (PIERCE et al., 2001). In this study, the fusiform gyrus, inferior occipital gyrus, and superior temporal sulcus also showed reduced activation, but no anatomical differences. Interestingly, participants with ASD performed as well as controls on the task, but none of the regions typically found to be active during face processing in TD were significantly active in ASD individuals, which implies that people with ASD use a different neural system when responding to faces (PIERCE et al., 2001). Individual-specific neural sites in ASD participants (e.g., frontal cortex, primary visual cortex) were found to be active when processing faces, in contrast to the traditional fusiform face area that is active in TD (PIERCE et al., 2001).

However, despite the different neural correlates that are active in ASD in comparison to TD when processing faces, attention towards faces can be effectively cured in ASD (for example, using clear task instructions as mentioned above in KIKUCHI et al., 2011) to show a more "typical" allocation pattern (BAR-HAIM et al., 2006). In a study looking at attention directed to the mouth and eye area in neutral and static faces, participants were instructed to respond to the location of a probe presented either on the eyes or mouth of 16 different faces. The face was presented for 1500 ms after the probe offset. High functioning boys with ASD allocated attention firstly to the eye area and not the mouth, and disengaged from the eyes similarly to controls (BAR-HAIM et al., 2006).

Typical attention allocation towards faces is also seen in van der Geest et al. (2002) research, where it is suggested that both ASD and TD children would direct their first looks to the eye area when viewing static faces. Loth, Gómez, and Happé (2010) also found that ASD participants directed as much eye gaze as the control group towards the eyes in greyscale face stimuli. Riby et al. (2013) used eye-tracking to measure the gaze behavior of ASD children and adolescents, presenting pictures showing people, eye cues and plausible and implausible target objects. While participants with autism showed eye gaze towards the face and eyes, they did not seem to follow eye cues to look at right targets and looked much more at implausible targets, showing difficulties when naming items, related to socio-communicative deficits. Thus, the authors suggested that atypicalities in face processing in autism might not be due to an impaired allocation of attention to parts of the face due to intact performance but social impairments. It is arguable that previous findings of abnormal gaze orienting to the eye area might be the result of the nature of static face stimuli *versus more naturalistic and dynamic social scenes. In a recent review of eye-gaze findings and orienting of attention towards faces,* Guillon et al. (2014) does not find enough evidence of deficits in face processing and suggests that ASD individuals do not demonstrate a generalized deficit in attentional engagement towards faces but that it is context-dependent. The contradictory findings regarding eye-gaze could also be explained by later avoidance, problems in disengagement or lack of interest in social stimuli (e.g., eyes not being as naturally salient for people with ASD in comparison to TD individuals; BIRD et al., 2006).

Also, the manipulation of the task could influence the performance of ASD participants, exhibiting intact attention allocation towards faces when clear task instructions and more availability of time are employed (e.g., BAR-HAIM et al., 2006). Individuals with ASD were, in fact, able to recognize different images of faces, showing that low-level perceptual atypicalities did not seem to underlie facial recognition (ADOLPHS; SEARS; PIVEN, 2006; HUMPHREYS et al., 2007). Atypicalities in face processing found in autism seem to be linked to impairments in spontaneously directing eye gaze to faces (RIBY; HANCOCK, 2009) but not when clear task instructions are given (BAR-HAIM et al., 2006; FISCHER et al., 2014; KIKUCHI et al., 2011). Impairments in face processing also seem to occur when ASD participants need to link faces to emotions (e.g., “fear”), or when experiments require social or verbal constructs, but not when discriminating between faces (ADOLPHS; SEARS; PIVEN, 2006; HUMPHREYS et al., 2007). These impairments found in research are directly related to difficulties in social skills (e.g., directing spontaneous eye-gaze to faces or parts of the face, following eye-gaze, recognizing emotions), which are core impairments found in ASD. These social skills are not utilized in visual tasks when performance of ASD participants is intact, particularly in experiments making use of clear instructions and static and neutral faces (e.g., BAR-HAIM et al., 2006). Atypicalities in attention allocation towards faces in ASD might also be related to enhanced attention to details and/or difficulties with processing global information, further explored in the following section.

GLOBAL AND LOCAL PROCESSING IN AUTISM

Not only face processing seems to be atypical in ASD, but there are also accounts of difficulties in processing global information and a bias towards the local level of stimuli in this disorder. Images or stimuli usually contain a local (smaller parts) and a global (the small parts put together to form the whole) feature. Earlier studies on global and local processing suggested that perception follows a global-to-local path where global level processing tends to precede local processing in TD individuals (NAVON, 1977). It was later found, however, that such global precedence can be altered by manipulating various properties of the stimuli (e.g., the difference in salience or number of local elements) and that such properties can determine whether global or local aspects are attended to first (e.g., MEVORACH et al., 2010). In contrast to TD individuals, Mottron and Belleville (1993) suggested that persons with autism demonstrate detail-focused processing. Specifically, ASD individuals were believed to show a reversal of the typical Navon (1977) direction of interference: from the local to the global level (MOTTRON; BELLEVILLE, 1993). In an early study, the authors tested this hypothesis in a case study with one participant with autism with exceptional graphics abilities, who was presented with a series of hierarchically structured stimuli formed by large letters constructed of small letters. While the ASD patient showed comparable global interference to participants without autism, he also exhibited signs of interference from local to global (local interference) which were not evident for the controls (MOTTRON; BELLEVILLE, 1993). The authors concluded that although individuals with autism process the global level in a normal way, it does not have any special hierarchical precedence over the local processing (MOTTRON; BELLEVILLE, 1993) as initially found in TD adults (NAVON, 1977). Later on, Plaisted, Swetteham, and Rees (1999) further investigated hierarchical precedence from the global or the local level in children with ASD using a variation of the global-local task from Navon (1977). It was found that both ASD and TD groups were quicker at responding to the global target, pointing to normal global processing in children with ASD, although children with autism had more errors at the global target level, in comparison to the control group, which presented more errors for the local condition (PLAISTED; SWETTENHAM; REES, 1999).

The notion of local bias and difficulties in the global processing in ASD was further investigated by Wang et al. (2007). The authors used a task where participants had a free-choice or forced choice for the global or local level in a Navon-like task. In the free-choice task, participants with ASD showed no preference for level but were faster at the local condition. The opposite was found in controls, who were faster for the global condition. In the forced choice task, participants with ASD showed local-to-global interference, whereas controls showed a global advantage and interference from both levels. Results indicate normal global processing, no hierarchical precedence but a local bias with local interference in individuals with ASD (WANG et al., 2007). Similar findings are reported by Koldewyn et al. (2013); using the same free-choice and forced-choice task, they found that children with ASD showed less preference to report the global stimuli when given a choice, but their ability to process global properties when instructed to do so was intact. In turn, Kana et al. (2013) found similar performance between TD and ASD adults in global and local processing, although different neural correlates were active in the autism group. Similarly, D'Souza et al. (2016) did not find consistent evidence of local bias in ASD, and in fact, suggest that a local or global inclination might be due to the different types of stimuli utilized in research. Finally, Booth and Happé (2018) found that participants with ASD needed more time than TD to complete integration of geometrical figures, suggesting difficulty integrating information into a meaningful whole and requiring more effort to do so.

