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DISENGAGEMENT, SHIFTING AND ENGAGEMENT OF
ATTENTION IN CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM
DISORDER (ASD)

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Abstract

The present study examined the disengaging, shifting, and engaging abilities of children and adolescents with ASD compared to age- and cognitive ability-matched typically developing (TD) peers. Previous research has found that individuals with ASD have difficulty disengaging and shifting their attention or what has been termed 'sticky' attention. This 'sticky' attention has been hypothesized as a general deficit of the broader ASD phenotype, and subsequently as an aid in the early identification of ASD. However, researchers to date have only examined endogenous and exogenous attention abilities, which pertain to when the cue to shift and disengage attention is externally provided. Given that this type of attention may not be representative of everyday attention situations, in the present study I investigated autogenous attention abilities, which relate to when the cue to shift and disengage is internally generated. Due to the implications of attention on later social and language development and repetitive behaviour, a richer understanding of attention abilities in children and adolescents with ASD is critical.

Using a novel eye-tracking task, an aim of the present study was to determine whether 'sticky' attention is a core deficit of ASD or whether it is task dependent by evaluating performance on two types of attention tasks: exogenous (attention that is externally cued) and autogenous (attention that is internally cued). Additionally, I examined how the type of stimuli, level of complexity of the stimuli, and participants' engagement effect attention abilities. Lastly, I determined if demographic and clinical factors predict attention abilities in children with ASD and TD children.

Overall, findings from the present study do not support previous research indicating inferior disengaging and shifting abilities in children with ASD, as attention

abilities in the present study varied based on attention type, and other task-dependent variables, including trial type and task stimuli. Although only chronological age and verbal cognitive ability predicted performance, engagement in the trial was associated with attention abilities, regardless of group. Given the numerous variables that predicted disengaging and shifting abilities in children with ASD, the current study does not provide support for the hypothesis that 'sticky' attention is a core deficit of ASD, and thus its potential as a diagnostic marker in this population is questionable.

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CHAPTER ONE:

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that emerges in the first three years of life and is characterized by significant abnormalities related to reciprocal social interactions, communication, and repetitive and restrictive behaviour (American Psychiatric Association [APA], 2013). Other features often associated with ASD are deficits in adaptive functioning, sensory or perceptual difficulties, and delayed or impaired cognitive processes (Williams, Goldstein, & Minshew, 2006). In particular, previous research indicates that cognitive processes, such as executive functions, memory, and attention abilities are also impaired in children with ASD (Hill, 2004). Deficits in these cognitive areas not only influence the ability of children with ASD to accurately process information from the environment, but also potentially explain deficits in areas such as social-communicative functioning and repetitive and restrictive behaviours.

Bahrick and Todd (2012) hypothesized that there are two cognitive processes that act as the foundation for the attainment of social-communication skills: 1) intersensory perception/intersensory functioning, and 2) the disengagement and shifting of attention, which is the focus of the present study. More specifically, deficits in attention disengagement and shifting are suggested to impact basic social development such as orienting to one's name (Dawson, Toth, Abbott, Osterling, Munson, Estes, & Liaw, 2004) and joint attention (Mundy & Burnette, 2005). Compared to typically developing individuals (TD) and individuals with intellectual disabilities (ID), both attention disengagement and shifting are impaired in individuals across the lifespan with ASD (Elsabbagh, Volein, Holmboe, Tucker, Csibra, Baron-Cohen et al., 2009; Elsabbagh, Fernandes, Webb, Dawson, Charman, Johnson et al., 2013; Landry & Bryson, 2004;

Pruett, LaMacchia, Hoertel, Squire, McVey, Todd et al., 2011; Renner, Klinger, & Klinger, 2006). Previous research studies examining these abilities in infant siblings of individuals with ASD (at-risk infants) have also shown deficits in attention (Zwaigenbaum, Bryson, Rogers, Roberts, Brian, & Szatmari, 2005). Researchers have termed these attention difficulties as 'sticky' attention. 'Sticky' attention difficulties are hypothesized as a general deficit of the broader ASD phenotype, and therefore can aid in the early identification and diagnosis of ASD.

Studies examining disengagement and shifting have primarily used visual orientation tasks, or what is commonly known as the gap-overlap task, in which a peripheral stimulus is presented while a central fixation remains (disengagement) or disappears (shifting; e.g., Landry & Bryson, 2004). Although research using this type of task has frequently shown that individuals with ASD are slower to shift and disengage their attention to the peripheral stimulus compared to TD individuals, there are a number of limitations of previous research with this type of task. One important limitation is that these studies have solely focused on examining the *exogenous* attention abilities (i.e., cued from something in the environment to shift or disengage attention, typically the onset of a new target stimulus; e.g., Wainwright-Sharp & Bryson, 1993) of individuals with ASD rather than examining attention abilities when the cue to disengage and shift is self-directed or generated. Other methodological limitations in earlier research include the unrealistic stimuli typically used in this task (shapes; e.g., Landry & Bryson, 2004), and utilizing static and unimodal (visual) stimuli instead of multimodal or dynamic stimuli. Additionally, attention abilities have been examined using experimental paradigms that only require a single shift or disengagement of attention versus providing

individuals with multiple opportunities to disengage, shift, and re-engage with different stimuli (e.g., Elsabbagh et al., 2009). Finally, the role of engagement during visual orienting tasks has not been well researched; as a result little is known about how engagement impacts disengagement and shifting abilities. Taken together, it is unknown if difficulties in attention disengagement and shifting that have been found in previous research are general deficits of ASD or whether these abilities are more variable and task-dependent.

The primary objective of the present study was to understand the disengaging, shifting, and engagement abilities of individuals with ASD compared to TD individuals using a self-directed and ecologically valid task. The disengaging, shifting, and engaging of attention in children and adolescents with ASD was examined; that is, attention abilities when an external cue was provided were compared to attention abilities when no explicit cue was provided, in which the decision to shift or disengage to be self-generated. This was tested using a modified visual orientation task with dynamic, multimodal, and realistic stimuli.

In the following, I first describe exogenous and endogenous attention, and introduce a new term, autogenous attention, to disambiguate overlapping but distinct concepts referred to interchangeably as endogenous attention. I also describe the three processes of disengagement, shifting, and engagement that are fundamentally affected by these three types of attention. I then describe the two tasks that are frequently used to examine exogenous and endogenous attention, as well as highlight some of the methodological limitations of these tasks. I discuss the previous research that examines

these abilities in individuals with ASD and lastly, discuss the rationale, objectives, and hypotheses of the present study.

Exogenous and Endogenous Attention

Posner and Petersen (1990) and Posner and Fan (2004) theorized that attention is a complex system consisting of a number of specialized networks, including 1) the alerting system, 2) the orienting system, and 3) the executive control system. Whereas the alerting attention system is suggested to be in control of sustaining an awareness of incoming information from the environment, the orienting system is responsible for selecting information by disengaging, shifting, and re-engaging with sensory information from the environment. Lastly, the executive control system is a higher-order attention system that is hypothesized to be responsible for a variety of cognitive processes such as inhibition, planning, and cognitive flexibility.

For the purposes of this dissertation, I primarily focus on the orienting system, particularly two aspects of attention which have been identified as part of the orienting system, exogenous and endogenous. Exogenous attention is theorized to be an automatic process that is driven primarily by an external stimulus or cue from the environment, such as a sudden appearance of an object in the periphery that draws attention. In contrast, endogenous attention is conceptualized as being an internally cued or a more goal-driven, deliberate decision-making process, which requires some mental effort and is within an individual's conscious awareness (Posner, 1980).

The term endogenous has been used in a variety of overlapping, but conceptually separable, ways. For example, Posner (1980) used endogenous to refer to an external cue, such as an arrow or other directional cue, that is presented in a location, typically

centrally, that is different from a peripheral target location, and signals the location of the next stimulus. Thus, the cue signifies the location of the target and may encourage the subject to voluntarily attend to the location signalled by the central cue. This is in contrast to the exogenous cue, which is presented in the periphery, outside the central focus.

In the present studies, a further differentiation is made. In previous literature, endogenous attention has encompassed a two-component process: the visual orienting process that follows an external, but central cue, and the internal or voluntary process that is a result from the external cue. However, orienting responses can also be internally generated, in the absence of intended external triggers, such as when an individual simply decides to re-orient attention. This latter re-orientation of attention will be termed *autogenous attention*. The "auto-" in autogenous" is meant to encapsulate the self-initiation of the process versus the externally cued initiation of the exogenous and endogenous attention trials. Autogenous attention is used to describe situations in which there is no explicit cue provided to the individual as part of the central visual field or in the periphery. In autogenous processing, the decision to disengage or shift attention is *entirely* internally generated, such as in the course of scanning complex scenes or interactions or, as in the current study, while watching dynamic visual stimuli that are ongoing and offer multiple foci for attention, but where no specific cue is presented to shift attention. For example, as outlined in the Figure 1, in both endogenous and exogenous attention tasks, participants are externally cued as to if, when, and where to disengage, shift, and re-engage their attention using an external cue such an arrow, or simply the appearance of another image. However, in autogenous attention trials, the cue to disengage, shift, and re-engage is initiated by participants themselves, and their own

interest or agenda. Given the internally generated disengaging and shifting inherent in autogenous attention, it could be argued that autogenous attention is used more frequently in individuals' day-to-day functioning, such as during social interactions, compared to exogenous and endogenous attention.

Figure 1

Sample tasks involving exogenous, endogenous, or autogenous attention trials

Exogenous Trials (in this case, the new stimulus is the cue to shift)

Central fixation   *Central stimulus presented for 3 s*   *Peripheral stimulus (external cue)*
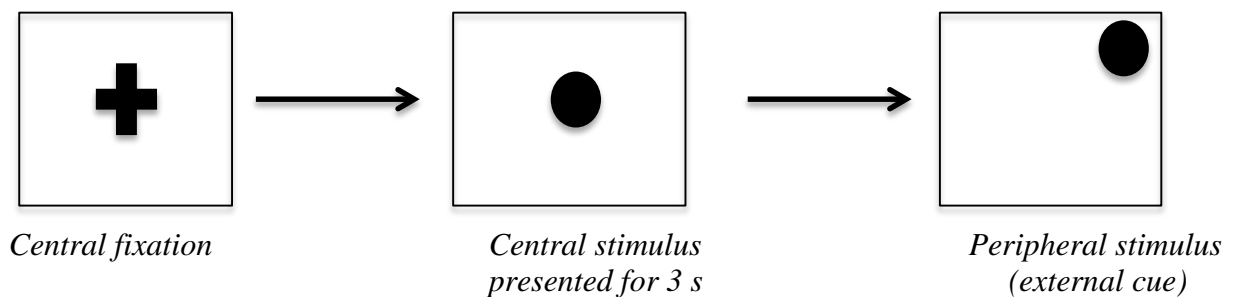
Endogenous Trials (in this case, an arrow is presented to cue or prime a not-yet presented new stimulus for a pending shift)

Central fixation   *External cue*   *Peripheral stimulus*
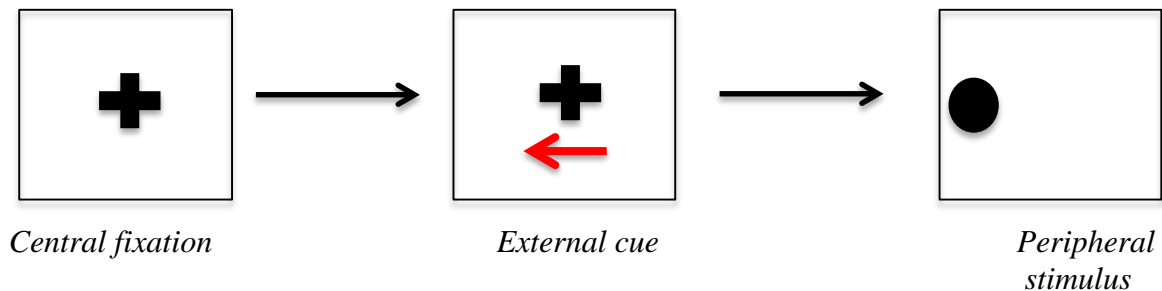
Autogenous Trials (in this case, no new external cue to shift is provided; the impetus to shift is entirely internally generated)

Central fixation   *Multiple stimuli presented for 12 s trial*
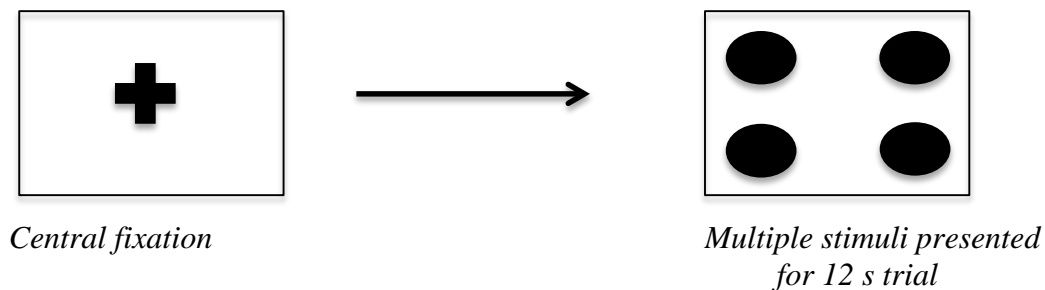
While exogenous attention is the first type of attention to develop at 4 months of age, endogenous abilities continue to emerge throughout childhood (Renner, Klinger, & Klinger, 2006). Previous research indicates that children 6 years of age and older, as well as adults, show similar exogenous abilities; however, children show weaker and less efficient endogenous attention than adults (Enns & Brodeur, 1989). The development of endogenous abilities can be attributed to the maturation of cortical processes that are associated with the orienting system, such as the frontal lobe, parietal cortex, visual cortex, and the basal ganglia (McConnell & Bryson, 2005). No research has examined the development of autogenous attention abilities. However, given that it is primarily internally driven, and is likely involved in self-motivated visual exploration of one's environment, it may be early to develop. On the other hand, it may develop and mature later than exogenous attention, which is assumed to be triggered, rather automatically, by external cues. Endogenous attention requires the understanding of referents, such as arrows or similar cues, which likely need to be learned, so would be the latest to develop.

Regardless of whether orienting of attention is internally generated or externally cued, endogenous, exogenous, and autogenous attention involve the same three cognitive steps: 1) disengaging, 2) shifting, and 3) re-engaging of attention (Bahrick & Todd, 2012). For example, to redirect our attention from one object to another, individuals have to first be engaged in a stimulus, then disengage their focus from that object, shift their attention to the second focus, and then re-engage their attention at the next target or stimulus (Posner & Peterson, 1990). Although these three cognitive steps are basic, lower-order cognitive functions, they are hypothesized to be fundamental to our ability to learn and interact with our environment and respond to and regulate our emotions to

events occurring in the environment. As a result, the maturation of an individual's disengaging, shifting, and re-engagement are critical for other aspects of development and daily living, including social relationships, and language and communication abilities (Keehn, Lincoln, Muller, & Townsend, 2010).

Researchers have primarily utilized two tasks to examine exogenous and endogenous attention and orienting: 1) Posner's (1978) visual orienting paradigm (or what has been frequently referred to as the flanker task), and 2) the gap-overlap task. In Posner's visual orienting paradigm, which measures endogenous abilities, participants are cued as to which location the stimulus will appear. The cue can either be valid (e.g., the cue points to the target's correct location) or invalid (e.g., the cue indicates the incorrect location of the target). The premise of this task is if participants are processing and utilizing the cue, then they should respond quicker to the target when the cue is valid than invalid. The second type of task is the gap-overlap task, an exogenous attention task, in which the time it takes participants to initiate an eye movement from a centrally located stimulus to the onset of a peripheral stimulus is measured. In this task, participants' attention abilities are measured using two types of trials. Specifically, if the central and peripheral stimuli overlap in timing (e.g., the central stimulus stays present while the peripheral stimulus is present) then it is considered a measure of participants' *disengaging* abilities. If there is a gap between when the central stimulus disappears and when the peripheral stimulus is presented, then this is a measure of *shifting*. Previous research in TD individuals indicates similar looking patterns, or time to initiate an eye movement, on both shifting and disengaging trials.

Numerous researchers have utilized these tasks, or some variant of these tasks with modifications to the stimuli and presentation times to examine the visual orienting abilities of a variety of diagnostic groups and ages (Landry & Parker, 2013). Consistently, however, the gap-overlap task has involved a single-shift paradigm; that is, each trial consists of only one opportunity for an individual to disengage or shift rather than providing individuals with multiple opportunities to disengage and shift. Additionally, stimuli have typically involved static images of shapes, objects, and faces, which consequently limit findings to unimodal visual information. Thus, it is unclear if this type of task is representative of the dynamic and multimodal information and input that individuals typically encounter in their daily environment.

Attention in Individuals with ASD

Difficulties in the orienting, gazing, and arousal of attention have been hypothesized to help explain ASD symptomatology (Keehn, Lincoln, Muller, & Townsend, 2010; Landry & Bryson, 2004; Zwaigenbaum et al., 2005). Researchers have attempted to explain how attention, specifically visual orienting, is related to the deficits and symptoms typically present in individuals with ASD (Bryson et al., 2007). In particular, using both the gap-overlap and the visual cueing paradigms, researchers have attempted to determine whether individuals with ASD have a deficit in visual orientation and if so, what the nature of this deficit is, however, findings have been equivocal. Some researchers have found that individuals with ASD are consistently slow to disengage and shift their attention from one stimulus to another, and have suggested that 'sticky' attention is a core deficit in those individuals with ASD (e.g., Landry & Bryson, 2004). But, other researchers have shown that disengaging and shifting in exogenous and

endogenous attention abilities are intact in individuals with ASD (e.g., Fischer et al., 2014).

Deficits in visual orienting, or 'sticky' attention, have been found in individuals with ASD with varying chronological ages and developmental stages (e.g., infants at risk, adolescents, adults,), diagnostic sub-groups, degree of symptom severity (e.g., high-functioning, Asperger syndrome, Pervasive Developmental Disorder-Not Otherwise Specified; PDD-NOS), and using a variety of simple stimuli (e.g., still pictures, shapes, objects, faces). For example, in a simple visual orienting task using basic shapes as stimuli, Landry and Bryson (2004) found that compared to TD children and children with Down syndrome, children with ASD were significantly slower to disengage and shift from a central stimulus to a peripheral stimulus. Additionally these researchers found that children with ASD showed more difficulties disengaging than shifting. Using a similar experimental paradigm, a number of other researchers (Elsabbagh et al., 2009; Elsabbagh et al., 2013; Sweetenham et al., 1998; Zwaigenbaum et al., 2005) have found that infants at risk to develop ASD (siblings of children diagnosed with ASD) also present with disengagement and shifting deficits, with longer latencies to a peripheral stimulus than not at risk infants. Similarly, in a visual orientating task, high-functioning children and adolescents with ASD responded less accurately (8%) to valid cues relative to the TD comparison group (16%) (Renner, Klinger, & Klinger, 2006). Most recently, Keehn et al. (2010) examined the visual orienting, alerting, and executive control skills of children and adolescents with ASD using the Attention Network Task (ANT; Fan et al., 2002), which simultaneously assesses the three attention systems using a simple integrated task based on a combination of the visual orientation task and gap-overlap task. They found

that the visual orienting system (e.g., disengaging and shifting), not the alerting or the executive control system, is impaired in children and adolescents with ASD, regardless of IQ. However, Keehn et al. (2010) did not find a relationship between this visual orienting deficit and social-communication difficulties as measured by the ADOS**.**

The previous research suggests that children and adolescents with ASD have disengaging and shifting deficits, as frequently shown by their slower latencies to a peripheral stimulus, as well as inaccurate responses to a valid orienting cues. Although it is unclear as to what may explain these difficulties, 'sticky' attention has been suggested to be a fundamental characteristic of ASD (Bahrick & Todd, 2012). Consequently visual orienting is theorized to be a contributing factor for the development of atypical intersensory processing (Bahrick & Todd, 2012), social-communication (Dawson et al., 1998), and repetitive, restrictive behaviours (e.g., narrow focus or 'over-selectivity') in individuals with ASD (Renner, Klinger, & Klinger, 2004). For example, Dawson et al. (1998) suggested that deficits with attention disengagement and shifting are related to difficulties with orienting to naturally occurring social stimuli and have further implications for social interactions, joint attention, and peer relationships. Similarly, McConnell and Bryson (2005) found a relationship between difficulties in visual orienting and temperament (e.g., likelihood of smiling and level of frustration) in infants at risk to develop ASD.

Despite the abundance of evidence supporting this disengagement deficit hypothesis, a number of researchers have shown conflicting findings, and conclude that the visual orienting system is intact in individuals with ASD. For example, in a simple visual cueing task, there were no differences in the ability of adults with ASD to

disengage and shift their attention from a centrally presented stimulus compared to a TD comparison group, however, the ASD group was slower in their eye movement latencies from the central stimulus to a peripheral stimulus (Kuhn et al., 2010). Additionally, Kuhn et al. (2010) also found intact exogenous attention abilities in adults with Asperger syndrome, providing further evidence for visual orienting to be intact in individuals with ASD. Renner, Klinger, and Klinger (2009) showed that although the endogenous attention abilities of children with ASD are similar to TD children, exogenous attention abilities might be impaired.

In light of these conflicting findings and the implications that such deficits have on later development, researchers have attempted to provide explanations for why individuals with ASD have difficulties with visual orientation. Difficulties in processing the cue, including slow processing speed, and large cognitive load have been suggested to explain poor performance on the gap-overlap task and the visual cueing task in individuals with ASD (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001; Wainwright–Sharp & Bryson, 1993). However, subsequent research has not supported such claims. The stimuli type has also been proposed to impact the disengaging and shifting abilities of individuals with ASD. For example, through a series of experiments using the Multisensory Attention Assessment Protocol (MAAP), Bahrick and Todd (2012) have demonstrated that compared to TD children, children with ASD show disengaging difficulties to social information, but not to non-social information. Similarly, Kikuchi et al. (2011) showed that children did not show the same gap effect (i.e., quick response latencies) for face stimuli as TD peers.

Research examining level of engagement, or the degree to which one directs attention to a particular stimulus, as indicated by the length of time attending to that stimulus, has been limited. It is unclear if the degree to which a participants' overall involvement or participation in the task impacts disengagement and shifting abilities. That is, it is undetermined if those individuals, who are *more engaged* in the task, have more or less difficulty, disengaging and shifting their attention between task stimuli on exogenous, endogenous, and autogenous trials.

Another factor that has shown to impact exogenous and endogenous attention abilities in individuals with ASD is the type of task that is administered. Research in our lab (Study 1: Bebko et al., 2009; Study 2: McMorris et al., 2010; Study 3: McMorris et al., 2012) has examined the disengaging abilities in children with ASD. Children with ASD, TD children and children with ID, all matched on age and receptive language skills were tested using a preferential-looking paradigm. Two identical dynamic images on the right and left sides of the computer screen (Study 1 and Study 2) or four images on the screen (Study 3) were presented. Stimuli varied in complexity across the three studies, ranging from: a) simple vowel sounds and high frequency sounds being pronounced (Study 1); b) brief stimuli categorized as either high- (man reciting story), low- (man counting) or non-linguistic (mousetrap) stimuli (Study 2); and c) linguistic (women telling a story) and non-linguistic (piano) stimuli, using a four-screen array (Study 3). For each trial, only one screen was synchronized with the sound track, that is, the auditory and visual information matched. Results from all three studies indicate no differences in disengaging abilities between ASD and other groups as they scanned the displays, with comparable numbers and durations of eye fixations across groups for these dynamic

stimuli. The findings of apparently intact general attention disengaging skills with dynamic linguistic stimuli are inconsistent with previous research, and may highlight an important difference between attention skills on tasks that require frequent disengagement attention compared to single-shift paradigms.

In terms of the conceptual distinctions made in the present review, these multi-shift studies are definitive examples of autogenous attention, in that the cue to disengage must be self-generated versus in response to an explicit external cue. Performance on such autogenous tasks provides a better representation of individuals' disengaging and shifting capabilities in their everyday interactions in the environment, and thus may be a more ecologically valid representation of attention. These previous studies with dynamic stimuli, then, suggest that children with ASD show similar disengaging abilities on autogenous-type tasks.

CHAPTER TWO:

PRESENT STUDY

To date, there has been no research examining disengaging and shifting abilities of children and adolescents with ASD using a multiple shifts paradigm with the degree of complexity of the stimuli and stimulus type varying. Additionally, research has primarily focused on the exogenous attention abilities of children with ASD, and no research has compared both exogenous and autogenous attention. Given the potential implications of difficulties in disengaging and shifting for later social development (e.g., orienting to one's name, joint attention, imitation, and social interactions) and language development (e.g., language acquisition, back and forth conversations), as well as repetitive, restrictive behaviour (e.g., narrow or 'over-selectivity of focus'), a richer understanding of the attention abilities in children and adolescents with ASD is critical. Not only does understanding disengaging, shifting, and engaging abilities of children with ASD provide insight into whether these abilities are a core deficit in ASD, they also provide an important steps towards understanding the role attention has as a foundational component for the development of social-communicative functioning in children with and without ASD.

The disengagement and shifting abilities in children and adolescents with ASD compared to TD children were examined in the present study. More specifically, by evaluating performance on two different types of attention tasks (exogenous and autogenous), this project determined whether children with ASD have a deficit in shifting, disengaging, and engaging, and whether there is evidence for a general deficit or one that may be task-dependent. Additionally, how task stimuli impacts disengaging, shifting, and engaging abilities was studied. Specifically, the goal was to determine whether both the content of stimuli (i.e., social-linguistic information versus non-social,

non-linguistic information), and the level of complexity of the stimuli impacts

participants' attention abilities. Stimulus complexity included 1) the modality of the

information (i.e., unimodal versus multimodal), 2) the motion of the stimuli (i.e., static

stimulus versus dynamic), and 3) the degree of synchrony between visual and auditory

information (i.e., synchronous, asynchronous, versus no synchrony). How performance

on the attention task is related to symptoms consistent with an ASD diagnosis, such as

social-communication and restrictive and repetitive behaviours was also investigated, as

well as how engagement in a trial impacts participants' performance on the attention task.

Lastly, how specific demographic characteristics and clinical variables, such as cognitive

level, were related to exogenous and autogenous abilities of children with ASD compared

to TD children, was also explored.

Hypotheses

The following hypotheses are based on previous research conducted both with TD

children and adolescents as well as individuals with ASD.

1) If 'sticky' attention is a general deficit of the broader ASD phenotype, as

previous research has suggested (Elsabaggh et al., 2009; Elsabaggh et al., 2013; Landry

& Bryson, 2004; Zwaigenbaum et al., 2005), then the children and adolescents with ASD

should show inferior attention abilities on both exogenous attention and autogenous

attention trials compared to TD children, as indicated by *fewer* fixations and *longer* mean

durations per fixation. However, given that autogenous trials are considered a more

ecologically valid representation of attention, coupled with previous research showing

that autogenous attention abilities seem to be intact in individuals with ASD (e.g.,

McMorris et al., 2012), then the attention abilities of the TD children and the children

with ASD should differ based on attention type. In particular, for *autogenous attention trials* it was expected that participants' attention abilities would not differ between groups as indicated by *similar* number of fixations and mean fixation durations.

2) Consistent with previous research (e.g., Landry & Bryson, 2004), regardless of the type of information or complexity of the stimuli, it was expected that within the exogenous trials, the children with ASD would show *slower* times to fixate on subsequently presented stimuli on *disengaging trials* compared to *shifting trials.* Additionally, it was expected that the children with ASD would be more 'sticky' on disengaging trials, as shown by *fewer* number of fixations and longer mean fixation durations. In contrast, the TD children's performance on disengaging and shifting trials were not expected to differ.

3) A variety of experimental paradigms (e.g., gap-overlap task, natural occurring scenes) and stimuli (e.g., pictures, scenes from old movies, and tactile toys and objects), research has consistently shown that children with ASD are slower to disengage and shift attention to peripheral or competing stimuli that contains social information (Bahrick & Todd, 2012; Baron-Cohen et al., 1998; Dawson et al., 1998; Sacrey et al., 2014). Thus, the children with ASD were hypothesized to have *fewer* fixations, *longer* mean fixation durations, and *longer* times to fixate, or more 'sticky', when presented with social-linguistic stimuli compared to non-social, non-linguistic stimuli, when controlling for potential differences in trial type and group.

4) Consistent with previous research (McMorris et al., 2012), the degree of stimulus complexity was expected to impact exogenous attention abilities, with stimulus complexity consisting of three distinct areas: a) modality of the stimulus (e.g., visual or

visual and auditory); b) motion of the stimulus (static or dynamic); and c) synchrony between visual and auditory information (e.g., synchronous, asynchronous, and no synchrony). Trials that contained static images were coded as unimodal, as well as no synchrony, as no auditory information was present. Regardless of trial type and group, it was hypothesized that stimulus complexity would predict attention abilities on the exogenous trials, as shown by *shorter* times to fixate to subsequently presented stimuli (signifying less difficulty disengaging and shifting attention to subsequent stimulus), *longer* mean fixation durations, and *fewer* fixations, suggesting that complexity facilitates disengagement and shifting abilities. For example, it was hypothesized that the modality of the stimulus would be related to attention abilities, with individual's time to fixation being *shorter* for multimodal stimuli (visual and auditory information). Related to the degree of motion of the stimulus, it was predicted that the time to fixate would be *shorter* for dynamic stimuli versus static stimuli. Both groups were expected to have *shorter* times to fixate to synchronous stimuli than to asynchronous stimuli.

   5) If 'sticky' attention is related to social-communication and repetitive behaviour difficulties, then parent reported social-communication and repetitive behaviour symptoms would be expected to predict performance on the attention task, regardless of group. Thus, those individuals with more severe social-communication and repetitive behaviour difficulties were expected to have *longer* times to fixate and appear *more 'sticky'*, as indicated by *fewer* fixations and *longer* mean durations per fixation.

   6) If engagement in the task impacts attention abilities, then engagement, defined as the total time participants look at all stimuli in a trial, would be expected to predict their performance regardless of attention type, trial type, or group, however, the direction

of this relationship is ambiguous. Specifically, a negative association would indicate that those participants who are *more engaged* in the task might show *more 'stickiness'*, as indicated by fewer fixations, long durations, and slower times to fixate. Conversely, the opposite pattern may be seen where less overall engagement is shown, and this may be associated with *more fixations*, *shorter mean durations,* and *faster times to fixate*. This lower engagement pattern may indicate that participants were disinterested in the task or stimuli.

7) In addition to the above hypotheses, demographic characteristics including sex, chronological age, cognitive functioning, executive function skills, and attention difficulties as measured by parent-reported questionnaires, were examined as predictors of performance on the attention task.

CHAPTER THREE

METHOD

Participants

Two groups of children with a chronological age between 6 years, 3 months and 15 years, 4 months (M = 10 years 10 months; SD = 2.67 years) participated in the present study. There were n = 20 TD children (12 females and 8 males) and n = 18 children with a previous formal diagnosis of ASD (16 males and 2 females). Given that ASD affects far more males than females (4-5:1, Fombonne, 2003), the large proportion of males in the present sample was not unexpected. For the TD group, however, the emphasis was on the other matching variables, which resulted in a different proportion of males to females.

Participants with ASD were diagnosed according to the DSM-IV-TR diagnostic criteria (APA, 2000) or earlier editions, which included Autistic Disorder (3), Asperger syndrome (4), PDD-NOS (6), and ASD (5). Diagnoses were confirmed using either the *Autism Diagnostic Interview–Revised* (ADI-R; Lord, Rutter, & LeCouteur, 2003; n = 13) or the *Autism Diagnostic Observation Schedule* (ADOS; Lord, Rutter, DiLavore, & Risi, 2002; n = 1). If families were not available or willing to complete the ADI-R or ADOS, diagnosis was confirmed using diagnostic reports from a pediatrician or psychologist (n = 4). Both groups were recruited through local agencies and associations, or a previously established multi-site research registry (from Autism Spectrum Disorders - Canadian-American Research Consortium; ASD-CARC). All individuals were proficient in English, had normal or corrected-to-normal vision, and no pre-existing neurological issues. Participants were excluded from the study if their data indicated a less than 25% capture rate, as calculated by the eye-tracker. Overall, the average capture rate of the current sample was 72% (SD = 28.18).

Typically developing children were group-matched to children with an ASD based on their chronological age (CA), verbal ability (VA), nonverbal ability (NVA), and general cognitive abilities (GCA) as measured by the Early Years Cognitive Battery or School-Age Cognitive Battery of the Differential Abilities Scale, 2nd Edition (DAS-II; Elliott, 2006). One-way ANOVAs established that the groups were well-matched based on CA, VA, NVA, and GCA (all ps $\geq$ .09). See Table 1 for a summary of participant group characteristics.

Table 1

Sample demographic information

	ASD Sample (*n* = 18)		TD Sample (*n* = 20)			
	M **(SD)**	**Range**	**M** **(SD)**	**Range**	**F** **(df)**	**p**
Chronological Age (in months)	134.78 *(29.19)*	78-183	125.1 *(34.45)*	75-184	0.863 (1, 36)	0.359
DAS GCA Standard Score	95.65 *(22.01)*	65-145	102.45 *(10.03)*	81-118	2.878 (1, 36)	0.098
DAS VA Standard Score	92.89 *(20.98)*	34-131	101.85 *(10.34)*	86-126	1.583 (1, 36)	0.216
DAS NVA Standard Score	96.83 *(16.34)*	64-126	102.30 *(10.01)*	76-115	1.640 (1, 36)	0.209

Autism spectrum disorder (ASD), Typically developing (TD), Differential Ability Scale, 2nd Edition (DAS-II), general cognitive ability (GCA), verbal ability (VA), and nonverbal ability (NVA).