Taken together, findings on global and local processing seem to show that individuals with ASD can process global information as well as TD if instructed to do so, but might need more time and show a preference, or advantage and interference from the local level (BOOTH; HAPPÉ, 2018; KOLDEWYN et al., 2013; MOTTRON; BELLEVILLE, 1993; PLAISTED; SWETTENHAM; REES, 1999; WANG et al., 2007). There are different possible explanations for the local bias in autism, some suggesting that more extended fixation to elements in early infancy could be related to difficulties in disengagement of attention, and/or more time needed to process information culminating in a detail-oriented style of processing. Plaisted, Swettenham e Rees (1999) argued that local bias might be related to a deficit in shifting attention from the local to the global level. If there is a local processing bias, children may find it difficult to disengage attention from local features of stimuli and to shift it to their global properties, making more errors processing the global target (PLAISTED; SWETTENHAM; REES, 1999). In their case study, Mottron and Belleville (1993) also suggested that the atypicalities found in local to global precedence might be due to an impairment in disengaging and switching attention between the two levels. Research on typically developing infants investigating the mechanism underlying fixation duration has demonstrated that "long lookers" tend to show a local processing bias and seem to process visual information more slowly in comparison to "short-looking" infants (COLOMBO et al., 1995). One possible explanation for increased fixation duration seen in "long lookers" may be difficulties in the disengagement of attention. Besides, Colombo et al. (1995) found that TD "short-lookers" infants processed global information before local properties, similar to findings in the non-ASD population. TD infants with more extended fixation to stimuli seemed to show similar performance to infants who had increased fixation durations to stimuli, took longer to disengage attention and were later diagnosed with ASD (ELSABBAGH et al., 2009; ZWAIGENBAUM et al., 2005), showing a link between attention to details, disengagement of attention and longer fixation times to stimuli related to the autism phenotype since early infancy. The relationship between these different attentional functions and ASD is further discussed in the section below.

A BRIEF ACCOUNT OF EXECUTIVE FUNCTION IN AUTISM

Attention atypicalities in ASD may also be considered within the broader context of Executive control (EC), which is comprised of multiple overlapping systems, responsible for inhibition, planning, error monitoring, working memory or set shifting. Although there are accounts of impaired EC in ASD, it does not seem that all components of executive function are impaired in children with autism. Children with ASD exhibited impairments specifically in response monitoring in a cognitive estimation task, related to problems in cognitive flexibility (LISS et al., 2000), and response monitoring and performance on a battery of cognitive tests improved with age, reaching TD levels (HAPPÉ et al., 2006). Distractor inhibition alone was previously found to be intact in autism (KLEINHANS; AKSHOOMOFF; DELIS, 2005; OZONOFF; STRAYER, 1997), although different brain areas are utilized to respond to the same demands (KALDY et al., 2016). Difficulties in inhibition seem to appear particularly when more task demands, such as working memory, are involved

(GOWEN; HAMILTON, 2013; LUNA et al., 2007; RINEHART et al., 2002; SACHSE et al., 2013).

According to Keehn Müller, and Townsend (2013), ASD may be characterized by poorer performance in complex executive control tasks, which might be caused by a dysfunction of the modulation and regulation of arousal – possibly with subgroups of hyper and hypo-arousal (WATTS; RODGERS; RIBY, 2016). A state of hyper-arousal has been suggested to lead to over-focused attention found in ASD (LISS et al., 2006). In a study using a range of questionnaires with parents of 144 children with autism measuring sensory behavior and attention profile, Liss et al. (2006) found a pattern predicting overfocused attention and sensation, specifically comprising items regarding overreactivity, perseverative behavior and interests, overfocused attention and exceptional memory. In this paper, it is suggested that early impairments in arousal regulation may cause individuals with ASD to rely on less self-regulation to mediate hypo or hyper-arousal, which can result in inefficient executive control function. Increased sensory arousal, in turn, can result in a narrowed attentional focus ("overfocus"), in an attempt to filter out other sensory inputs. Indeed, such an overly narrow focus of attention could potentially be linked to the local processing inclination seen in autism. This developmental framework of sensorial and attentional functions could also have broader impacts on the development of ASD symptoms (KEEHN; MÜLLER; TOWNSEND, 2013). Overall, difficulties in EC are broadly documented in ASD, more often seen in complex tasks involving more than one executive function, but not always found when only one function is utilized, such as inhibition. In fact, there are reports of enhanced visual attention performance found in ASD.

ENHANCED PERFORMANCE IN VISUOSPATIAL TASKS

Attention atypicalities in ASD may also lead to benefit in certain tasks. For instance, over-focused attention could be beneficial when participants perform visuospatial tasks that require attention to small elements, such as visual search and learning patterns, which have been shown to be better performed in ASD compared with controls (see DAKIN; FRITH, 2005 for a review). Indeed, there are accounts of enhanced discrimination skills for visual stimuli in people with autism (BROWN; BEBKO, 2011). This ability can be seen in visual search tasks, where participants with ASD performed better than controls when asked to find a target hidden among distracting stimuli, showing the ability to differentiate between them, even when target and distractor are highly similar.

O'Riordan et al. (2001), for example, tested children with autism against matched controls in a conjunctive search task (where target and distractor share similar features), and a hard feature search task, where participants had to discriminate between a tilted line amidst vertical distractors. They found that children with autism were more accurate and showed faster responses in both visual search tasks. The authors attribute this enhanced ability to superior discrimination skills between items, and/or better inhibition of irrelevant distractors. O'Riordan (2004) also employed three visual search tasks in adults with autism and matched controls and found that ASD participants showed superior searching abilities, and were less affected by the increasing similarity between target and distractor (ASD participants did not reduce speed as much as controls). Results indicate that adults with autism also show superior visual discrimination ability (O'RIORDAN, 2004). The increased capacity for visuospatial processing in ASD was also demonstrated by Remington et al. (2009) who used a perceptual load paradigm (LAVIE, 1995) to test attentional selection in ASD. Findings in this study showed that even with higher levels of perceptual load ASD participants performed at the level of low perceptual load in TD participants. In this research, it is suggested that people with autism may have an advantage in perceptual skills, which contributes to an enhanced visual search ability, evidenced by the processing of a higher number of distractors in comparison to controls (REMINGTON et al., 2009).