Measures and Materials

        Child measures.

        Cognitive measure. The Differential Abilities Scale, 2nd Edition (DAS-II; Elliott, 2006) is a standardized measure of intellectual or cognitive ability used with individuals from two years, six months of age through seventeen years, eleven months of age. Given that the DAS-II has reduced verbal instructions, demands less social engagement, provides greater opportunities for teaching, has fewer timed tasks, and has more hands-on activities, it has been recommended (Nowell, 2012) as a more appropriate measure of cognitive functioning in individuals with ASD compared to other cognitive measures (e.g., Wechsler Intelligence Scale for Children – 4th Edition, Wechsler, 2004). The core cognitive batteries of the DAS-II are grouped into two batteries based on the child's chronological or developmental age: 1) the Early Years Cognitive Battery (2 years, 6 months to 6 years, 11 months of age) and 2) School-Age Cognitive Battery (7 years to 17 years, 11 months). These subtests are used to assess a variety of cognitive abilities including speed of processing, immediate and delayed recall, verbal and visual working memory, and phonological processing. Each cognitive battery provides a General Composite Ability (GCA), as well as a Verbal Composite and Non-verbal Composite. The DAS-II has been used with a variety of special populations, including individuals with ASD and those with developmental disabilities (Bishop, Guthrie, Coffing, & Lord, 2011; Rice, Mouriuchi, Jones, & Klin, 2012).

        Autism diagnostic measures. The Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) or the Autism Diagnostic Observation Scheduled

(ADOS; Lord, Rutter, DiLavore, & Risi, 2002) was used to confirm diagnosis in the ASD group.

The ADI-R is a standardized, semi-structured parent interview for assessing ASD in children and adults. The ADI-R assesses individuals' quality of social interaction, communication and language, and repetitive, restricted, and stereotyped interests and behaviours. The ADI-R provides a diagnostic algorithm for ASD consistent with the DSM-IV-TR (APA, 2000) criteria. The ADI-R has been utilized in numerous empirical studies not only as an assessment measure to confirm ASD diagnoses, but also as an outcome measure (Ozonoff, Goodlin-Jones, & Solomon, 2005). The ADI-R has strong psychometric properties, including internal consistency, inter-rater reliability, and test-retest reliability (Lecavalier et al., 2006). The ADI-R has also been shown to have strong sensitivity and specificity, that is, it is able to accurately diagnose and differentiate between ASD and TD children (Lecavalier et al., 2006), as well as between ASD and those individuals with ID (de Bildt et al., 2004).

The ADOS is a standardized semi-structured observation schedule designed to diagnose individuals with ASD. Using a number of standardized and structured activities or social contexts, the ADOS measures an individual's quality of social interaction, communication and language, and repetitive, restricted and stereotyped interests and behaviours. The ADOS is designed to be used with individuals with a 3-year-old mental age or older. The ADOS contains four different modules, which vary in terms of level of difficulty and verbal ability required. For example, Module 1 is used when the individual does not have consistent phrase speech, whereas Module 3 is for children with fluent speech. Each module takes approximately 30 to 45 min to administer. The module that is

administered depends on the individual's developmental level and verbal abilities. After administration, behaviours observed are then coded and a diagnostic algorithm is used to calculate a total score. Based on this total score, individuals can be classified as having Autistic Disorder, an ASD, or non-ASD.

The ADOS has been used in numerous empirical studies not only as an assessment measure to confirm ASD diagnoses, but also as an outcome measure (Ozonoff, Goodlin-Jones, & Solomon, 2005). The ADOS has been shown to have strong psychometric properties, including internal consistency, inter-rater reliability, and test-retest reliability (Lord et al, 2000). The ADOS has also been shown to have strong sensitivity and specificity, that is, it is able to accurately diagnose and differentiate between autism and non-autism disorders (Lord et al., 2000). Although a new algorithm has been published to coincide with the new diagnostic criteria for ASD in the DSM-V (APA, 2013), the current data were collected using the previous algorithm.

Parent-report questionnaires.

Behavior Rating Inventory of Executive Functioning (BRIEF) – Parent Questionnaire. The BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000) is an 86-item parent rating scale that asks parents to evaluate their child or adolescents' executive functioning skills. Executive functions refer to skills related to inhibiting behaviour, shifting attention, controlling emotion, initiating tasks, keeping information in memory while manipulating it, planning behaviour, organizing materials, and monitoring task progress. The BRIEF has been shown to be a useful parent-report questionnaire to evaluate the executive function skills in children and adolescents between the ages of 5 and 18, as well as in individuals with a variety of disabilities and disorders, such as

Attention-Deficit Hyperactivity Disorder (ADHD), learning disabilities, and ASD (Gioia et al., 2000), as well as for TD children and adolescents. It has been shown to have moderate to good reliability (e.g., test-retest reliability, inter-rater reliability, and internal consistency), as well as convergent and divergent validity with other well-established measures of emotional and behaviour abilities (Gioia, Isquith, Guy, Kenworthy, & Baron, 2000).

Repetitive Behavior Scale-Revised (RBS-R). In order to understand the relationship between performance on the attention task and participants' difficulties with repetitive or rigid behaviours (e.g., difficulties with transitions, flexibility, perseveration, etc.), the RBS-R (Bodfish, Symons, & Lewis, 2000) was also administered to both groups. The RBS-R is a 43-item parent-report measure, which assesses the breadth of repetitive behaviours in children and adolescents with ASD. Parents were asked to rate the presence and severity of specific behaviours over the last month. Specifically, each item has a 4-point Likert-type scale from (0) "behavior does not occur" to (3) "behavior occurs and is a severe problem". The RBS-R consists of six subscales: 1) Stereotyped Behavior (e.g., movements or actions that are repeated in a particular manner), 2) Self-Injurious Behavior (movements that cause or have the potential to cause harm to the body), 3) Compulsive Behavior (a certain behaviour that has to be performed according to a specific rule), 4) Ritualistic Behavior (repeatedly performing an action in the same manner), 5) Sameness Behavior (insisting on doing things in the same way, or resistance to change), and 6) Restricted Behavior (limited range of focus or interests). The RBS-R has recently been shown to have moderate to good psychometric properties (Bodfish, Symons, & Lewis, 2000).

Conners, 3rd Edition. The parents also completed the Conners 3rd Edition (Conners, 2008) which is used to assess attention and hyperactivity/impulsivity, as well as learning problems, aggression, executive functioning, and peer relationships in children and adolescents. The Conners is recommended for use with children between 6 and 18 years of age, and has shown to have strong reliability (e.g., test-retest reliability, inter-rater reliability, and internal consistency) as well as good construct and predictive validity. In particular, it has shown to be positively correlated with other measures assessing attention, and is able to differentiate between adolescents with ADHD and typically developing adolescents (Kao & Thomas, 2010).

Social Communication Questionnaire – Lifetime Form (SCQ). The SCQ – Lifetime Form (Rutter, Bailey, & Lord, 2003) was used to confirm diagnosis, as well as to determine the degree of severity in the ASD group. Additionally, the SCQ was used to ensure individuals in the TD group did not show clinical symptoms consistent with an ASD diagnosis. The SCQ is a brief parent-report questionnaire used with children and adolescents with a mental age above 2 years of age who may have ASD. The SCQ – Lifetime Form consists of 40 yes/no questions and evaluates communication skills and social functioning over the child's entire developmental history. The SCQ-Lifetime Form provides a cut-off score, which not only identifies individuals who may have ASD, but also is a good indication of symptom severity. Overall, the SCQ has been shown to have moderate to strong psychometric properties. For example, the SCQ-Lifetime Form has been shown strong convergent validity with other well-established ASD measures, specifically with the Autism Diagnostic Observation Scale (ADOS; Oosterling et al., 2010).

Attention measures.

Apparatus. The attention task was presented on a 26-inch wide screen LCD TV screen controlled by a Dell computer and presented using Tobii software. The Tobii-II X60 eye tracker was located beneath the centre of the computer screen to record each participants' looking behaviours.

Stimuli. The stimuli in the present study were presented in a four-image array on the computer screen, that is, for each trial there was one image presented in each of the four quadrants (top-left, top-right, bottom-left, and bottom-right) of the computer screen. In the exogenous trials, only one or two stimuli were presented concurrently (depending on whether it was a disengaging or shifting trial), however, stimuli were presented in each quadrant over the course of the trial. For the autogenous trials, all four stimuli were presented for the duration of the trial.

For the exogenous trials, stimuli varied based on 1) the type of information or the degree of social and linguistic information provided, and 2) the complexity of the stimuli.

Stimulus type. Stimuli contained either social-linguistic or non-social, non-linguistic information. The social-linguistic trials involved a woman telling a story. Participants saw three different stories, with the level ranging from grade 2 to grade 5. Additionally, to ensure that the child maintained interest in the stimuli, three different female actors were used. The non-social, non-linguistic stimuli consisted of three objects: a piano, a collection of squares, hexagons, and other small metal hardware fasteners on a string, and the materials from the game *Mousetrap*. Although all these objects provide visual and auditory information, they are not social or linguistic in nature. In all the non-social, non-linguistic stimuli, a participant saw minimal information about the individual

playing or doing the activity; that is, participants only saw a finger playing the piano, a hand dropping the hardware fasteners or a hand putting the ball in the *Mousetrap* maze.

Complexity of stimuli. Stimuli varied based on 1) the modality in which information was presented (visual or visual and auditory), 2) the amount of motion of the stimulus (static or dynamic), and 3) the synchrony of the visual and auditory information (auditory/visual information is synchronous or asynchronous). Thus, as outlined in Table 2, within the exogenous trials, there were four different types of trials presented to the participant which increased with complexity: 1) still image, 2) dynamic stimuli with only visual information (e.g., the person's lips moving or finger hitting the piano), 3) dynamic stimuli with multimodal information (auditory and visual), in which the visual and auditory information were synchronous, and 4) dynamic, multimodal stimuli, but the visual and auditory information were asynchronous (e.g., auditory information was delayed by three seconds from the visual information).

All the autogenous trials had dynamic and multimodal stimuli. The participants were presented with two types of trials: 1) social-linguistic and 2) non-social, non-linguistic, equivalent to the stimuli described in detail above.

Attention task and design. The participants' attention abilities were measured using an attention task that consisted of two different types of trials: 1) exogenous attention trials (i.e., examining attention abilities when provided with a peripheral cue to shift or disengage), and 2) autogenous attention trials (i.e., examining self-directed attention). The participants' eye movements, as measured by the Tobii eye-tracker, were an indication of their attention abilities during both types of trials.

In the current study, engagement was defined as the degree to which the participants were involved in the task stimuli. Accordingly, the longer the participants spent looking at a trial, the more they were assumed to be engaged with that stimulus. Participants' total engagement in the attention trial was measured by their total looking time at the overall four-image array out of the 12 seconds (s) trial.

Table 2

Attention task design

Trial Type/Level of Complex	EXOGENOUS TRIALS (32)			
	Disengage		Shift	
	Social-Linguistic	Non-Social, Non-Linguistic	Social-Linguistic	Non-Social, Non-Linguistic
Still	2	2	2	2
Dynamic & unimodal (visual information)	2	2	2	2
Dynamic, multimodal & synchronous	2	2	2	2
Dynamic, multimodal & asynchronous	2	2	2	2
AUTOGENOUS TRIALS (8)				
Dynamic, multimodal, and simultaneously synchronous and asynchronous	Social-Linguistic: 4 Non-Social, Non-Linguistic: 4			

Exogenous attention trials. In order to examine children's exogenous attention, participants completed a total of 32 exogenous attention trials, with 16 trials assessing

participants' shifting abilities and the remaining trials examining disengagement abilities. All trials lasted approximately 12 s, with shifting trials lasting slightly longer (12.09 s; described below) than disengaging trials (12 s). Each trial began with a cartoon picture or video (central fixation) presented in the middle of the screen, which remained for 3 s. In the *shifting trials,* the participants were then presented with a stimulus in one quadrant of the screen for 3 s, after which the stimulus disappeared. Then, following a brief delay (30 milliseconds – ms; or 1 frame), the same type of stimulus appeared in another quadrant. This sequence was repeated a total of 4 times and thus the participants had the opportunity to shift four times.

In the *disengagement trials,* following the presentation of the central fixation, the participants were presented with a stimulus in one quadrant of the screen for 3 s. After 3 s, a second stimulus appeared in another quadrant. In contrast to the shifting trials, here the first stimulus remained, then disappeared 500 ms after the onset of the second stimulus, thus requiring attention to be disengaged from the previous stimulus to shift to the new one. Similar to the shifting trials, this sequence was repeated 4 times, giving participants the opportunity to disengage four times.

For both shifting and disengagement trials, the order of the quadrants in which the stimulus was presented was randomized. Within each trial, the participants were presented with the same type of stimulus, however, the second stimulus presented was always discontinuous or slightly different than the first. For example, if the participants were first presented with a social-linguistic dynamic multimodal synchronous stimulus, such as a story with visual and auditory information that is synchronous, the second stimulus was the same story and actor; however, it would be at a different part of the

story. Thus, both the auditory and visual information was different from the previous stimulus, but the stimulus type was identical. The time that it took for the participants to look at the second stimulus from its onset time, termed time to fixate, was an indication of either their shifting or disengagement performance, depending on the type of trial. The order in which the exogenous trials were presented was randomized and took approximately 8 minutes (min) to complete.

　　　Autogenous attention trials. Participants were presented with a total of eight autogenous attention trials (four social-linguistic trials and four non-social, non-linguistic trials), each trial lasting 12 s. For every trial, all four images of the stimulus array consisted of the same trial type (e.g., all four images were of the same social-linguistic stimulus). However, there was only one image within the array in which the auditory or the visual information was matched or synchronous. The other three images were all the same video clip, but were asynchronous with the sound. More specifically, one image was delayed by 1 s from the matched screen, another was ahead of the matched screen by 1 s, and the third image was ahead of the matched screen by 3 s.

　　　Similar to the exogenous trials, the autogenous trials began with the presentation of a cartoon picture or video (central fixation) presented for 3 s. Given that all four images remained on the screen for the duration of the trial, the number of fixations and duration per fixation were measures of the participants' disengagement abilities. Difficulty with disengagement and shifting ('sticky' attention) would be represented by fewer fixations and longer durations per fixation. The order of the autogenous trials was randomized, and took approximately 2 min to complete.

Procedure

Prior to participation, the participants and their parents both completed the informed consent (Appendix A and B) and assent forms (Appendix C). During the testing, the participants were seated with their eyes in line with the middle of the screen (horizontally and vertically), and between 51 and 77 cm from the eye-tracker ($M = 60.92$; $SD = 5.57$). The participants were first presented with a moving ball in order for the eye-tracker to calibrate their eye-movements in preparation for data collection. Next, the participants completed the attention task, both exogenous and autogenous trials. These tasks took approximately 20 min in total, with a break halfway through the attention task. Following the attention task, the cognitive functioning measure (DAS-II) was administered.

At the same time, the parents completed the BRIEF, the Conners, the RBS-R, and the SCQ. To confirm the diagnosis, the parents of the children with ASD were asked to provide a copy of their diagnostic report. If the parents were willing and there was not enough time to complete the ADOS with the child, the parents were contacted at a later date to complete the ADI-R over the phone.

After completing the study, the participants were offered a certificate and gift card thanking them for participating in the study. At this time, the participants and the parents were debriefed and provided with a brief description of the present study's objectives, research questions, hypotheses, and potential clinical implications for the study's findings. The parents also had the opportunity to ask any questions regarding the study and request a summary of the study findings.

Data analyses

Tobii software was used to determine locations and durations of fixations. Statistical analyses were performed using SPSS and R software. The dependent variables for the present analyses were participants' attention abilities as indicated by their eye movements on the attention task. More specifically, participants' attention abilities were operationalized as the time it takes for a participant to move attention from one stimulus to the next (*time to fixate*) in addition to *duration per fixation* and *total number of fixations* per trial. Due to differences in the design of the autogenous and exogenous trials, different variables were used in the analyses of these trials. Given that all four stimuli remain on the screen for the 12 s trial in the autogenous trials, time to fixate was not used as an indication of attention. Thus, duration per fixation and total number of fixations were examined in autogenous trials, whereas time to fixate on a new stimulus, duration per fixation, and total number of fixations were used in the exogenous trials. Engagement in the attention task was determined by the participants' total looking time at the computer screen during the course of the 12 s trial.

Tobii eye-tracking software was used to extrapolate the above variables for each participant per trial. More specifically, for each trial, static and dynamic areas of interest (AOIs) were created for each stimulus within a trial (stimulus AOI), in addition to an AOI for the overall screen (screen AOI). Tobii then used these AOIs to calculate a number of metrics, including the above variables, for these specified areas. Both the stimulus and screen AOIs were rectangular in shape with the stimulus AOI being ¼ of an inch larger than each stimulus to account for any issues with calibration, and the screen AOI was the size of the computer screen. Thus, for each trial, five AOIs were created.

Static AOIs are those AOIs in which the AOI remains on the screen for the duration of the trial, whereas dynamic AOIs can be used for dynamic media (e.g., movies) or media in which objects may appear or disappear within the same trial. Consequently, dynamic AOIs can be set up to collect gaze data *only* when objects or stimuli in the media are present. In the present study, combinations of static and dynamic AOIs were used depending on the trial type and the dependent variable being calculated. Particularly, static AOIs were utilized for the autogenous trials, because the four images were present for the duration of the trial. For the exogenous trials both dynamic and static AOIs were created. More specifically, given the present study's operationalization of time to fixate, dynamic AOIs were created for both shifting and disengaging trials. However, for duration per fixation, and total number of fixations, static AOIs were used because of the need to consider whether participants looked at other stimulus quadrants *even if* that stimulus was not present. In considering if the participants had difficulty shifting and disengaging it was important to determine if participants were looking at other parts of the screen when a stimulus was not present (e.g., anticipating where the next stimulus would appear). If participants were looking at a stimulus when it was not present, gazes to this static AOI were still included.

Tobii software calculates eye movements based on each of the AOIs per trial and exports the gaze data accordingly. Time to fixate, total looking time, and total number of fixations for the four stimuli AOIs and screen AOI per trial were exported for each participant. Then, duration per fixation was calculated for each stimulus AOI by dividing the total looking time of each stimulus AOI by the total number of fixations at each stimulus AOI (duration per fixation = (total looking time) / (total number of fixations)).

Next, the mean time to fixate, mean duration per fixation, and mean total number of
fixations were calculated across the four stimulus AOIs. All the results are based on the
mean time to fixate, mean duration per fixation, and mean total number of fixations per
trial. The total looking time of the screen AOI was used as the measure of engagement in
the attention task.

The primary method of analysis to test the aforementioned hypotheses was
multilevel modeling (MLM). MLM is a statistical procedure for analyzing data that are
hierarchical, or data with non-independent observations. Repeated trials of an
experimental task are considered to be hierarchical because trials are nested within
subjects. By analyzing trial-level observations, then, it is required to account for the fact
that a given set of trials produces non-independent observations by virtue of coming from
the same participant (e.g., being nested within participants). Unlike analysis of variance
(ANOVA), MLM standard error estimates are not biased by non-independence of
observations. By accounting for the nesting, MLM provides a better representation of the
nature of the variability of the dependent variable, versus averaging across trials to
analyze participant-level aggregated observations, as done in ANOVA.

To evaluate the above hypotheses, the present study used two broad MLMs
(MLM 1 and MLM 2), and within these MLMs a series of models were estimated. In
particular, MLM 1 (912 trials nested within 38 individuals) was used to test hypotheses 1
and 6, while MLM 2 (1216 trials nested within 38 individuals) was used to investigate
hypothesis 2 to 6. These 2 separate MLMs were used for both conceptual and
methodological reasons. Specifically, whereas MLM 1 evaluated whether type of
attention (exogenous or autogenous) predicted performance on the attention task, MLM 2

solely focus on exogenous attention abilities. This was done to both replicate previous research on exogenous abilities among TD children and children with ASD (MLM 2), but also to add to the literature by evaluating whether autogenous and exogenous attention abilities differed in children with ASD (MLM 1). Additionally, two MLMs were used to account for differences in the design of some of the trials. That is, in the autogenous trials all four images remained on the screen for the whole trial (autogenous), whereas in the exogenous trials, images appeared and disappeared throughout the trial. These differences in the experimental design resulted in different variables used in analysis. Specifically, MLM 1 only involved mean number of fixations and mean duration per fixation, as it was not possible to determine time to fixate. However, in MLM 2, all three dependent variables were used.

Within MLM 1 and MLM 2, a series of models was estimated using restricted maximum likelihood (REML) for each dependent variable following the procedures outlined by Raudenbush and Bryk (2002). Each series began with the unconditional model, or the intercept-only model, which was used to examine whether there was a substantial amount of non-independence of trials due to their clustering within the participants. An unconditional model does not include any predictors, specifically, the dependent variable is not conditioned on any of the predictors, and the model only has an intercept and no slopes. Further, the unconditional model allows the variance of the dependent variable to be partitioned into trial-level variance and participant-level variance, prior to incorporating any predictors.

This unconditional model was then extended systematically to incorporate predictor variables in the level 1 model (trial-level predictors, or task characteristics), the

level 2 model (participant-level predictors, or participant characteristics), or both the level 1 and level 2 models (simultaneously considers task- and participant-level predictors). *Task type* (exogenous or autogenous), *exogenous trial type* (disengaging versus shifting), *level of complexity* (modality – unimodal/multimodal; state – still/dynamic; and synchrony – synchronous/asynchronous/no synchrony), and *stimulus type* (social-linguistic versus non-social, non-linguistic) were included as level 1 task characteristic predictors. Additionally, the participant characteristics of *group diagnosis* (ASD versus TD), *cognitive level* (general cognitive ability, verbal and nonverbal cognitive ability standard scores on the DAS-II), *executive functioning skills* (scores on the BRIEF subscales), and *attention difficulties* (total score on Conners subscales) were included as level 2 predictors.

First, a random-intercepts model (e.g., a model in which the intercepts of the dependent variables are allowed to vary) was estimated to determine whether the inclusion of a level 1 predictor accounted for the unexplained variance in the unconditional model. Next, a random-slopes model (i.e., a model in which the slopes of the predictor are allowed to vary) was estimated to understand the association between the dependent variable and the level 1 predictors, while allowing this relationship to vary across participants. Likelihood ratio tests were used to determine whether the random-intercepts model or random slopes model fit the data better than the unconditional model. The next model estimated the relationship between the dependent variables and level 2 predictors. The final model estimated included a cross level interaction (level 1 predictor by level 2 predictor).

CHAPTER FOUR:

RESULTS

Table 3 provides the descriptive statistics of the parent-reported measures for all the participants. The TD children and the children with ASD differed significantly on all parent-reported measures, ps < .001. Due to the differences in sex distribution in each group (i.e., 16 males in the ASD group versus 8 males in the TD group), descriptive statistics of the clinical variables (i.e., parent-report questionnaires and cognitive abilities), and performance on the attention task are outlined in Table 4. Males and females significantly differed on all of the of clinical variables and performance on the attention task, all ps $\leq$ .02.

Table 3

Descriptive statistics of parent-reported questionnaires

Mean *(SD)* Range	Whole Group (*n* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Clinical Variables			
SCQ: Total Score	8.87 *(8.93)* 0 - 30	15.67 *(8.48)* 3 - 30	2.75 *(2.76)* 0 - 8
RBS-R: Total Score	8.15 *(10.26)* 0 - 45	15.22 *(10.91)* 1 – 45	1.79 *(2.7)* 0 -11
BRIEF: Inhibition Subscale	51.76 *(11.59)* 37 – 82	58.83 *(11.93)* 40 - 82	45.4 *(6.43)* 37 - 63
BRIEF: Shifting Subscale	55.47 *(14.15)* 36 – 88	66.61 *(10.17)* 45 - 88	45.4 *(8.67)* 36 – 67
BRIEF: Behavioural Regulation Index (BRI)	52.58 *(11.38)* 36 - 76	61.22 *(8.22)* 46 - 76	44.8 *(7.57)* 36 – 63
BRIEF: Metacognition Index (MEI)	53.54 *(14.48)* 3 - 80	63.39 *(8.04)* 47 - 80	44.68 *(13.21)* 3 - 77
BRIEF: Global Executive Composite (GEC)	54.62 *(11.9)* 36 - 80	63.83 *(8.04)* 46 - 80	46.33 *(8.12)* 36 - 64

Table 3 continued

Descriptive statistics of parent-reported questionnaires

Mean *(SD)* Range	Whole Group (*n* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Clinical Variables			
Conners: Inattention Symptom Subscale	57.48 *(14.82)* 35 - 86	63.83 *(8.88)* 56 - 86	47.26 *(11.23)* 35 - 82
Conners: Hyperactivity-Impulsivity Symptom Subscale	56.35 *(15.08)* 38 - 90	64.56 *(13.52)* 42 - 90	48.96 *(12.34)* 38 - 86
DAS II: Verbal Cognitive Ability (VCA)	97.6 *(16.45)* 34 - 131	92.89 *(20.41)* 34 - 131	101.84 *(10.08)* 86 - 126
DAS-II: Nonverbal Cognitive Ability (NVCA)	99.71 *(13.3)* 64-126	96.83 *(14.89)* 64 - 126	102.3 *(9.76)* 76 - 115
DAS-II: General Cognitive Ability (GCA)	99.39 *(15.82)* 58 - 145	96 *(20.02)* 58 - 145	102.44 *(9.78)* 81 - 118
Performance on Attention Task			
Mean Number of Fixations	19.1 *(8.68)* 0 - 46	16.61 *(8.97)* 0 - 43	21.35 *(7.75)* 0 - 46
Mean Duration per Fixation	0.63 *(0.17)* 0 – 1.61	0.58 *(0.16)* 0 – 1.29	0.68 *(0.17)* 0 – 1.61
Mean Time to Fixate	0.73 *(0.24)* 0 – 3.12	0.77 *(0.27)* 0 – 2.62	0.68 *(0.2)* 0 – 3.12

Table 4

Descriptive statistics of clinical variables and performance on attention task by group and sex

Mean *(SD)* Range	Whole Sample		ASD Sample		TD Sample	
	Males (*n* = 24)	**Females** (*n* = 14)	**Males** (*n* = 16)	**Females** (*n* = 2)	**Males** (*n* = 8)	**Females** (*n* = 12)
Clinical Variables						
SCQ: Total Score	11.15 *(9.09)* 0 – 30	4.94 *(7.1)* 0 – 26	15.06 *(8.59)* 3 – 30	20.50 *(5.54)* 15 – 26	3.37 *(2.96)* 0 – 8	2.34 *(2.53)* 0 - 7
RBS-R: Total Score	10.27 *(11.54)* 0 – 45	4.51 *(6)* 0 – 20	15 *(11.51)* 1 – 45	17 *(3.02)* 14 – 20	0.86 *(1.35)* 0 – 4	2.42 *(3.16)* 0 -11
BRIEF: Inhibition Subscale	53.95 *(12.98)* 37 – 82	48 *(7.29)* 41 – 63	59.31 *(12.45)* 40 – 82	55 *(5.04)* 50 – 60	43.26 *(4.87)* 37 – 54	46.83 *(6.94)* 41 - 63
BRIEF: Shifting Subscale	60.07 *(12.31)* 36 – 80	47.57 *(13.61)* 37 – 88	66.63 *(7.65)* 50 – 80	66.50 *(21.67)* 45 – 88	47 *(8.99)* 36 – 67	44.41 *(8.30)* 37 - 63
BRIEF: Behavioural Regulation Index (BRI)	56.11 *(11.26)* 37 – 76	46.49 *(8.71)* 36 – 66	61.88 *(7.73)* 47 – 76	56 *(10.08)* 46 – 66	44.63 *(7.87)* 37 – 63	44.90 *(7.37)* 36 - 63
BRIEF: Metacognition Index (MEI)	59.48 *(11.04)* 37 – 80	43.32 *(14.01)* 3 – 70	64 *(7.27)* 51 – 80	58.5 *(11.59)* 47 – 70	50.47 *(11.74)* 37 –77	40.79 *(12.73)* 3 - 58
BRIEF: Global Executive Composite (GEC)	59.06 *(10.91)* 36 – 80	46.98 *(9.42)* 37 – 70	64.56 *(7.07)* 50 – 80	58 *(12.09)* 46 – 70	48.11 *(8.73)* 36 – 62	45.14 *(7.46)* 37 - 64

Table 4 continued

Descriptive statistics of clinical variables and performance on attention task by group and sex

Mean *(SD)* Range	Whole Sample	ASD Sample	TD Sample	59 *(2.02)* 57 – 61	47.48 *(14.56)* 35 – 82	47.11 *(8.29)* 39 - 68
	Males *(n* = 24)	**Females** *(n* = 14)	**Males** *(n* = 16)	**Females** *(n* = 2)	**Males** *(n* = 8)	**Females** *(n* = 12)
BRIEF: Global Executive Composite (GEC)	59.06 *(10.91)* 36 – 80	46.98 *(9.42)* 37 – 70	64.56 *(7.07)* 50 – 80	58 *(12.09)* 46 – 70	48.11 *(8.73)* 36 – 62	45.14 *(7.46)* 37 - 64
Clinical Variables						
DAS-II: Nonverbal Cognitive Ability	98.17 *(14.76)* 64 –126	102.37 *(9.79)* 76 – 115	96.88 *(16.81)* 64 – 126	96.50 *(3.53)* 93 – 100	100.74 *(8.92)* 89 – 115	103.35 *(10.16)* 76 - 115
DAS-II: General Cognitive Ability	98.58 *(18.63)* 58 –145	100.78 *(9.01)* 81 – 113	95.69 *(20.89)* 58 – 145	98.5 *(10.58)* 88 – 109	104.35 *(10.97)* 86 – 118	101.16 *(8.68)* 81 - 113
Performance on Attention Task						
Mean Number of Fixations	17.37 *(8.65)* 0 – 43	22.09 *(7.87)* 1 – 46	16.54 *(9.06)* 0 – 43	17.14 *(8.31)* 1 - 31	19.02 *(7.54)* 0 – 38	22.91 *(7.50)* 3 - 46
Mean Duration per Fixation	0.62 *(0.18)* 0 –1.53	0.66 *(0.16)* 0.31 – 1.61	0.57 *(0.16)* 0 – 1.29	0.64 *(0.14)* 0.31 – 1.07	0.71 *(0.17)* 0 – 1.53	0.66 *(0.17)* 0.40 – 1.61
Mean Time to Fixate	0.75 *(0.25)* 0 – 2.62	0.69 *(0.22)* 0.32 – 3.12	0.78 *(0.28)* 0 – 2.62	0.70 *(0.21)* 0.32 – 1.51	0.69 *(0.17)* 0 – 1.60	0.69 *(0.22)* 0.37 – 3.12

Prior to fitting the MLMs, the data were screened for skewness and kurtosis using descriptive statistics and plots, which indicated that the assumption of normality was violated. In particular, MLM requires that the level 1 and level 2 residuals are normally distributed. The descriptive statistics (Table 5) and plots showed that the residuals for the mean duration per fixation, and mean time to fixate had positive skewness and kurtosis in both MLM 1 and MLM 2. As a result, log transformations were applied to these dependent variables, and descriptive statistics indicated the residuals no longer violated the assumption of normality. The descriptive statistics of the log-transformed dependent variables are provided below for the overall sample, and by group (Table 6 and 7)

Table 5

Descriptive statistics of dependent variables

	Mean Number of Fixations	Mean Duration per Fixation (in s)	Log (Mean Duration per Fixation) (in s)	Mean Time to Fixate (in s)	Log (Mean Time to Fixate) (in s)
MLM 1					
n	912	912	912		
M	18.94	0.47	0.65		
SD	8.65	0.42	0.22		
Mdn	19	0.39	0.63		
Min	0	0	0		
Max	46	5.8	2.41		
Skew	-0.11	5.8	2.03		
Kurtosis	-0.6	47.78	11.29		
MLM 2					
n	1216	1216	1216	1216	1216
M	19.09	0.43	0.63	0.59	0.73
SD	8.69	0.26	0.17	0.51	0.24
Mdn	20	0.38	0.62	0.45	0.67
Min	0	0	0	0	0
Max	46	2.58	1.61	9.76	3.12
Skew	-0.05	3.21	0.71	8.4	2.14
Kurtosis	-0.49	18	5.26	120.89	15.14

Table 6

Log-transformed typically developing descriptive statistics of dependent variables

	Mean Number of Fixations	Mean Duration per Fixation (in s)	Mean Time to Fixate (in s)
MLM 1			
n	480	480	
M	20.69	0.71	
SD	8.16	0.22	
Mdn	21	0.66	
Min	0	0	
Max	46	1.97	
Skew	-0.13	2.35	
Kurtosis	-0.45	8.77	
MLM 2			
n	640	640	640
M	21.32	0.68	0.69
SD	7.79	0.17	0.2
Mdn	22	0.65	0.64
Min	0	0	0
Max	46	1.61	3.12
Skew	-0.03	1.62	4.89
Kurtosis	-0.29	6.19	48.34

Table 7

Log-transformed autism spectrum disorder (ASD) descriptive statistics of the dependent

variables

	Mean Number of Fixations	Mean Duration per Fixation (in s)	Mean Time to Fixate (in s)
MLM 1			
n	432	432	
M	17	0.59	
SD	8.77	0.21	
Mdn	18	-0.59	
Min	0	0	
Max	39	2.41	
Skew	-0.02	2.11	
Kurtosis	-0.78	17.55	
MLM 2			
n	576	576	576
M	16.61	0.58	0.77
SD	8.97	0.16	0.27
Mdn	17	0.58	0.72
Min	0	0	0
Max	43	1.29	2.62
Skew	0.14	-0.36	0.71
Kurtosis	-0.65	3.38	4.02

Random intercepts models are reported for all the subsequent analyses, because there were no significant differences between the random-intercept model and the random-slope model using the likelihood ratio test, all ps > 0.05. Although the likelihood ratio test indicated no significant difference, the fit statistics, specifically the AIC (Akaike information criterion) and BIC (Bayesian information criterion) were smaller for the random-intercept model, and thus deemed to be a better fit for the present study's data.