Furthermore, Brian et al. (2003) did not find significant reaction time differences between ASD and control groups when they were detecting a target while inhibiting distractors. The authors investigated selective distractor inhibition of spatial location with a negative priming task in which individuals with autism were instructed to detect a target, which matched to a primed color while inhibiting responses to a co-occurring distractor. The ability to selectively inhibit a task-relevant distractor was intact in ASD, and the irrelevant feature of color produced a facilitation effect. These results suggest enhanced performance in visual tasks that require not only low-level perceptual abilities but also distractor suppression in individuals with ASD, supporting the notion that individuals with autism excel in visual tasks in comparison to typically developing peers when inhibition is required (DAKIN; FRITH, 2005; O'RIORDAN et al., 2001; O'RIORDAN, 2004; REMINGTON et al., 2009).

Different theories, including the Enhanced Perceptual Functioning or EPF (MOTTRON et al., 2006) and the Weak Central Coherence – WCC (HAPPÉ, 1999), have been proposed to explain these atypicalities. The EPF theory argues that enhanced performance in visuospatial tasks is due to differences in low-level perceptual abilities that are overdeveloped and enhanced, based on a local processing bias. The WCC hypothesis also points to a detail focused cognitive style in autism coming from a difficulty in extracting meaning from complex situations that require a more holistic approach. Happé (1999) also suggests that the local processing bias can be overcome in tasks that require global processing with explicit demands. Both theories propose that enhanced ASD performance in visuospatial tasks is due to, at least in part, a local processing bias and individuals with autism might find it easier to focus on local pieces of information, thus benefiting performance when such ability can be used. In sum, there are reports of enhanced performance in visuospatial tasks in ASD involving discrimination skills, visual search, and distractor inhibition, often attributed to a detail-focused style of processing. The same advantage can also be found in TD adults without a diagnosis of ASD but with the presence of increased autistic-like traits, a new route that is being explored in recent research: the Broader Autism Phenotype (BAP).

AUTISTIC TRAITS IN THE TD POPULATION

Although research in autism and attention mainly focuses on the clinical population, there is a growing body of research on how great autistic traits present in the neurotypical population manifest for those who do not have a diagnosis of ASD, in the Broader Autism Phenotype (BAP). There are reports suggesting that people with a high amount of self-reported autistic traits show a better performance in comparison to those with a low amount of autistic traits, in various visual search tasks (ALMEIDA et al., 2013; BROCK; XU; BROOKS, 2011; MILNE et al., 2013). There are also accounts for enhanced discrimination skills in individuals with high autistic traits, related to a possible increase in levels of GABA (DICKINSON; JONES; MILNE, 2014), while parents of children with autism showed a similar profile of sensory alterations to their children (GLOD et al., 2017; RONCONI et al., 2014). Considering autism as a continuum, ranging from very low autistic traits to ASD, autistic-like traits should also be present in varying degrees in the standard population (BARON-COHEN et al., 2001). In fact, a recent study found similar neural structural differences in reduction of cortical thickness in ASD and higher degrees of autistic traits in TD participants, showing that the neural differences found in ASD extend along a continuum into the TD population (GEBAUER et al., 2015). When it comes to face processing, participants with high autistic traits showed no attentional bias towards fearful faces (MIU; PANĂ; AVRAM, 2012), but seemed to have difficulties identifying emotions (anger, disgust and sadness; POLJAC; POLJAC; WAGEMANS, 2013), similarly to some findings within the ASD population (e.g. HUMPHREYS et al., 2007; BIRD et al., 2006). The AQ (BARON-COHEN et al., 2001) is a well-known instrument used in research to measure autistic traits in the normal population (see WOODBURY-SMITH et al., 2005; RUZICH et al., 2015). It consists of 50 questions divided into 5 sets of 10, each set measuring an area generally atypical in autism: social skills, communication, imagination, attention switching and attention to details. Research within the BAP is a promising route to follow to help unveil cognitive mechanisms underlain ASD, making it possible to study a larger cohort of participants without a clinical diagnosis and using different experiments that might not be suitable to the clinical population. In conclusion, individuals with a higher amount of autistic-like traits might show the same advantage in performance in visual attention tasks and also atypical face processing as people with ASD, suggesting that similar processing is also present within the BAP. While some accounts attribute enhanced performance to detailed oriented processing, in the next section we propose a different framework that might explain these findings.

DUAL MECHANISM OF CONTROL (DMC) THEORY

A different theoretical framework that could explain the divergent findings in the literature and advantage or impairments seen in participants with ASD in visual tasks is the DMC theory, in which a possible bias towards proactive and difficulties in reactive control of attention could be influencing the performance of participants with autism. Reactive control is triggered by external stimuli, and it requires a quick shift of attention occurring "on-the-go". For example, when driving a car on the road, after the green signal from the traffic light, a sudden appearance of an ambulance would require the driver to stop and adaptively change its course in response to the sudden occurrence. Proactive control of attention refers to tasks that require previous preparation in anticipation of a known situation. It includes tasks where the requirement to inhibit certain targets is known in advance. For example, when driving a car, it is anticipated that speed should be reduced when approaching a zebra crossing.

An example of a task that requires reactive control is the gap-overlap task. Participants respond to a target unaware of the timing of the appearance or disappearance of the distractor (gap or overlap trials), requiring "on-the-go" responses. Other tasks with no clear instructions or preparation time, such as eye-tracking experiments measuring spontaneous eye gaze to specific stimuli also rely on reactive control. Thus, previous findings pointing to impairments in disengagement of attention and reduced eye gaze to faces or certain parts of the face might rely on reactive control of attention. Some studies that did not utilize strict task instructions might have elicited reactive control, which might be atypical in participants with autism (e.g. ELSABBAGH et al., 2009; GOLDBERG et al., 2002; KAWAKUBO et al., 2004, 2007; KLIN et al., 2002; LANDRY; BRYSON, 2004; RIBY; HANCOCK, 2009; ZWAIGENBAUM et al., 2005). On the other hand, tasks that rely on proactive control of attention, providing specific instructions and enough time for preparation, tend to produce similar performance between ASD and TD, or even superior abilities for participants with autism in search tasks, when ignoring distractors or attending to faces (e.g. BAR-HAIM et al., 2006; BRIAN et al., 2003; FISCHER et al., 2014; GRUBB et al., 2013b; HUMPHREYS et al., 2007; KIKUCHI et al., 2011; O'RIORDAN et al., 2001; O'RIORDAN, 2004; REMINGTON et al., 2009). Indeed, excessive adherence to routines, ritualized behaviour, resistance to change and rigid thinking are all common ASD symptoms (DSM 5, AMERICAN PSYCHIATRIC ASSOCIATION, 2013). Considering that individuals with autism might rely on a proactive cognitive style assumes that more time and preparation is needed before activities. Therefore, one could argue that those individuals would depend on structured and predictable routines (inherent to a proactive cognitive mode). Moreover, if reactive control is atypical in autism, it could be inferred that people with autism would have difficulties when "on-the-go" (reactive) changes are necessary, showing increased attachment to routines, resistance to change, and rituals and stereotyped behaviors, found within core ASD symptoms.