The correlations among participant-level predictors are in Table 8.

Table 8

Correlations among participant-level predictors

	CA	DAS VA	DAS NVA	DAS GCA	SCQ	RBS-R	Conners HI	Conners IA	BRIEF BRI	BRIEF MEC	BRIEF GEC
CA		.11*	.13*	.09*	.14*	0.06	.02	.01	.12*	-.04	.12*
DAS VA	.11*		.56*	.80*	-.42*	-.63*	-.47*	-.28*	-.36*	-.16*	-.28*
DAS NVA	.13*	.56*		.85*	-.19*	-.31*	-.20*	-.25*	-.13*	-.08*	-.09*
DAS GCA	.09*	.8*	.85*		-.35*	-.47*	-.34*	-.24*	-.22*	-.01*	-.13*
SCQ	.14*	-.42*	-.19*	-.35*		.75*	.49*	.60*	.65*	.47*	.62*
RBS-R	.06	-.63*	-.31*	-.47*	.75*		.73*	.65*	.72*	.44*	.67*
Conners HI	.02	-.47*	-.2*	-.34*	-.49*	.73*		.65*	.74*	.30*	.72*
Conners IA	.01	-.28*	-.25*	-.24*	.60*	.65*	.65*		.64*	.70*	.83*
BRIEF BRI	.12*	-.36*	-.13*	-.22*	.65*	.72*	.74*	.64*		.50*	.89*
BRIEF MEC	-.04	-.12*	-.08*	-.01	.47*	.44*	.30*	.71*	.50*		.70*
BRIEF GEC	.12*	-.28*	-.09*	-.13*	.62*	.67*	.72*	.83*	.89*	.70*	

* $p < .01$

Chronological Age (CA), Differential Ability Scale, 2nd Edition (DAS), general cognitive ability (GCA), verbal ability (VA), and nonverbal ability (NVA), Social-Communication Questionnaire-Lifetime Version (SCQ), Repetitive Behavior Scale-Revised (RBS-R), Conners, 3rd Edition, Hyperactivity symptom subscale (Conners HI), Conners 3rd Edition, Inattentive symptom subscale (Conners IA), Behaviour Rating Inventory of Executive Functions (BRIEF), Behaviour Regulation Index (BRI), Metacognition Composite (MEC), Global Executive Composite (GEC).

Hypothesis 1: Exogenous versus Autogenous Attention Abilities

Overall, it was hypothesized that attention abilities of the TD children and the children with ASD would differ based on attention type. In particular, for the *autogenous attention trials* it was expected that the participants' attention abilities were not expected to differ by diagnosis, as indicated by *similar* numbers of fixations and mean durations per fixation. In contrast, the children with ASD were expected to display *fewer* fixations and *longer* mean fixation durations on *exogenous attention trials* compared to the TD group. For these analyses, the disengaging exogenous attention trials were compared to the autogenous attention trials, as they were the most comparable to the nature of the autogenous trials, given the brief overlap of stimuli. To test hypothesis 1, the models included attention type (level 1 predictor: exogenous attention versus autogenous attention), group (level 2 predictor: ASD and TD), and an interaction between these variables to predict mean number of fixations and mean duration per fixation (Table 9).

The intraclass correlations (ICCs) for the mean number of fixations and mean duration per fixation computed for the unconditional models were 0.42 and 0.20, respectively. Thus, 42% of the variance of the mean total number of fixations and 20% of the variance in mean duration per fixation is due to the nesting of trials within the participants, or the repeated measures nature of the attention task. Consequently, this variance will be accounted for in the subsequent MLM analyses.

Table 9

Descriptive statistics: Attention type and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Autogenous Trials			
Mean number of fixations	18.35 *(8.92)*	17.28 *(8.97)*	19.32 *(8.79)*
Mean duration per fixation (in s)	0.7 *(0.29)*	0.63 *(0.29)*	0.76 *(0.28)*
Exogenous Trials			
Mean number of fixations	19.23 *(8.5)*	16.85 *(8.68)*	21.38 *(7.75)*
Mean duration per fixation (in s)	0.63 *(0.17)*	0.57 *(0.16)*	0.68 *(0.17)*

Mean number of fixations. Overall, attention type (exogenous versus autogenous) was significantly related to the mean number of fixations, $t(872) = 3.276$, $p = 0.001$, however, group was not significantly associated with mean number of fixations, $p = 0.301$. The attention type by group interaction was included in the model, it was significant, $p = 0.007$ (Figure 2), when included in the model. Specifically, among the TD children the predicted number of fixations for exogenous attention trials was 2.056 higher than for autogenous attention trials on average, and this difference was significant, $t(872) = 3.28$, $p = 0.001$. Among the participants with ASD, the predicted number of fixations for exogenous attention trials was 0.424 lower than autogenous attention trials, but this difference was not significant, $t(872) = -0.64$, $p = 0.522$. Therefore the interaction is such that exogenous attention trials were associated with more fixations than autogenous attention trials for the TD children. Among the participants with ASD, the exogenous attention trials were associated with fewer fixations than autogenous attention trials; however, this effect was not significant (Table 10).

Figure 2

Interaction between attention type and group
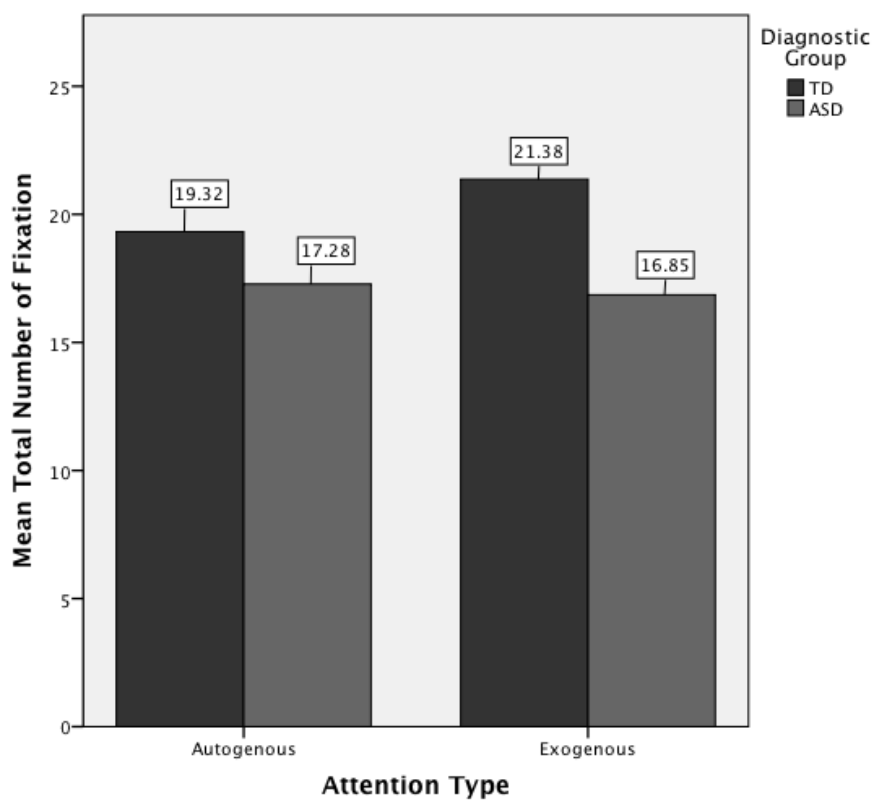
Table 10

Predictors of mean number of fixations: Attention type and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Simple intercept and slope effects for TD group					
Intercept	19.319	1.338	14.436	872	0.000
Attention type	2.056	0.627	3.276	872	0.001
Simple intercept and slope effects for ASD group					
Intercept	17.278	1.411	12.248	872	0.000
Attention type	-0.424	0.662	-0.64	872	0.522

Consistent with hypothesis 1, attention type (exogenous and autogenous) and

group (TD and ASD) significantly predicted number of fixations and mean durations per

fixation on the attention task; however, the pattern of results was different than expected. In particular, contrary to the hypothesis that the TD participants and the participants with ASD would display comparable autogenous attention abilities, as indicated by similar number of fixations and mean durations per fixation, the participants with ASD displayed more fixations on autogenous attention trials compared to exogenous trials. Thus, consistent with previous research, the participants with ASD appeared to display fewer fixations on exogenous attention trials than autogenous trials, suggesting that the attention of the participants with ASD may have been be more 'sticky' on these trials. Of note, TD children had more fixations on exogenous attention trials than autogenous attention trials.

Mean duration per fixation. Attention type was significantly related to mean duration per fixation, $t(873) = -4.294$, $p < 0.001$, with the mean duration per fixation being 0.068 s shorter on average for exogenous attention trials than autogenous attention trials. Group was also significantly related to mean duration per fixation, with the mean duration per fixation being 0.113 s shorter for the participants with ASD than the TD children, on average, $t(36) = -3.935$, $p < 0.001$. The interaction term, attention type by group, was not significant, $t(872) = 0.989$, $p = 0.323$ (Table 11).

Table 11

Predictors of mean duration per fixation: Attention type and group

Fixed effects	Coefficient	Standard Error	t	df	p
Intercept	0.763	0.026	29.441	872	<0.001
Attention type	-0.083	0.022	-3.795	872	<0.001
Group	-0.137	0.038	-3.647	36	0.001

Inconsistent with hypothesis 1, regardless of group, the participants displayed shorter mean duration per fixation on exogenous trials. Additionally, regardless of attention type trial, children with ASD displayed longer mean durations per fixation compared to TD children (Figure 3).

Figure 3

Predictors of mean duration per fixation: Group
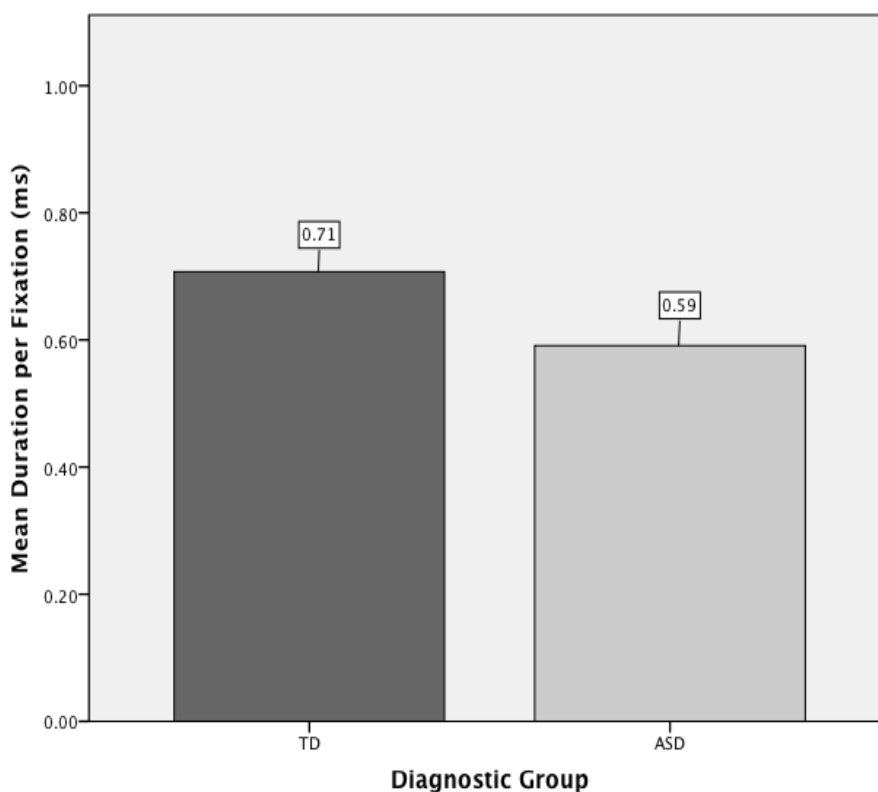
Hypothesis 2: Shifting versus Disengaging Attention Abilities

On the exogenous trials, the participants with ASD were expected to show *slower* time to fixate on subsequently present stimuli on disengaging trials compared to shifting trials, regardless of the type of information or complexity of the stimuli. Additionally, the attention abilities of the participants with ASD were expected to be more 'sticky' on disengaging trials, as shown by *fewer* number of fixations and longer mean fixation

durations. The TD participants' performance on shifting and disengaging trials would not show differences between disengaging and shifting trials. To investigate hypothesis 2, trial type (disengaging and shifting trails), group (ASD and TD) and their interaction were included in a second model to predict mean number of fixations, mean duration per fixation, and the mean time to fixate (Table 12). These analyses are limited to the exogenous trials because, given the design of the autogenous trials, there was no exact measure of participants' shifting abilities.

The ICCs for the mean number of fixations, mean duration per fixation, and the mean time to first fixate computed for the unconditional models were 0.46, 0.33, and 0.17 respectively. Thus, 46% of the variance of mean total number of fixations, 33% of the variance in mean duration per fixation, and 17% of mean time to fixate were due to the nesting of trials within participants, or the repeated measures nature of the attention task. Consequently, this variance will be accounted for in the subsequent MLM analyses.

Table 12

Descriptive statistics: Mean number and duration per fixation (in s) and mean time to fixate (in s) by trial type and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Shifting Trials			
Mean number of fixations	18.97 *(8.85)*	16.36 *(9.27)*	21.33 *(7.75)*
Mean duration per fixation (in s)	0.63 *(0.18)*	0.58 *(0.17)*	0.68 *(0.17)*
Mean time to fixate (in s)	0.69 *(0.21)*	0.74 *(0.25)*	0.64 *(0.15)*
Disengaging Trials			
Mean number of fixations	19.23 *(8.5)*	16.85 *(8.67)*	21.34 *(7.75)*
Mean duration per fixation (in s)	0.63 *(0.17)*	0.57 *(0.16)*	0.68 *(0.17)*
Mean time to fixate (in s)	0.77 *(0.26)*	0.81 *(0.29)*	0.74 *(0.23)*

Trial type (disengaging versus shifting) was not related to the mean number of fixations, $t(1177) = 0.793$, $p = 0.428$, nor mean durations per fixation, $t(1177) = -0.496$, $p = 0.62$. However, trial type was related to mean time to fixate, $t(1177) = 6.640$, $p < 0.001$. In particular, as expected, the predicted mean time to fixate was longer (0.82 s) for disengaging trials than shifting trials, as the participants took longer to look at a subsequently presented stimulus on the disengaging trials than the shifting trials.

Group was significantly related to mean number of fixations, $t(36) = -2.567$, $p = 0.015$; that is, the participants with ASD displayed 4.713 fewer fixations on average than the TD participants. Additionally, group significantly predicted mean duration per fixation, $t(36) = -3.519$, $p = 0.001$, with the predicted mean duration per fixation of the participants with ASD 0.104 s shorter on average than that of the TD participants, $t(36) = -3.519$, $p = 0.001$. Similarly, the predicted mean time to fixate was 0.084 s longer, on average, for the participants with ASD than for the TD participants, $t(36) = 2.604$, $p = 0.013$.

Unexpectedly, the interaction between trial type and group did not significantly predict mean number of fixations, $t(1176) = 0.522$, $p = 0.602$, mean duration per fixations, $t(1176) = -0.268$, $p = 0.789$, nor mean time to fixate, $t(1176) = -1.495$, $p = 0.135$ (Table 13).

Table 13

Predictors of mean number of fixations, mean duration per fixation, and mean time to

fixate: Trial type and group

Fixed effects	Coefficient	Standard Error	t	df	p
Mean Number of Fixations					
Intercept	21.175	1.277	16.586	1177	<0.001
Trial type	0.291	0.367	0.793	1177	0.428
Group	-4.712	1.836	-2.567	36	0.015
Mean Duration per Fixation					
Intercept	0.683	0.021	32.979	1177	<0.001
Trial type	-0.004	0.008	-0.496	1177	0.62
Group	-0.104	0.028	-3.519	36	0.001
Mean Time to Fixate					
Intercept	0.649	0.023	28.155	1177	<0.001
Trial type	0.082	0.012	6.64	1177	<0.001
Group	0.084	0.032	2.604	36	0.01

The present findings are partially consistent with hypothesis 2, with trial type

significantly related to time to fixate to a new stimulus. Specifically, the participants were

slower to fixate on subsequent stimuli during disengaging trials than shifting trials. Thus,

the participants took longer to look at a subsequent stimulus when there was an overlap of

stimuli, or some competing information. Inconsistent with hypothesis 2, trial type did not

predict the mean number of fixations, nor mean duration of fixation. On average, the

participants with ASD, regardless of trial type, took longer to fixate, had shorter duration

per fixation, and fewer number of fixations compared to the TD participants. The findings

suggest that although participants may take longer to fixate on subsequent stimuli during

disengaging trials, once fixated, attention abilities do not differ between disengaging and shifting trials.

Hypothesis 3: Role of Social Linguistic Information

For the TD participants, the stimulus type, or whether the stimulus was social and linguistic information or non-social, non-linguistic, was not expected to predict performance on the attention task. However, given previous research showing that children with ASD are slower to disengage and shift attention to peripheral or competing stimuli that contains social information (Bahrick & Todd, 2012; Baron-Cohen et al., 1998; Dawson et al., 1998; Sacrey et al., 2014), the stimulus type was expected to predict their attention abilities in children with ASD. In particular, the participants with ASD were expected to display *fewer* number of fixations, *longer* mean fixation durations, and *longer* times to fixate when presented with social-linguistic stimuli compared to non-social, non-linguistic stimuli.

To examine hypothesis 3, stimulus type (social-linguistic versus non-social, non-linguistic) was included as a level 1 predictor into the model, along with trial type (disengaging versus shifting) and group (ASD and TD) in predicting mean number of fixations, mean durations per fixation, and mean time to fixate (Table 14).

Table 14

Descriptive statistics: Mean number and duration per fixation (in s) and mean time to

fixate (in s) by stimulus and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Social-linguistic Trials			
Mean number of fixations	18.3 *(8.09)*	15.91 *(8.01)*	20.46 *(7.55)*
Mean duration per fixation (in s)	0.64 *(0.17)*	0.59 *(0.16)*	0.69 *(0.17)*
Mean time to fixate (in s)	0.71 *(0.25)*	0.76 *(0.28)*	0.67 *(0.21)*
Non-social, Non-linguistic Trials			
Mean number of fixations	19.81 *(9.11)*	17.23 *(9.71)*	22.14 *(7.84)*
Mean duration per fixation (in s)	0.62 *(1.8)*	0.56 *(0.16)*	0.67 *(0.18)*
Mean time to fixate (in s)	0.75 *(0.23)*	0.78 *(0.26)*	0.71 *(0.19)*

Stimulus type was significantly associated with the mean number of fixations,

$t(1176) = -4.008$, $p = 0.001$, and mean time to fixate, $t(1176) = -3.338$, $p = 0.001$.

Participants had 1.462 fewer fixations on average and time to fixate was 0.041 s shorter

for social-linguistic stimuli than for non-social, non-linguistic trials. However, stimulus

type was not significantly associated with mean duration per fixation, $t(1176) = 1.726$, p

$= 0.085$.

Trial type only predicted mean time to fixate, $(1176) = 6.669$, $p < 0.001$. Group,

however, continued to predict the mean number of fixations, $t(36) = -2.567$, $p = 0.015$

(4.713 fewer fixations for the ASD than TD participants) mean duration per fixation,

$t(36) = -3.519$, $p = 0.001$ (0.104 s shorter than the TD participants), and mean time to

fixate, $t(36) = 2.604$, $p = 0.013$ (0.084 s longer than the TD participants).

Inconsistent with previous research, the interaction between group and stimulus

type was not significant when predicting mean number of fixations, $t(1175) = 0.263$, $p =$

0.793, mean duration per fixation, $t(1175) = 0.017$, $p = 0.772$, and mean time to fixate,

$t(1175) = -1.501$, $p = 0.134$.

Table 15

Predictors of mean number and duration of fixation, and mean time to fixate: Trial type,

stimulus type, and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Mean Number of Fixations					
Intercept	21.906	1.289	16.988	1176	0.000
Trial type	0.291	0.365	0.798	1176	0.425
Stimulus type	-1.462	0.365	-4.008	1176	0.001
Group	- 4.713	1.836	-2.567	36	0.015
Mean Duration per Fixation					
Intercept	0.675	0.021	32.008	1176	0.000
Trial type	-0.004	0.008	-0.497	1176	0.62
Stimulus type	0.014	0.008	1.726	1176	0.085
Group	-0.104	0.029	-3.519	36	0.001
Mean Time to Fixate					
Intercept	0.67	0.023	28.076	1176	0.000
Trial type	0.082	0.012	6.668	1176	0.000
Stimulus type	-0.041	0.012	-3.338	1176	0.001
Group	0.084	0.032	2.604	36	0.013

Overall, stimulus type significantly predicted mean total number of fixations and

mean time to fixate, however, stimulus type did not predict mean duration per fixation.

More specifically, while the participants with ASD had had *fewer* fixations on social-

linguistic stimuli compared to non-social, non-linguistic stimuli, they also had *shorter*

times to fixate on subsequently presented social-linguistic stimuli. Overall, the findings

were only partially in the expected direction. Consistent with previous research among

children and adolescents with ASD, the attention abilities of children and adolescents

with ASD were expected to be negatively impacted by social-linguistic stimuli, as indicated by fewer fixations, longer mean fixation durations, and time to fixate. Although the present findings of fewer fixations suggest that social-linguistic information negatively impacted attention abilities, shorter times to fixate and no difference between mean duration per fixation undermine the idea that the participants with ASD would be more 'sticky' on social-linguistic information than non-social, non-linguistic information. Most notably, this trend, of shorter times to fixate and fewer fixations to social-linguistic stimuli was seen in both groups

Hypothesis 4: Role of Task Complexity

Consistent with previous research (McMorris et al., 2012), the degree of stimulus complexity was expected to impact exogenous attention abilities, with stimulus complexity consisting of three distinct areas: a) degree of motion of the stimuli (static versus dynamic), b) modality of the stimuli (unimodal, multimodal, or no modality), and c) degree of synchrony between visual and auditory stimuli (synchronous, asynchronous, or no synchrony). Trials that included static images were coded as no modality and no synchrony, because no auditory information was present. Regardless of trial type and group, it was hypothesized that the degree of stimulus complexity was expected to predict attention abilities on the exogenous trials, as shown by faster times to shift and disengage, shorter mean durations, and fewer fixations to more complex stimuli, suggesting that complexity facilitates disengagement and shifting abilities.

The modality of the stimuli, degree of motion of the stimuli, and degree of synchrony of the stimuli were included in the model along with trial type (disengaging and shifting) and group (ASD and TD) (Table 16, 17 and 18).

Table 16

Descriptive statistics: Mean number and duration per fixation (in s) and mean time to

fixate (in s) by stimulus motion and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Static Stimuli			
Mean number of fixations	19.92 *(9.14)*	16.42 *(9.17)*	23.08 *(7.92)*
Mean duration per fixation (in s)	0.59 *(0.15)*	0.56 *(0.15)*	0.63 *(0.15)*
Mean time to fixate (in s)	0.68 *(0.23)*	0.72 *(0.25)*	0.64 *(0.21)*
Dynamic Stimuli			
Mean number of fixations	18.83 *(8.5)*	16.67 *(8.92)*	20.78 *(7.61)*
Mean duration per fixation (in s)	0.64 *(0.18)*	0.58 *(0.17)*	0.70 *(0.18)*
Mean time to fixate (in s)	0.75 *(0.24)*	0.79 *(0.28)*	0.71 *(0.19)*

Table 17

Descriptive statistics: Mean number and duration per fixation (in s) and mean time to

fixate (in s) by stimulus modality and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Unimodal Stimuli			
Mean number of fixations	18.40 *(8.77)*	15.83 *(9.29)*	20.72 *(7.58)*
Mean duration per fixation (in s)	0.65 *(0.19)*	0.59 *(0.18)*	0.70 *(0.19)*
Mean time to fixate (in s)	0.75 *(0.23)*	0.81 *(0.27)*	0.69 *(0.16)*
Multimodal Stimuli			
Mean number of fixations	19.04 *(8.36)*	17.09 *(8.71)*	20.81 *(7.64)*
Mean duration per fixation (in s)	0.64 *(0.17)*	0.58 *(0.16)*	0.70 *(0.17)*
Mean time to fixate (in s)	0.75 *(0.25)*	0.78 *(0.28)*	0.72 *(0.21)*
No Modality Stimuli			
Mean number of fixations	19.92 *(9.14)*	16.42 *(9.17)*	23.08 *(7.92)*
Mean duration per fixation (in s)	0.59 *(0.15)*	0.56 *(0.15)*	0.63 *(0.15)*
Mean time to fixate (in s)	0.68 *(0.23)*	0.72 *(0.25)*	0.64 *(0.21)*

Table 18

Descriptive statistics: Mean number and duration per fixation (in s) and mean time to fixate (in s) by synchrony of stimuli and group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
Synchronous Stimuli			
Mean number of fixations	19.97 *(8.73)*	17.82 *(9.23)*	21.9 *(7.79)*
Mean duration per fixation (in s)	0.64 *(0.16)*	0.58 *(0.16)*	0.68 *(0.16)*
Mean time to fixate (in s)	0.74 *(0.27)*	0.78 *(0.29)*	0.71 *(0.24)*
Asynchronous Stimuli			
Mean number of fixations	17.86 *(8.68)*	16.15 *(7.93)*	19.4 *(7.23)*
Mean duration per fixation (in s)	0.65 *(0.19)*	0.58 *(0.16)*	0.72 *(0.18)*
Mean time to fixate (in s)	0.75 *(0.24)*	0.78 *(0.26)*	0.73 *(0.15)*
No Synchrony Stimuli			
Mean number of fixations	19.16 *(8.99)*	16.13 *(9.22)*	21.9 *(7.83)*
Mean duration per fixation (in s)	0.62 *(0.17)*	0.57 *(0.17)*	0.66 *(0.17)*
Mean time to fixate (in s)	0.71 *(0.23)*	0.77 *(0.26)*	0.66 *(0.19)*

Hypothesis 4a: Motion of stimulus.

Mean number of fixations. Both group and motion of stimulus (static versus dynamic) were significantly associated with the mean number of fixations (Table 19). The participants with ASD displayed 4.713 fewer fixations on average than the TD participants, $t(36) = -2.567$, $p = 0.015$. Additionally, degree of stimulus motion was significantly associated with the number of fixations, $t(1175) = -4.028$, $p = 0.001$. The stimulus motion by group interaction was also significant, $t(1175) = 3.063$, $p = 0.002$ (Figure 4). Specifically among the TD participants, the observed number of fixations was 2.334 more for static stimuli than for dynamic stimuli on average, $t(1175) = -4.028$, $p = 0.001$. Among the participants with ASD, the number of fixations was 0.245 fewer for

static trials than dynamic trials, but this effect was not significant, $t(1175) = 0.401, p = 0.689$. Therefore, the interaction is such that static trials are associated with more fixations than dynamic trials for the TD participants, but among the participants with ASD, the mean number of fixations did not significantly differ between static and dynamic stimuli.

Table 19

Predictors of mean number of fixations: Trial type, stimulus motion, and diagnostic group

Fixed effects	Coefficient	Standard Error	t	df	p
Simple intercept and slope effects for TD group					
Intercept	21.175	1.277	16.588	1175	<0.001
Trial type	0.291	0.365	0.798	1175	0.425
Stimulus motion	-2.34	0.581	-4.028	1175	<0.001
Simple intercept and slope effects for ASD group					
Intercept	16.462	1.344	12.247	1175	<0.001
Trial type	0.291	0.365	0.798	1175	0.425
Stimulus motion	0.245	0.612	0.4	1175	0.689

Figure 4

Interaction between group diagnosis and motion of stimulus on number of fixations

Mean duration per fixation. When predicting duration per fixation, degree of stimulus motion was also significant (Table 20). As expected, the group by degree of stimulus motion interaction was also significant, $t(1175) = -2.204$, $p = 0.028$ (Figure 5). For the TD participants, the mean duration per fixation was 0.07 s shorter for static stimuli than for dynamic stimuli on average, $t(1175) = 5.434$, $p < 0.001$. Similarly, the mean duration per fixation was 0.029 s shorter for static trials than dynamic trials in children with ASD, $t(1175) = 2.117$, $p = 0.035$. Thus, the participants looked longer at dynamic versus static trials in both groups, although this difference in attention was more pronounced among the TD participants.

Table 20

Predictors of mean duration per fixation: Trial type, stimulus motion, and diagnostic

group

_____

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Simple intercept and slope effects of TD group					
Intercept	0.683	0.021	32.996	1175	<0.001
Trial type	-0.004	0.008	-0.503	1175	0.615
Stimulus motion	0.07	0.013	5.434	1175	<0.001
Simple intercept and slope effects of ASD group					
Intercept	0.579	0.022	26.599	1175	<0.001
Trial type	-0.004	0.008	-0.503	1175	0.615
Stimulus motion	0.029	0.014	2.117	1175	0.035

Figure 5

Interaction between stimulus motion and group on duration per fixation
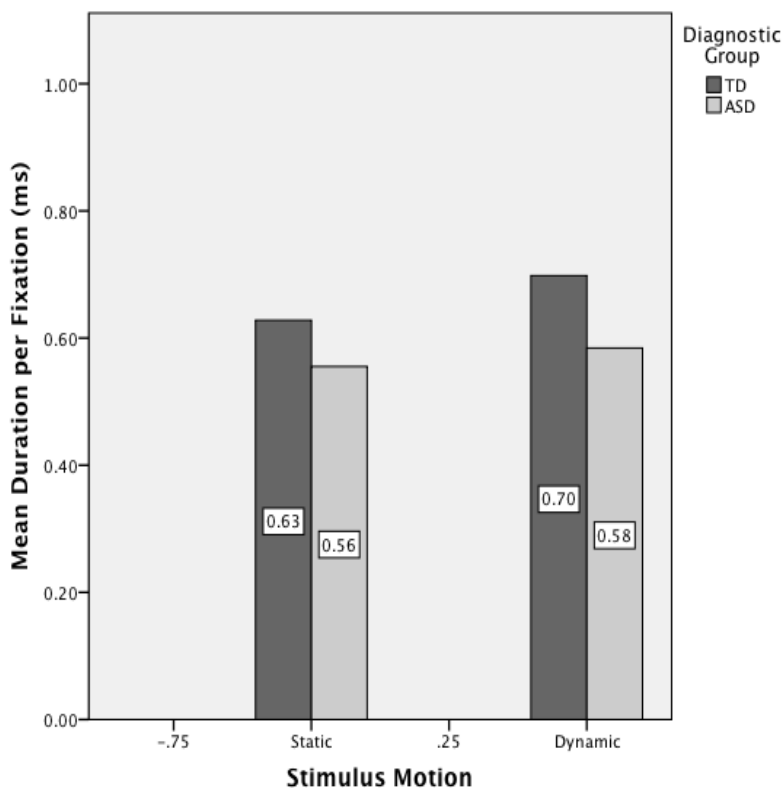
Mean time to fixate. As expected, the degree of stimulus motion predicted mean time to fixate, $t(1176) = 4.742$, $p < 0.001$, with participants' predicted mean time to fixate 0.067 s longer for dynamic stimuli than static trials (Table 21). Similar to previous analyses, trial type (disengaging and shifting) also predicted mean time to fixate, $t(1176) = 6.7$, $p < 0.001$. Additionally, group was associated with mean time to fixate, $t(36) = 2.604$, $p = 0.013$. Inconsistent with the hypothesis, the interaction between group and degree of stimuli motion was not significant, $t(1175) = 0.049$, $p = 0.961$.
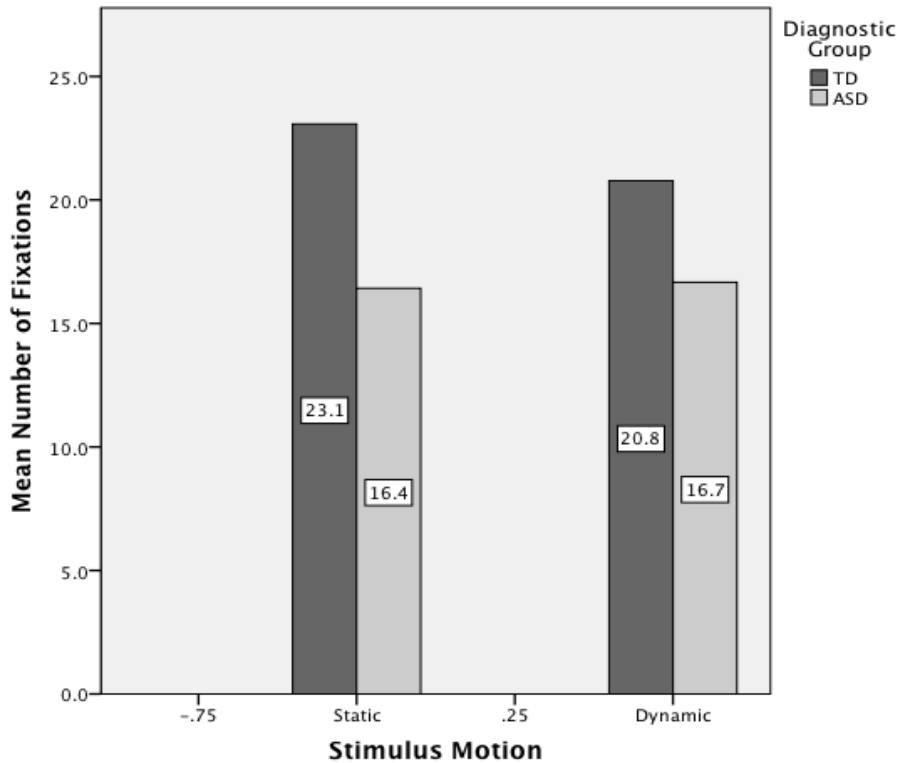
Table 21

Predictors of mean time to fixate: Trial type, stimulus motion, and group

Fixed effects	Coefficient	Standard Error	t	df	p
Intercept	0.649	0.023	28.173	1176	<0.001
Trial type	0.082	0.013	6.7	1176	<0.001
Stimulus motion	0.067	0.014	4.742	1176	<0.001
Group	0.084	0.032	2.604	36	0.013

In summary, consistent with hypothesis 4, the degree of motion of the stimulus predicted all attention abilities, and the interaction between stimulus motion and group was also significant. For the TD group, there were more fixations and shorter mean duration per fixations for static trials versus dynamic trials. Among the ASD group, attention abilities did not differ based on stimulus motion. Both groups took longer to fixate on dynamic stimuli than static stimuli.