Recent research has (SPANIOL et al., 2017) investigated attention control and suppression of distractors in the context of faces, scenes, global and local stimuli. While the perception of features did not differ between groups with high *versus low autistic-like traits, results suggest enhanced distractor suppression in adults with more autistic traits, when preparatory control is utilized,* evidencing a bias towards proactive control and impairments in reactive control in this population, according to the DMC theory. Previous research has suggested a neural underpinning for this mechanism, as the parietal cortex (intraparietal sulcus) seems to be involved in proactive control (MEVORACH; HUMPHREYS; SHALEV, 2009) and the left temporal parietal junction (TPJ) and inferior frontal gyrus (IFG) might play a role in reactive control (DIQUATTRO; GENG, 2011).

The DMC theory proposes a new framework to understand discrepancies in performance in visual attention tasks in people with ASD. It poses that when a proactive mode of attention is available, ASD participants will show an advantage in performance whereas when the reactive control needs to be utilized, it is detrimental. Nevertheless, attention atypicalities are present in ASD from infancy into adult age, and this might be due to its atypical development.

DEVELOPMENTAL MODEL

Attentional differences have been present since the first descriptions of autism (KANNER et al., 1943) and there is evidence to support early and lifelong impairments in modulating different areas of the attentional network in ASD (ELSABBAGH et al., 2009; LANDRY; BRYSON, 2004; ZWAIGENBAUM et al., 2005). Keehn, Müller, and Townsend (2013) propose a developmental model where impaired disengagement of attention in early childhood may cause many other dysfunctions found in autism, also culminating in enhanced visual search abilities, linking attentional differences to the development of ASD symptoms. The same model has been used by Karmiloff-Smith (2009) to explain delayed language development in Williams Syndrome. This model is based on findings on the disengagement of attention as the earliest deficit reported in children at-risk for ASD (ELSABBAGH et al., 2009; ZWAIGENBAUM et al., 2005), which is an initial cue that atypical disengagement of attention is a primary difference in autism. Different attention functions develop rapidly in the first year of life and continue into childhood and adolescence (LIN; HSIAO; CHEN, 1999; RUEDA et al., 2004), and lower attentional functions may be essential for the development of higher-level social and communicative processes. Difficulties in attention disengagement have been linked to impairments in joint attention (SCHIETECATTE; ROEYERS; WARREYN, 2012) and problems in the development of joint attention are linked to impairments in social communicative behaviours (DAWSON et al., 2004; SCHIETECATTE; ROEYERS; WARREYN, 2012), and may also be associated with the development of perceptual biases (COLOMBO et al., 1995). Also, disengagement of attention might have considerable influence in the development of arousal regulation

(WATSON et al., 2007) and it is suggested that a state of hyperarousal leads to an over selective attention in attempts to filter out irrelevant information (LISS et al., 2006).

Therefore, early disturbances in attentional disengagement, combined with other primary dysfunctions, may result in a phenotypic end-state associated with ASD. Furthermore, it may be argued that early impairments in disengagement of attention in addition to a dysfunctional arousal regulation (which in turn can lead to a narrowed, over-focused attention), combined with atypical perceptual processing may ultimately lead to enhanced visual search ability in autism (LISS et al., 2006; KEEHN; MÜLLER; TOWNSEND, 2013). Attentional atypicalities are present in ASD since an early age, causing the development of further processing differences and even possible life-long impairments. Under this framework, early attention training might be a route to pursue with ASD children to try and avert the development of future deficit and facilitate learning.

ATTENTION TRAINING IN AUTISM

Although there is much discussion about atypical attentional performance in autism, previous work is primarily descriptive and does not address the effects of training on the brain and behavioral development and functioning or how these mechanisms may change in autism. Furthermore, there is a need to examine whether attentional processes in ASD individuals, involving disengagement of attention or executive control, can be changed by targeted intervention in childhood and adolescence. Early interventions might train and improve attentional abilities in autism to prevent developmental consequences of impaired attention.

The idea that attention training can be used as a cognitive rehabilitation tool is not a novelty (SOHLBERG; MATEER, 1987). In an early study, Sohlberg and Mateer (1987) used a program to train attention in four brain-injured patients, showing improvements in attention following treatment. It is further suggested that attention training, through repetition, can change brain function and bring generalized improvements not only to attention but also to cognition and executive control, and consequently help improving academic skills in children, such as numeracy or reading in school settings (POSNER; ROTHBART, 2007). An attention training program utilizing technology (computer "games") brought improvements in cognition and executive attention in children from

4 to 6 years old, showing that the attentional network is susceptible to intervention during development (RUEDA et al., 2005).

Another attention training program that has proven successful in training attention and showing generalized improvements in a variety of populations is the Computerized Progressive Attention Training (CPAT) developed by Shalev, Tsal, and Mevorach (2007). The CPAT was first utilized with children with ADHD, improving academic skills such as maths, reading, and copying. It was later tested as a cognitive rehabilitation tool with stroke patients, showing improvements in sustained attention and generalized cognitive skills (i.e., numeracy, language; SAMPANIS et al., 2015). It was also effective for children and adolescents with fetal alcohol syndrome, bringing improvements to several attention measures including sustained and selective attention, as well as to cognitive performance, seen in improved working memory, maths, and reading abilities (KERNS et al., 2010).

A recent study using the CPAT to train attention in children with ASD (SPANIOL et al., 2017) has in fact found generalized improvements in academic skills (maths, reading and writing) as well as cognitive performance after training, in comparison to an active control group. This shows that computerized attention training can change not only attention but also generalize to different domains of children with ASD. The CAPT was developed to train sustained, selective and executive attention, in a fun and interacting manner in the format of computer games. It is especially appropriate for children 7 years of age and above and is currently available and being used in research.

FINAL CONSIDERATIONS

In conclusion, findings regarding the disengagement of attention in ASD suggest difficulties disengaging from stimuli since infancy, which are not always seen in adults. Nevertheless, it appears that under certain conditions, such as uncertainty or when allocating attention towards social content and faces, attention disengagement is still atypical in ASD. This might be due to the nature of stimuli utilized, as more normal responses are given to neutral, static and grey-scale faces whereas atypical performance appears in more naturalistic settings. Also, increased attention to details has always been linked to ASD and atypical performance in visual tasks, although findings on global and local processing suggest that global information can be typically processed if participants are instructed to do so, but they might need more time and show a preference, or advantage in the local level. An advantage in performance is also seen within ASD and the BAP in discrimination, visual search, and distractor inhibition. Here, we suggest a new framework to understand discrepant findings better whereas individuals with ASD show advantage in performance when a proactive mode of attention is utilized, and a detriment to performance when reactive control is needed.

Finally, further investigation of the neural underpinnings of proactive and reactive control in the BAP and ASD is needed, such as the involvement of the parietal cortex (intraparietal sulcus) in proactive control and the enhanced performance in people with more autistic traits and the left temporal parietal junction (TPJ) and inferior frontal gyrus (IFG) role in reactive control and if this is indeed impaired in the BAP and ASD.

Early deficits in attention might also be linked to the further development of social and communicative impairments in ASD, and also to the advantage found in visual attention tasks. Therefore, attention training is a promising tool to be used in future research to investigate its effects on the development of children with ASD. Recent results from the application of the CPAT with ASD children have shown positive implications for future research and for the application of the CPAT in school settings as a tool to improve attention, to aid cognition and academic learning in children with autism. It relies on proactive control of attention in early levels and progresses to train reactive control in further levels. Thus, it could be said that reactive, as well as proactive control, were further trained with the CPAT, and therefore this might also be responsible for the improvements in non-trained abilities. Further research utilizing attentional training programs are suggested, with larger cohort sizes, long-term effects, parental involvement within the educational and public settings and in different cultural and social environments. It is also promising to test if attention training if applied in younger ages could transfer to various domains and possibly avert some of the deficits found in ASD. It is worth noting that possible limitations of this article include a lack of methodical systematic search, inclusion and exclusion criteria for papers, as this is a theoretical review it does not only focuses on new research but on a broad range of subjects related to the field.

Diferenças atencionais no transtorno do espectro autista e no fenótipo ampliado do autismo

Resumo

Embora diferenças atencionais não sejam sintomas centrais do Transtorno do Espectro Autista (TEA), déficits atencionais são frequentemente encontrados entre crianças e adultos com TEA, e até mesmo relacionados ao desenvolvimento de sintomas do TEA. Neste artigo teórico, serão discutidas diferenças atencionais precoces observadas no TEA, como o desengajamento da atenção. Outras diferenças na percepção também serão revisadas, no que concerne à alocação atípica de atenção e percepção de faces e estímulos sociais, e ao processamento de recursos globais e locais. A teoria da função executiva no TEA é revisada brevemente, contrastando com evidências de desempenho aprimorado em tarefas visuoespaciais, trazendo uma nova estrutura teórica (Teoria de Mecanismo Duplo de Controle) para explicar discrepâncias no desempenho no TEA e no Fenótipo Ampliado do Autismo. Finalmente, o conceito de treinamento atencional em TEA também é sugerido como uma intervenção viável para trazer melhorias generalizadas para crianças com TEA.

Palavras-chave

Transtorno do Espectro Autista. Atenção. Percepção. Fenótipo ampliado do autismo. Intervenção.

Diferencias atencionales en el trastorno del espectro autista y el fenotipo ampliado del autismo

Resumen

Aunque las diferencias atencionales no son síntomas centrales del Trastorno del Espectro Autista (TEA), los déficit de atención son frecuentemente encontrados entre niños y adultos con TEA, e incluso relacionados con el desarrollo de los síntomas del TEA. En este artículo teórico, se discutirán diferencias atencionales tempranas observadas en el TEA, como el desajuste de la atención. Otras diferencias en la percepción también serán revisadas, en lo que concierne a la asignación atípica de atención y percepción de caras y estímulos sociales, y al procesamiento de recursos globales y locales. La teoría de la función ejecutiva en el TEA es revisada brevemente, contrastando con evidencias de desempeño mejorado en tareas visuoespaciales, trayendo una nueva estructura teórica (Teoría de Mecanismo Doble de

Control) para explicar discrepancias en el desempeño en el TEA y en el Fenotipo Ampliado del Autismo. Finalmente, el concepto de entrenamiento atencional en TEA también es sugerido como una intervención viable para traer mejoras generalizadas para niños con TEA.

Palabras clave

Trastorno del Espectro Autista. Atención. La percepción. Fenotipo ampliado del autismo. Intervención.

REFERENCES

ADOLPHS, R.; SEARS, L.; PIVEN, J. Abnormal Processing of Social Information from Faces in Autism. *Journal of Cognitive Neuroscience*, v. 13, n. 2, p. 232-240, 2006.

ALMEIDA, R. A. et al. Visual search targeting either local or global perceptual processes differs as a function of autistic-like traits in the typically developing population. *Journal of Autism and Developmental Disorders*, v. 43, n. 6, p. 1272-1286, 2013. doi: 10.1007/s10803-012-1669-7

AMERICAN PSYCHIATRIC ASSOCIATION. Diagnostic and statistical manual of mental disorders (DSM-5®). *American Psychiatric Pub*, 2013.

AYLWARD, E. et al. Normal activation of fusiform gyrus in adolescents and adults with autism during viewing of familiar, but not unfamiliar, faces. In: STAART/CPEA (Studies To Advance Autism Research and Treatment/Collaborative Programs for Excellence in Autism) NIH network meeting, May. 2004. p. 17-20.

BAR-HAIM, Y. et al. Attention to eyes and mouth in high-functioning children with autism. *Journal of Autism and Developmental Disorders*, v. 36, n. 1, p. 131-137, 2006. doi: 10.1007/s10803-005-0046-1

BARON-COHEN, S. et al. The autism-spectrum quotient (AQ): evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, v. 31, n. 1, p. 5-17, 2001.

BEHRMANN, M. et al. Configural processing in autism and its relationship to face processing. *Neuropsychologia*, v. 44, n. 1, p. 110-129, 2006a. doi: 10.1016/j.neuropsychologia. 2005.04.002

BEHRMANN, M.; THOMAS, C.; HUMPHREYS, K. Seeing it differently: visual processing in autism. *Trends in Cognitive Sciences*, v. 10, n. 6, p. 258-264, 2006. doi: 10.1016/j.tics.2006.05.001

BIRD, G. et al. Attention does not modulate neural responses to social stimuli in autism spectrum disorders. *Neuroimage*, v. 31, n. 4, p. 1614-1624, 2006. doi: 10.1016/j.neuroimage.2006.02.037

BOOTH, R. D.; HAPPÉ, F. G. Evidence of reduced global processing in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, v. 48, n. 4, p. 1397-1408, 2018. doi: 10.1007/s10803-016-2724-6

BRIAN, J. A. et al. Inhibitory mechanisms in autism spectrum disorders: typical selective inhibition of location *versus* facilitated perceptual processing. *Journal of Child Psychology and Psychiatry*, v. 44, n. 4, p. 552-560, 2003.