Hypothesis 4b. Stimulus modality.

Inconsistent with hypothesis 4b, modality of the stimulus, unimodal (only visual information) versus multimodal (visual and auditory information), was not associated with the mean number of fixations, $t(1176) = 1.58$, $p = 0.115$, mean duration per fixation,

$t(1176) = -0.4$, $p = 0.69$, or mean time to fixate, $t(1176) = 0.012$, $p = 0.99$ (Table 22).

Furthermore, the interactions between group by stimulus modality for all the dependent

variables were not significant, all ps > 0.05.

Table 22

Predictors of mean number and mean duration per fixations, and mean time to fixate:

Trial type, stimulus modality, and group

Fixed effects	Coefficient	Standard Error	t	df	p
Mean number of fixations					
Intercept	21.177	1.277	15.587	1176	<0.001
Trial type	0.291	0.367	0.793	1176	0.428
Stimulus modality	0.71	0.449	1.58	1176	0.115
Group	-4.713	1.836	-2.567	36	0.015
Mean duration per fixation					
Intercept	0.683	0.021	32.978	1176	<0.001
Trial type	-0.004	0.008	-0.496	1176	0.612
Stimulus modality	-0.004	0.01	-0.4	1176	0.69
Group	-0.004	0.029	-3.52	36	0.012
Mean time to fixate					
Intercept	0.649	0.023	28.154	1176	<0.001
Trial type	0.082	0.012	6.637	1176	<0.001
Stimulus modality	0.0002	0.015	-0.012	1176	0.99
Group	0.084	0.032	2.604	36	0.013

Hypothesis 4c: Degree of stimulus synchrony.

Consistent with hypothesis 4c, when entered into the model, degree of synchrony

of the stimulus (synchronous, asynchronous, and no synchrony) predicted mean number

of fixations, $t(1176) = -4.385$, $p < 0.001$ (Table 23). In particular, regardless of trial type

or group, the participants' displayed 2.353 fewer fixations for asynchronous trials

compared to trials in which the stimulus was synchronous or those in which there was no

synchrony. Degree of synchrony of the stimulus did not predict mean duration per fixation, $t(1176) = 1.229$, $p = 0.219$, or mean time to fixate, $t(1176) = -1.663$, $p = 0.097$.

Unexpectedly, none of the interactions between group and stimuli synchrony were significant, all ps > 0.05.

Table 23

Predictors of mean number and mean duration of fixations, and mean time to fixate:

Trial type, stimulus synchrony, and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Mean number of fixations					
Intercept	20.881	1.278	16.335	1176	<0.001
Trial type	0.732	0.378	1.938	1176	0.053
Stimulus synchrony	-2.353	0.537	-4.385	1176	<0.001
Group	-4.713	1.836	-2.567	36	0.015
Mean duration per fixation					
Intercept	0.685	0.021	32.971	1176	<0.001
Trial type	-0.007	0.009	-0.806	1176	0.421
Stimulus synchrony	0.015	0.012	1.229	1176	0.219
Group	-0.104	0.029	-3.52	36	0.012
Mean time to fixate					
Intercept	0.649	0.023	27.859	1176	<0.001
Trial type	0.087	0.013	6.848	1176	<0.001
Stimulus synchrony	-0.03	0.018	-1.663	1176	0.097
Group	0.084	0.032	2.604	36	0.013

Stimulus synchrony, or whether the auditory and visual information of the stimulus was synchronous, predicted the number of fixations, with participants having fewer fixations to asynchronous stimuli. Despite this relationship, stimuli synchrony was unrelated to mean duration per fixation and mean time to fixate, for both groups.

Hypothesis 5: Attention and Social-Communication and Repetitive Behaviour

If 'sticky' attention is related to social-communication and repetitive behaviour difficulties, parent-reports of social-communication (as measured by the SCQ) and repetitive behaviour symptoms (as measured by the RBS-R) were expected to predict performance on the attention task, regardless of trial type and group. Thus, those with reports of more severe social-communication and repetitive behaviour difficulties would have slower disengagement and shifting abilities and appear more 'sticky' as indicated by fewer fixations, longer mean durations per fixation, and longer time to fixate.

To test this hypothesis, first the relationship between the RBS-R total score and SCQ total score was examined using correlational analysis. Overall, there was a strong positive correlation between these variables, r (1216) = .746, $p < 0.001$ (see Table 8). Next, the RBS-R total score and SCQ total score were entered into the following models as level 2 predictors; 1) MLM 1: attention type (exogenous versus autogenous) and group; and 2) MLM 2: trial type (disengaging and shifting) and group (Table 23).

When controlling for trial type and group, participants' total scores on neither the RBS-R, nor the SCQ predicted performance on the attention task, in either MLM 1 or MLM 2, all $ps > 0.05$ (Table 24 & 25). Not surprisingly, when group was excluded from the models, both the RBS-R and the SCQ predicted attention abilities in both MLM 1 and MLM 2 (Table 26 and 27). For example, the total SCQ score significantly predicted mean fixation duration when included along with attention type, $t(872) = -3.557$, $p < 0.001$. However, this relationship could not be distinguished from the fact that SCQ and RBS-R are highly correlated with group.

Table 24

Predictors of mean number of fixations, mean fixation duration, and mean time to fixate:

Attention type, trial type, group, and social-communication

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
MLM 1					
Mean number of fixations					
Intercept	20.353	1.379	14.756	872	<0.001
Attention type	0.88	0.457	1.926	872	0.054
Group	-2.516	2.687	-0.937	36	0.355
SCQ total score	-0.091	0.15	-0.607	872	0.544
Mean duration per fixation					
Intercept	0.76	0.023	33.283	872	<0.001
Attention type	-0.068	0.014	-4.894	872	<0.001
Group	-0.008	0.042	-1.972	36	0.056
SCQ total score	-0.003	0.002	-1.129	872	0.259
MLM 2					
Mean number of fixations					
Intercept	21.452	1.349	15.898	1176	<0.001
Trial type	0.292	0.367	0.796	1176	0.426
Group	-3.490	2.669	-1.277	36	0.21
SCQ total score	-0.101	0.149	-0.677	1176	0.499
Mean duration per fixation					
Intercept	0.692	0.021	32.302	1176	<0.001
Trial type	-0.004	0.008	=0.491	1176	0.623
Group	-0.06	0.042	-1.432	36	0.161
SCQ total score	-0.034	0.002	-1.435	1176	0.152
Mean time to fixate					
Intercept	0.641	0.024	26.588	1176	<0.001
Trial type	0.082	0.012	6.638	1176	<0.001
Group	0.042	0.047	1.011	36	0.319
SCQ total score	0.003	0.003	1.095	1176	0.273

* SCQ: Social Communication Questionnaire

Table 25

Predictors of mean number of fixations, mean fixation duration, and mean time to fixate:

Attention type, trial type, group, and repetitive/rigid behaviour

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
MLM 1					
Mean number of fixations					
Intercept	20.309	1.326	15.318	872	<0.001
Attention type	0.883	0.457	1.932	872	0.054
Group	-2.134	2.443	-0.873	36	0.38
RBS-R total score	-0.116	0.119	-0.978	872	0.328
Mean duration per fixation					
Intercept	0.756	0.022	34.079	872	<0.001
Attention type	-0.068	0.014	-4.889	872	<0.001
Group	-0.09	0.038	-2.355	36	0.024
RBS-R total score	-0.009	0.002	-1.057	872	0.291
MLM 2					
Mean number of fixations					
Intercept	21.395	1.293	16.553	1176	<0.001
Trial type	0.291	0.367	0.791	1176	0.429
Group	-3.066	2.421	-1.266	36	0.214
RBS-R total score	-0.123	0.118	-1.041	1176	0.298
Mean duration per fixation					
Intercept	0.687	0.021	32.961	1176	<0.001
Trial type	-0.004	0.008	-0.498	1176	0.619
Group	-0.073	0.039	-1.877	36	0.069
RBS-R total score	-0.002	0.002	-1.231	1176	0.219
Mean time to fixate					
Intercept	0.643	0.023	28.09	1176	<0.001
Trial type	0.082	0.012	6.642	1176	<0.001
Group	0.04	0.042	0.96	36	0.343
RBS-R total score	0.003	0.002	1.609	1176	0.108

* RBS-R: Repetitive Behavior Scale – Revised

Table 26

Predictors of mean number of fixations, mean fixation duration, and mean time to fixate:

Attention type, trial type, and social-communication

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
MLM 1					
Mean number of fixations					
Intercept	20.062	1.339	14.982	872	<0.001
Attention type	0.879	0.457	1.923	872	0.055
SCQ total	-0.193	0.103	-1.861	872	0.063
Mean duration per fixation					
Intercept	0.75	0.023	32.566	872	<0.001
Attention type	-0.068	0.014	-4.88	872	<0.001
SCQ total	-0.006	0.002	-3.557	872	<0.001
MLM 2					
Mean number of fixations					
Intercept	21.053	1.324	15.906	1176	<0.001
Trial type	0.294	0.367	0.801	1176	0.423
SCQ total score	-0.238	0.104	-2.288	1176	0.022
Mean duration per fixation					
Intercept	0.685	0.021	32.373	1176	<0.001
Trial type	-0.004	0.008	-0.487	1176	0.626
SCQ total score	-0.006	0.002	-3.517	1176	0.005
Mean time to fixate					
Intercept	0.647	0.024	27.473	1176	<0.001
Trial type	0.081	0.012	6.636	1176	<0.001
SCQ total score	0.005	0.002	2.638	1176	0.009

* SCQ: Social Communication Questionnaire

Table 27

Predictors of mean number of fixations, mean fixation duration, and mean time to fixate:

Attention type, trial type, and repetitive/rigid behavior

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
MLM 1					
Mean number of fixations					
Intercept	19.85	1.214	16.348	872	<0.001
Attention type	0.884	0.457	1.934	872	0.053
RBS-R total score	-0.184	0.09	-2.051	872	0.041
Mean duration per fixation					
Intercept	0.737	0.022	32.079	872	<0.001
Attention type	-0.068	0.014	-4.886	872	<0.001
RBS-R total score	-0.005	0.002	-3.236	872	0.001
MLM 2					
Mean number of fixations					
Intercept	20.737	1.193	17.382	1176	<0.001
Trial type	0.29	0.367	0.79	1176	0.43
RBS-R total score	-0.22	0.09	-2.447	1176	0.015
Mean duration per fixation					
Intercept	0.671	0.02	33.989	1176	<0.001
Trial type	-0.004	0.008	-0.499	1176	0.618
RBS-R total score	-0.005	0.001	-3.14	1176	0.002
Mean time to fixate					
Intercept	0.652	0.0231	30.94	1176	<0.001
Trial type	0.082	0.012	6.642	1176	<0.001
RBS-R total score	0.005	0.001	2.96	1176	0.003

* RBS-R: Repetitive Behavior Scale – Revised

Hypothesis 6: Role of Engagement

Engagement, a continuous variable defined as the total time participants look at

all stimuli in a trial, was expected to predict performance regardless of attention type,

trial type, or group. Engagement, along with attention type (exogenous and autogenous attention trials) and group, was examined as a predictor of the mean total number of fixations and mean duration per fixation in MLM 1 (Table 28). It was also used in addition to trial type (disengaging and shifting) and group as a predictor of mean number of fixations, mean duration per fixation, and mean time to fixate in MLM 2.

Table 28

Descriptive statistics: Engagement (in s) by group

M *(SD)*	Whole Group (*N* = 38)	ASD Group (*n* = 18)	TD Group (*n* = 20)
MLM 1			
Autogenous trials (in s)	8.295 *(3.354)*	7.008 *(0.307)*	9.454 *(2.533)*
Exogenous trials (in s)	7.972 *(3.372)*	6.364 *(3.582)*	9.42 *(2.379)*
MLM2			
Disengaging trials (in s)	7.972 *(3.372)*	6.364 *(3.582)*	9.42 *(2.379)*
Shifting trials (in s)	7.974 *(3.39)*	6.334 *(3.668)*	9.449 *(2.269)*

Engagement and attention type (MLM 1). Overall, a moderate positive correlation was found between the participants' level of engagement and the number of fixations and mean duration per fixation, in both groups (see Table 29).

The participants' level of engagement significantly predicted the total number of fixations on the attention task, $t(871) = 5.475$, $p < 0.001$ (Table 30). Consistent with hypothesis 6, the interaction between group and engagement was significant, $t(871) = 3.313$, $p = 0.001$ (Figure 6). More specifically, among the TD participants, the predicted number of fixations was 0.895 higher for the individuals who spent more time engaging in the task stimuli than for those who were less engaged, $t(871) = 5.47$, $p < 0.001$. Among the ASD participants, the predicted number of fixations was 1.575 higher for those who

spent more time engaged in the trial, $t(871) = 12.68$, $p < 0.001$. Engagement in the trial significantly predicted mean duration per fixation on the attention task, $t(872) = 10.601$, $p < 0.0001$, with participants' mean duration per fixation 0.029 longer for those who were more engaged in the trial stimuli (Table 31). The interaction between group and engagement for duration per fixation was not significant, $t(871) = -0.579$, $p = 0.563$.