BROCK, J.; XU, J. Y.; BROOKS, K. R. Individual differences in visual search: Relationship to autistic traits, discrimination thresholds, and speed of processing. *Perception*, v. 40, n. 6, p. 739-742, 2011. doi: 10.1068/p6953

BROWN, S. M.; BEBKO, J. M. Generalization, overselectivity, and discrimination in the autism phenotype: a review. *Research in Autism Spectrum Disorders*, v. 6, p. 733-740, 2011. doi: https://doi.org/10.1016/j.rasd.2011.10.012

COLOMBO, J. et al. Individual differences in infant fixation duration: dominance of global *versus* local stimulus properties. *Cognitive Development*, v. 10, n. 2, p. 271-285, 1995. doi: https://doi.org/10.1016/0885-2014(95)90012-8

DAKIN, S.; FRITH, U. Vagaries of visual perception in autism. *Neuron*, v. 48, n. 3, p. 497-507, 2005. doi: https://doi.org/10.1016/j.neuron.2005.10.018

DAWSON, G. et al. Early social attention impairments in autism: social orienting, joint attention, and attention to distress. *Developmental Psychology*, v. 40, n. 2, p. 271, 2004.

DERUELLE, C. et al. Attention to low-and high-spatial frequencies in categorizing facial identities, emotions and gender in children with autism. *Brain and Cognition*, v. 66, n. 2, p. 115-123, 2008. doi: 10.1016/j.bandc.2007.06.001

DERUELLE, C. et al. Spatial frequency and face processing in children with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, v. 34, p. 199-210, 2004.

DICKINSON, A.; JONES, M.; MILNE, E. Oblique orientation discrimination thresholds are superior in those with a high level of autistic traits. *Journal of Autism and Developmental Disorders*, v. 44, n. 11, p. 2844-2850, 2014. doi: 10.1007/s10803-014-2147-1

DIQUATTRO, N. E.; GENG, J. J. Contextual knowledge configures attentional control networks. *Journal of Neuroscience*, v. 31, n. 49, p. 18026-18035, 2011. doi: 10.1523/JNEUROSCI.4040-11.2011.

D'SOUZA, D. et al. Rethinking the concepts of "local or global processors": evidence from Williams syndrome, Down syndrome, and Autism Spectrum Disorders. *Developmental science*, v. 19, n. 3, p. 452-468, 2016. doi: 10.1111/desc.12312

ELSABBAGH, M. et al. Visual orienting in the early broader autism phenotype: disengagement and facilitation. *Journal of Child Psychology and Psychiatry*, v. 50, n. 5, p. 637-642, 2009. doi: 10.1111/j.1469-7610.2008.02051.x

FISCHER, J. et al. Unimpaired attentional disengagement and social orienting in children with autism. *Clinical Psychological Science*, v. 2, n. 2, p. 214-223, 2014. doi: 10.1177/2167702613496242

GEBAUER, L. et al. Is there a bit of autism in all of us? Autism spectrum traits are related to cortical thickness differences in both autism and typical development. *Research in Autism Spectrum Disorders*, v. 13, p. 8-14, 2015. doi: https://doi.org/10.1016/j.rasd.2014.12.013

GILLESPIE-SMITH, K. et al. That looks familiar: attention allocation to familiar and unfamiliar faces in children with autism spectrum disorder. *Cognitive neuropsychiatry*, v. 19, n. 6, p. 554-569, 2014. doi: 10.1080/13546805.2014.943365

GLOD, M. et al. Sensory atypicalities in dyads of children with autism spectrum disorder (ASD) and their parents. *Autism Research*, v. 10, n. 3, p. 531-538, 2017. doi: 10.1002/aur.1680

GOLDBERG, M. C. et al. Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. *Neuropsychologia*, v. 40, n. 12, p. 2039-2049, 2002.

GOWEN, E.; HAMILTON, A. Motor abilities in autism: a review using a computational context. *Journal of Autism and Developmental Disorders*, v. 43, n. 2, p. 323-344, 2013. doi: 10.1007/s10803-012-1574-0

GRUBB, M. A. et al. Exogenous spatial attention: evidence for intact functioning in adults with autism spectrum disorder. *Journal of Vision*, v. 13, n. 14, p. 1-13, 2013a. doi: 10.1167/13.14.9.

GRUBB, M. A. et al. Endogenous spatial attention: evidence for intact functioning in adults with autism. *Autism Research*, v. 6, n. 2, p. 108-118, 2013b. doi: 10.1002/aur.1269

GUILLON, Q. et al. Visual social attention in autism spectrum disorder: insights from eye tracking studies. *Neuroscience & Biobehavioral Reviews*, v. 42, p. 279-297, 2014. doi: 10.1016/j.neubiorev.2014.03.013.

HADJIKHANI, N. et al. Abnormal activation of the social brain during face perception in autism. *Human Brain Mapping*, v. 28, n. 5, p. 441-449, 2007. doi: https://doi.org/10.1002/hbm.20283

HADJIKHANI, N. et al. Anatomical differences in the mirror neuron system and social cognition network in autism. *Cerebral Cortex*, v. 16, n. 9, p. 1276-1282, 2006. doi: 10.1093/cercor/bhj069

HALL, G. B.; SZECHTMAN, H.; NAHMIAS, C. Enhanced salience and emotion recognition in autism: a PET study. *American Journal of Psychiatry*, v. 160, n. 8, p. 1439-1441, 2003.

HAPPÉ, F. Autism: cognitive deficit or cognitive style?. *Trends in Cognitive Sciences*, v. 3, n. 6, p. 216-222, 1999. doi: 10.1176/appi.ajp.160.8.1439

HAPPÉ, F. et al. Executive function deficits in autism spectrum disorders and attention-deficit/hyperactivity disorder: examining profiles across domains and ages. *Brain and Cognition*, v. 61, n. 1, p. 25-39, 2006. doi: 10.1016/j.bandc.2006.03.004

HUBL, D. et al. Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology*, v. 61, n. 9, p. 1232-1237, 2003. doi: https://doi.org/10.1212/01.WNL.0000091862.22033.1A

HUMPHREYS, K. et al. A fine-grained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia*, v. 45, n. 4, p. 685-695, 2007. doi: https://doi.org/10.1016/j.neuropsychologia.2006.08.003

KALDY, Z. et al. The mechanisms underlying the ASD advantage in visual search. *Journal of Autism and Developmental Disorders*, v. 46, n. 5, p. 1513-1527, 2016. doi: 10.1007/s10803-013-1957-x

KANA, R. K. et al. The local, global, and neural aspects of visuospatial processing in autism spectrum disorders. *Neuropsychologia*, v. 51, n. 14, p. 2995-3003, 2013. doi: 10.1016/j.neuropsychologia.2013.10.013

KANNER, L. et al. Autistic disturbances of affective contact. *Nervous Child*, v. 2, n. 3, p. 217-250, 1943.

KARMILOFF-SMITH, A. Nativism *versus* neuroconstructivism: rethinking the study of developmental disorders. *Developmental Psychology*, v. 45, n. 1, p. 56, 2009. doi: 10.1037/a0014506.

KAWAKUBO, Y. et al. Electrophysiological abnormalities of spatial attention in adults with autism during the gap overlap task. *Clinical Neurophysiology*, v. 118, n. 7, p. 1464-1471, 2007. doi: 10.1016/j.clinph.2007.04.015

KAWAKUBO, Y. et al. Spatial attention in individuals with pervasive developmental disorders using the gap overlap task. *Psychiatry Research*, v. 125, n. 3, p. 269-275, 2004. doi: 10.1016/j.psychres.2003.12.012

KEEHN, B.; MÜLLER, R. A.; TOWNSEND, J. Atypical attentional networks and the emergence of autism. *Neuroscience & Biobehavioral Reviews*, v. 37, n. 2, p. 164-183, 2013. doi: 10.1016/j.neubiorev.2012.11.014

KERNS, K. A. M. et al. Investigating the efficacy of an attention training programme in children with foetal alcohol spectrum disorder. *Developmental Neurorehabilitation*, v. 13, n. 6, p. 413-422, 2010. doi: 10.3109/17518423.2010.511421

KIKUCHI, Y. et al. 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*, v. 41, n. 5, p. 629-645, 2011. doi: 10.1007/s10803-010-1082-z

KLEINHANS, N. M. et al. Reduced neural habituation in the amygdala and social impairments in autism spectrum disorders. *American Journal of Psychiatry*, v. 166, n. 4, p. 467-475, 2009. doi: 10.1176/appi.ajp.2008.07101681

KLEINHANS, N.; AKSHOOMOFF, N.; DELIS, D. C. Executive functions in autism and Asperger's disorder: flexibility, fluency, and inhibition. *Developmental Neuropsychology*, v. 27, n. 3, p. 379-401, 2005. doi: 10.1207/s15326942dn2703_5

KLIN, A. et al. Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of general psychiatry*, v. 59, n. 9, p. 809-816, 2002.

KOLDEWYN, K. et al. Global/local processing in autism: not a disability, but a disinclination. *Journal of Autism and Developmental Disorders*, v. 43, n. 10, p. 2329-2340, 2013. doi: 10.1007/s10803-013-1777-z

LANDRY, R.; BRYSON, S. E. Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry*, v. 45, n. 6, p. 1115-1122, 2004. doi: 10.1111/j.1469-7610.2004.00304.x

LAVIE, N. Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human perception and performance*, v. 21, n. 3, p. 451, 1995.

LIN, C. CH; HSIAO, C. K.; CHEN, W. J. Development of sustained attention assessed using the continuous performance test among children 6-15 years of age. *Journal of Abnormal Child Psychology*, v. 27, n. 5, p. 403-412, 1999.

LISS, M. et al. Sensory and attention abnormalities in autistic spectrum disorders. *Autism*, v. 10, n. 2, p. 155-172, 2006. doi: 10.1177/1362361306062021

LISS, M. et al. Brief report: cognitive estimation in individuals with pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, v. 30, n. 6, p. 613-618, 2000.

LOMBARDO, M. V.; CHAKRABARTI, B.; BARON-COHEN, S. The amygdala in autism: not adapting to faces? *The American Journal of Psychiatry*, v. 166, n. 4, p. 395-397, 2009. doi: 10.1176/appi.ajp.2009.09010044

LOTH, E.; GÓMEZ, J. C.; HAPPÉ, F. When seeing depends on knowing: adults with autism spectrum conditions show diminished top-down processes in the visual perception of degraded faces but not degraded objects. *Neuropsychologia*, v. 48, n. 5, p. 1227-1236, 2010. doi: https://doi.org/10.1016/j.neuropsychologia.2009.12.023

LUNA, B. et al. Maturation of executive function in autism. *Biological Psychiatry*, v. 61, n. 4, p. 474-481, 2007. doi: 10.1016/j.biopsych.2006.02.030

MEVORACH, C. et al. Ignoring the elephant in the room: a neural circuit to downregulate salience. *Journal of Neuroscience*, v. 30, n. 17, p. 6072-6079, 2010. doi: 10.15 23/JNEUROSCI.0241-10.2010

MEVORACH, C.; HUMPHREYS, G. W.; SHALEV, L. Reflexive and preparatory selection and suppression of salient information in the right and left posterior parietal cortex. *Journal of Cognitive Neuroscience,* v. 21, n. 6, p. 1204-1214, 2009. doi: 10.1162/jocn.2009.21088.

MILNE, E. et al. Visual search performance is predicted by the degree to which selective attention to features modulates the ERP between 350 and 600 ms. *Neuropsychologia*, v. 51, n. 6, p. 1109-1118, 2013. doi: 10.1016/j.neuropsychologia.2013.03.002

MIU, A. C.; PANĂ, S. E.; AVRAM, J. Emotional face processing in neurotypicals with autistic traits: implications for the broad autism phenotype. *Psychiatry research*, v. 198, n. 3, p. 489-494, 2012. doi: 10.1016/j.psychres.2012.01.024

MOTTRON, L. et al. Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, v. 36, n. 1, p. 27-43, 2006. doi: 10.1007/s10803-005-0040-7

MOTTRON, L.; BELLEVILLE, S. A study of perceptual analysis in a high-level autistic subject with exceptional graphics abilities. *Brain and Cognition*, v. 23, n. 2, p. 279-309, 1993. doi: 10.1006/brcg.1993.1060

NAVON, D. Forest before trees: the precedence of global features in visual perception. *Cognitive Psychology*, v. 9, n. 3, p. 353-383, 1977. doi: https://doi.org/10.1016/0010-0285(77)90012-3

O'RIORDAN, M. A. Superior visual search in adults with autism. *Autism*, v. 8, n. 3, p. 229-248, 2004. doi: 10.1177/1362361304045219

O'RIORDAN, M. A. et al. Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, v. 27, n. 3, p. 719-730, 2001. doi: 10.1177/1362361304045219

OZONOFF, S.; STRAYER, D. L. Inhibitory function in nonretarded children with autism. *Journal of Autism and Developmental Disorders*, v. 27, n. 1, p. 59-77, 1997.

PELPHREY, K. A.; MORRIS, J. P.; MCCARTHY, G. Neural basis of eye gaze processing deficits in autism. *Brain,* v. 128, n. 5, p. 1038-1048, 2005. doi: 10.1093/brain/awh404

PELPHREY, K. A. et al. Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, v. 32, n. 4, p. 249-261, 2002.

PIERCE, K. et al. The brain response to personally familiar faces in autism: findings of fusiform activity and beyond. *Brain*, v. 127, n. 12, p. 2703-2716, 2004. doi:10.1093/brain/awh289

PIERCE, K. et al. Face processing occur outside the fusiform face area in autism: evidence from functional MRI. *Brain*, v. 124, n. 10, p. 2059-2073, 2001.

PIGGOT, J. et al. Emotional attribution in high-functioning individuals with autistic spectrum disorder: a functional imaging study. *Journal of the American Academy of Child & Adolescent Psychiatry*, v. 43, n. 4, p. 473-480, 2004. doi: 10.1097/00004583-200404000-00014

PLAISTED, K.; SWETTENHAM, J.; REES, L. Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, v. 40, n. 5, p. 733-742, 1999. doi: https://doi.org/10.1111/1469-7610.00489

POLJAC, E.; POLJAC, E.; WAGEMANS, J. Reduced accuracy and sensitivity in the perception of emotional facial expressions in individuals with high autism spectrum traits. *Autism*, v. 17, n. 6, p. 668-680, 2013. doi: 10.1177/1362361312455703

POSNER, M. I.; ROTHBART, M. K. Research on attention networks as a model for the integration of psychological science. *Annu. Rev. Psychol.*, v. 58, p. 1-23, 2007. doi: 10.1146/annurev.psych.58.110405.085516

REMINGTON, A. et al. Selective attention and perceptual load in autism spectrum disorder. *Psychological Science*, v. 20, n. 11, p. 1388-1393, 2009. doi: 10.1111/j.1467-9280.2009.02454.x

RIBY, D. M. et al. Spontaneous and cued gaze-following in autism and Williams syndrome. *Journal of Neurodevelopmental Disorders*, v. 5, n. 1, p. 13, 2013. doi: https://doi.org/10.1186/1866-1955-5-13

RIBY, D. M.; HANCOCK, P. J. Do faces capture the attention of individuals with Williams syndrome or autism? Evidence from tracking eye movements. *Journal of Autism and Developmental Disorders*, v. 39, n. 3, p. 421-431, 2009. doi: 10.1007/s10803-008-0641-z

RIBY, D. M.; DOHERTY-SNEDDON, G.; BRUCE, V. The eyes or the mouth? Feature salience and unfamiliar face processing in Williams syndrome and autism. *Quarterly Journal of experimental psychology*, v. 62, n. 1, p. 189-203, 2009. doi: 10.1080/17470210701855629

RINEHART, N. J. et al. A neurobehavioral examination of individuals with high-functioning autism and Asperger's disorder using a frontostriatal model of dysfunction. *Behavioral and Cognitive Neuroscience Reviews*, v. 1, n. 2, p. 164-177, 2002.

RONCONI, L. et al. Paternal autistic traits are predictive of infants visual attention. *Journal of Autism and Developmental Disorders*, v. 44, n. 7, p. 1556-1564, 2014. doi: 10.1007/s10803-013-2018-1

RUEDA, M. R. et al. Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the United States of America*, v. 102, n. 41, p. 14931-14936, 2005. doi: 10.1073/pnas.0506897102

RUEDA, M. R. et al. Development of attentional networks in childhood. *Neuropsychologia*, v. 42, n. 8, p. 1029-1040, 2004. doi: 10.1016/j.neuropsychologia.2003.12.012

RUZICH, E. et al. Measuring autistic traits in the general population: a systematic review of the Autism-Spectrum Quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism*, v. 6, n. 1, p. 2, 2015. doi: https://doi.org/10.1186/2040-2392-6-2

SACHSE, M. et al. Executive and visuomotor function in adolescents and adults with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, v. 43, n. 5, p. 1222-1235, 2013. doi: 10.1007/s10803-012-1668-8

SACREY, L. et al. Impairments to visual disengagement in autism spectrum disorder: a review of experimental studies from infancy to adulthood. *Neuroscience & Biobehavioral Reviews*, v. 47, p. 559-577, 2014. doi: 10.1016/j.neubiorev.2014.10.011

SAMPANIS, D. S. et al. Reducing cognitive deficits after stroke through Computerized Progressive Attentional Training (CPAT): a pilot study. *Physical Medicine and Rehabilitation – International*, v. 2, n. 7, 2015. doi: 10.1080/09297040600770787

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. *Journal of Autism and Developmental Disorders*, v. 42, n. 1, p. 1-12, 2012. doi: 10.1007/s10803-011-1209-x

SCHULTZ, R. T. et al. Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry*, v. 57, p. 331-340, 2000. doi: 10.1001/archpsyc.57.4.331

SHALEV, L.; TSAL, Y.; MEVORACH, C. Computerized progressive attentional training (CPAT) program: effective direct intervention for children with ADHD. *Child neuropsychology*, v. 13, n. 4, p. 382-388, 2007. doi: 10.1080/09297040600770787

SOHLBERG, M. M.; MATEER, C. A. Effectiveness of an attention-training program. *Journal of Clinical and Experimental Neuropsychology*, v. 9, n. 2, p. 117-130, 1987. doi: 10.1080/01688638708405352

SPANIOL, M. M. et al. Attention training in Autism as a potential approach to improving academic performance: a school-based pilot study. *Journal of Autism and Developmental Disorders*, p. 1-19, 2017. doi: 10.1007/s10803-017-3371-2

TREUE, S. Visual attention: the where, what, how and why of saliency. *Current opinion in neurobiology*, v. 13, n. 4, p. 428-432, 2003.

VAN DER GEEST, J. N. et al. Gaze behavior of children with pervasive developmental disorder toward human faces: a fixation time study. *Journal of Child Psychology & Psychiatry*, v. 43, p. 669-678, 2002. doi: https://doi.org/10.1111/1469-7610.00055

WANG, A. T. et al. Neural correlates of facial affect processing in children and adolescents with autism spectrum disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, v. 43, n. 4, p. 481-490, 2004. doi: 10.1097/00004583-200404000-00015

WANG, L. et al. Local bias and local-to-global interference without global deficit: a robust finding in autism under various conditions of attention, exposure time, and visual angle. *Cognitive Neuropsychology*, v. 24, n. 5, p. 550-574, 2007. doi: 10.1080/13546800701417096

WATSON, L. R. et al. The first year inventory: retrospective parent responses to a questionnaire designed to identify one-year-olds at risk for autism. *Journal of Autism and Developmental Disorders*, v. 37, n. 1, p. 49-61, 2007. doi: 10.1007/s10803-006-0334-4

WATTS, S. J.; RODGERS, J.; RIBY, D. A systematic review of the evidence for hyporesponsivity in ASD. *Review Journal of Autism and Developmental Disorders*, v. 3, n. 4, p. 286-301, 2016. doi: 10.1007/s40489-016-0084-y

WOODBURY-SMITH, M. R. et al. Screening adults for Asperger syndrome using the AQ: a preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders*, v. 35, n. 3, p. 331-335, 2005. doi: 10.1007/s10803-005-3300-7

ZWAIGENBAUM, L. et al. Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience*, v. 23, n. 2, p. 143-152, 2005. doi: 10.1016/j.ijdevneu.2004.05.001