Table 29

Correlations between participants' engagement and mean number of fixations and mean fixation duration

	Participants' Level of Engagement	Mean Number of Fixations	Mean Duration per Fixation
Participants' Level of Engagement			
r	1	0.57	0.446
p		<.001	<.001
N	912	912	912
Mean Number of Fixations			
r	0.57	1	-0.212
p	0.00		<.001
N	912	912	912
Mean Duration per Fixation			
r	0.446	-0.212	1
p	<.001	<.001	
N	912	912	912

Table 30

Predictors of mean number of fixations: Attention type, engagement, and diagnostic group

Fixed effects	Coefficient	Standard Error	t	df	p
Simple intercept and slope effects for TD group					
Intercept	11.332	1.794	6.327	871	<0.001
Attention type	1.378	0.424	3.247	871	0.001
Engagement	0.895	0.163	5.475	871	<0.001
Group	-5.613	2.153	-2.617	36	0.013
Simple intercept and slope effects for ASD group					
Intercept	5.718	1.276	4.482	871	<0.001
Attention type	1.378	0.424	3.247	871	0.001
Engagement	1.575	0.124	12.685	871	<0.001
Group	5.613	2.153	2.607	36	0.013

Figure 6

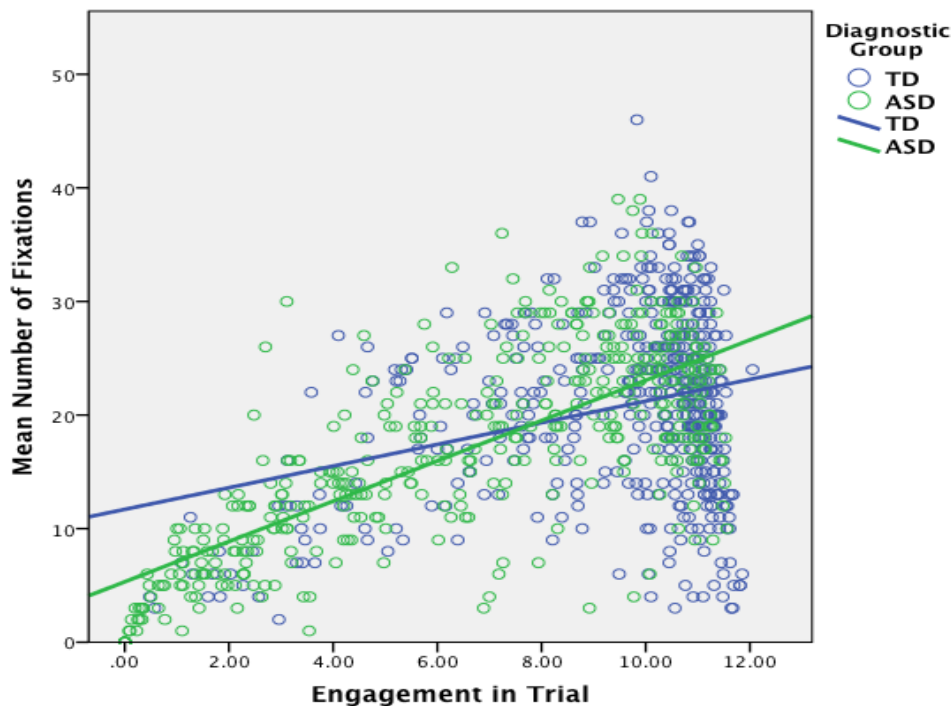*Predictors of mean number of fixations: Group and task engagement*

Table 31

Predictors of mean fixation durations: Attention type, engagement, and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Intercept	0.475	0.032	14.998	872	<0.001
Attention type	-0.059	0.013	-4.419	872	<0.001
Engagement	0.029	0.003	10.601	872	<0.001
Group	-0.034	0.024	-1.443	36	0.158

Engagement and trial type (MLM 2). Similar to MLM 1, a moderate positive correlation was found between participants' level of engagement and the number of fixations and mean duration per fixation. However, a weak negative relationship was found between engagement and mean time to fixate (Table 32).

When controlling for group and trial type, the participants' level of engagement in the trial stimuli predicted participants' total number of fixations, mean time to fixate, and mean duration per fixation on the attention task, all *ps* < 0.001 (Table 33). Next, the interaction of group by engagement predicted total number of fixations, *t*(1175) = 3.853, *p* = 0.001 (Figure 7). More specifically, among the TD participants, the predicted number of fixations was 0.994 higher for the participants who spent more time engaged in the task stimuli, *t*(1176) = 6.846, *p* < 0.001. Among the participants with ASD, the predicted number of fixations was 1.678 higher for those highly engaged in the task stimuli, *t*(1176) = 16.41 p < 0.001 (Table 34). The group by engagement interaction did not predict mean duration of fixation, *t*(1175) = -0.562, *p* = 0.574, nor mean time to fixate, *t*(1175) = -1.006, *p* = 0.315.

Table 32

Correlation between participants' engagement and mean number of fixations, mean

fixation duration, and mean time to fixation

	Participants' Level of Engagement	Mean Number of Fixations	Mean Duration per Fixation	Mean Time to First Fixate
Participants' Level of Engagement				
r	1	0.609	0.562	-0.360
p		0.000	0.000	0.000
N	1216	1216	1216	1216
Mean Number of Fixations				
r	0.609	1	-0.120	-0.354
p	0.00		0.000	0.000
N	1216	1216	1216	1216
Mean Duration per Fixation				
r	0.562	-0.120	1	-0.005
p	0.000	0.000		865
N	1216	1216	1216	1216
Mean Time to Fixate				
r	-0.360	-0.354	-0.005	1
p	0.000	0.000	0.865	
N	1216	1216	1216	1216

Table 33

Predictors of mean total number of fixations, mean duration per fixation, and mean time

to fixate: Trial type, engagement, and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Mean Total Number Fixations					
Intercept	11.801	1.622	7.272	1175	<0.001
Trial type	0.283	0.331	0.855	1175	0.393
Engagement	0.994	0.145	6.85	1175	<0.001
Group	-5.99	1.957	-3.061	36	0.004
Interaction	0.684	0.178	3.853	1175	0.001
Mean Duration per Fixation					
Intercept	0.411	0.023	18.079	1176	<0.001
Trial type	-0.004	0.008	-0.533	1176	0.594
Engagement	0.029	0.002	15.666	1176	<0.001
Group	-0.015	0.021	-0.693	36	0.493
Mean Time to Fixate					
Intercept	0.847	0.031	27.563	1176	<0.001
Trial type	0.082	0.012	6.707	1176	<0.001
Engagement	-0.021	0.003	-7.735	1176	<0.001
Group	0.019	0.025	0.789	36	0.435

Figure 7

Predictor of mean number of fixations: Group and task engagement
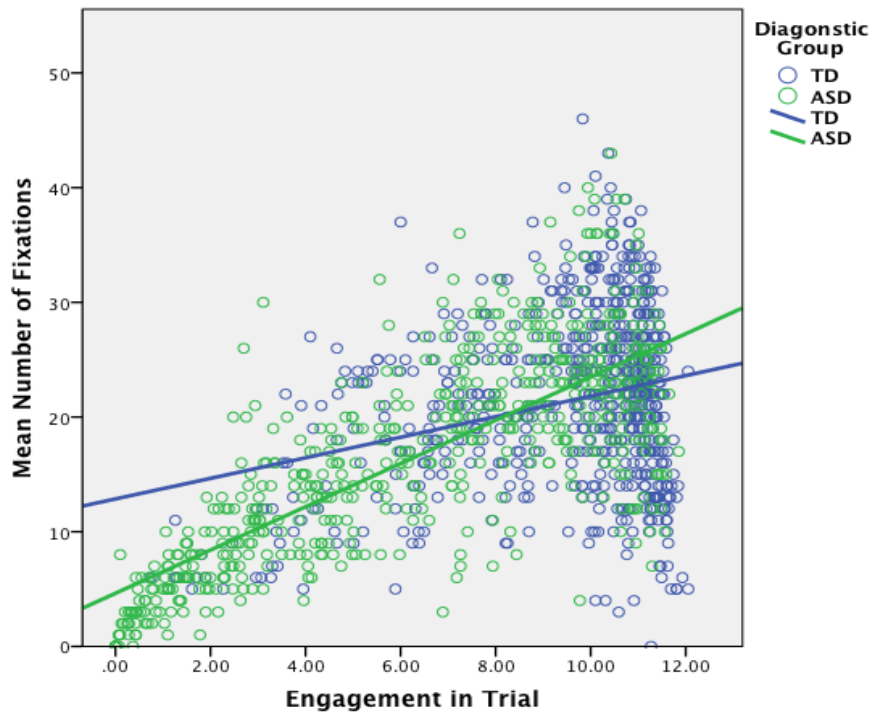
Table 34

Predictors mean number of fixations: Trial type, engagement, and group

Fixed effects	Coefficient	Standard Error	*t*	df	*p*
Simple intercept and slope effects for TD group					
Intercept	11.801	1.622	7.272	1175	<0.001
Trial type	0.283	0.331	0.855	1175	0.393
Engagement	0.994	0.145	6.85	1175	<0.001
Simple intercept and slope effects for ASD group					
Intercept	5.811	1.12	5.189	1175	<0.001
Trial type	0.283	0.331	0.855	1175	0.393
Engagement	1.678	0.102	16.412	1175	<0.001

Exploratory Hypotheses: Individual Clinical Predictors of Attention Abilities

In addition to the above hypotheses, I examined whether individual variables such as sex, level of chronological age, cognitive functioning (measured by the DAS), executive function skills (measured by the BRIEF), and attention difficulties (measured by the Conners) predicted performance on the attention task. The verbal cognitive abilities, nonverbal cognitive abilities, and general cognitive abilities subscales from the DAS were used. For the BRIEF, the inhibition and shifting subscales were used in addition to 3 composites scores: the behavioral regulation scale, the metacognition scale, and the global executive composite. The Conners inattentive symptom, and hyperactivity symptom scales were included. All level 2 predictors were entered into MLM 1 and MLM 2 to predict attention abilities.

For MLM 1, none of the demographic nor clinical variables were significant predictors of performance on the attention task, over and above attention type (autogenous and exogenous attention) and group, all $ps \geq 0.05$. However, while controlling trial type (disengaging and shifting) and group (TD and ASD), chronological age, $t(1176) = -2.813$, $p = 0.005$) and DAS-II verbal abilities $t(1176) = -3.892$ $p = 0.0001$, predicted mean time to fixate (Table 35) in MLM 2. In particular, as the participants' chronological age increased, their mean time to fixate decreased. There was similar negative association was found between the participants' verbal cognitive ability and mean time to fixate. No significant interactions were found between group and these level 2 predictors, all $ps > 0.05$.

Table 35

Level 2 predictors of mean time to fixate: Chronological age and verbal cognitive

Ability

Fixed effects	Coefficient	Standard Error	t	df	p
Chronological Age					
Intercept	0.815	0.062	12.98	1176	<0.001
Trial type	0.082	0.012	6.641	1176	<0.001
Group	0.097	0.03	3.241	36	0.003
Chronological age	-0.001	0.0004	-2.813	1176	0.005
DAS-II Verbal Cognitive Ability					
Intercept	0.991	0.09	11.01	1176	<0.001
Trial type	0.082	0.012	6.643	1176	<0.001
Group	0.054	0.028	1.903	36	0.065
Verbal cognitive ability	-0.003	0.001	-3.892	1176	0.001

CHAPTER FIVE:

DISCUSSION

The disengaging, shifting, and engaging of attention in children and adolescents with ASD were compared to age- and cognitive ability-matched TD peers in the present study. Children and adolescents with ASD have been shown to take longer to disengage and shift their attention, referred to as 'sticky' attention. This 'sticky' attention has been suggested as a core deficit of ASD (Landry & Bryson, 2004). However, only endogenous and exogenous attention abilities, or when the cue to shift and disengage attention is externally provided, have been examined in the literature. Given that this type of attention may not be representative of everyday attention situations, autogenous attention abilities, or when the cue to shift and disengage is internally generated, were investigated in the current study.

Using a novel eye-tracking task, an aim of the current study was to determine whether 'sticky' attention is a core deficit in children with ASD or whether it is task dependent by evaluating performance on two different types of attention tasks: exogenous and autogenous. How task stimuli impact disengaging, shifting, and engaging abilities was also examined in the present study, that is, if or how the type of stimuli (social-linguistic information or non-social, non-linguistic information), the level of complexity of the stimuli (modality of the information, motion of the stimulus, and degree of synchrony of the stimulus), and the participants' engagement affect attention abilities. In addition to task-specific predictors, participant-level predictors, including demographic characteristics and clinical factors, were examined to determine if they predicted attention abilities among participants with ASD and TD children.

Overall, the participants with ASD took longer time to fixate, and had fewer fixations than TD children, supporting previous research suggesting that 'sticky' attention

is a core deficit in this population. However, a number of other task-specific variables (e.g., attention type, trial type, stimuli type, and stimuli motion and synchrony) and participant-specific variables (chronological age and verbal cognitive ability) predicted performance on the attention task in both groups. Specifically, whereas exogenous attention abilities were stronger among the TD participants, the participants with ASD had stronger autogenous attention abilities. The participants in both groups showed a disengaging deficit, as they were slower to fixate on subsequent stimuli when competing stimuli was present. However, no interaction between group and trial type was found.

Both diagnostics groups also displayed more difficulty disengaging, shifting, and re-engaging in social-linguistic stimuli than non-social, non-linguistic stimuli, as shown by longer mean durations and fewer fixations. Stimulus motion also predicted number of fixations, fixation durations, and time to fixate, with participants taking longer to disengage and shift from dynamic stimuli than static stimuli. Stimulus synchrony, however, only partially predicted performance, as shown by more fixations when the auditory and visual information of the stimulus was synchronous. Degree of engagement in the task also predicted performance on the attention task in both groups, with those who were more engaged in the task showing less difficulty disengaging, shifting, and re-engaging.

Chronological age and cognitive ability significantly predicted attention, over and above the variance accounted for by group, and attention type/or trial type. Taken together, given the task and individual level factors that predict attention abilities in children with ASD, the present findings question the validity of the 'sticky' attention hypothesis as an across the board deficit in children with ASD.

ASD Diagnosis

Across the majority of the analyses, the participants with ASD displayed fewer fixations, and longer time to fixate on subsequent stimuli compared to TD peers. These difficulties in disengaging, shifting, and re-engaging in stimuli support previous research hypothesizing that children with ASD have may have 'sticky' attention, a deficit that underlies a number of core symptoms associated with ASD. The current findings not only provide evidence for impaired or inferior attention abilities in children and adolescents with ASD.

While, the participants with ASD in the present study generally had 'stickier' attention than the TD participants, there are a number of factors examined in the current study that may qualify this interpretation. Specifically, attention abilities in children with ASD vary based on attention type (exogenous versus autogenous) and trial type (shifting versus disengaging), as well as task-dependent predictors, such as stimulus type, synchrony of the stimulus, and engagement in the task. Clinical and demographic variables, including chronological age, verbal cognitive abilities, social-communication abilities, and the presence of repetitive or rigid behaviours also predicted attention abilities in both TD children and children with ASD.

Considering the various individual- and task-specific variables which predict attention in children with ASD, difficulties in disengaging, shifting, and re-engaging might not necessarily be considered core deficits of ASD after all. Rather, the attention abilities of children with ASD may fluctuate as a result of the type of attention, trial, and stimulus type, in addition to a variety of individual variables. Thus, such factors need to

be considered prior to making any definitive conclusions related to 'sticky' attention as a diagnostic marker in individuals with ASD.

Attention Type

Consistent with hypothesis 1, attention type predicted attention abilities in both groups, however, the pattern of results was different among the participants with ASD than for the TD participants. Whereas the participants with ASD showed superior autogenous than exogenous attention abilities, the TD participants showed the opposite pattern. Superior autogenous abilities in participants with ASD have been found in previous research. Specifically, McMorris et al. (2012) found that children with ASD had a similar number of fixations and mean durations per fixation on autogenous attention trials as compared to TD children and children with intellectual disabilities (ID). Taken together, this pattern of results not only emphasizes the usefulness of examining autogenous attention abilities of children with ASD, but also questions the generalizability of existing exogenous attention tasks when investigating the attention abilities of children with ASD. Although research to date has been solely focused on endogenous and exogenous attention, the present findings indicate that exogenous attention may not be representative of the attention abilities of children with ASD. Self-directed or internally generated attention is an important aspect of attention, and it is also a more ecological valid indicator of everyday attention abilities among individuals with ASD.

To date, this is the first study to compare autogenous and exogenous attention abilities in youth with ASD and TD youth in the same study. The attention of individuals with ASD may be more internally driven, that is, compared to TD individuals they may

rely less or pay less attention to external cues from the environment. If attention is more internally driven among youth with ASD, then the external cue may be ignored or not processed in the same way that it is for TD youth, resulting in weaker exogenous attention abilities, as seen in the present study. Similarly, in the presence of an external cue, whether the appearance of a peripheral stimulus or an arrow indicating where to look next, participants with ASD may find it more challenging to process the external cue, thus impacting the efficiency with which they disengage, shift, and re-engage their attention.

Discrepancies between autogenous and exogenous attention abilities could also be explained by the participants' ability to perceive synchrony in the stimuli of the current study. The multiple fixations exhibited by the ASD group to the autogenous trials may be a result of difficulties in perceiving which stimulus was synchronous. Individuals with ASD have been shown to have difficulty with intersensory perception, or find it challenging to identify the stimulus in which the auditory and visual information is synchronous in social-linguistic stimuli (Bebko, Weiss, Denmark, & Gomez, 2006). Given that previous research has consistently shown that TD children have no difficulty perceiving synchronous stimuli, this finding could explain why TD children in the present study showed fewer fixations to the autogenous than exogenous trials.

Although the present findings provide further evidence for deficits in exogenous attention abilities among youth with ASD, they support the notion that autogenous attention abilities are superior as compared to TD youth. Given the enhanced autogenous attention abilities of the children with ASD in the current study, the present findings discount a general, 'across the board', 'sticky' attention deficit in individuals with ASD.

Trial Type

Regardless of group, trial type (i.e., disengaging versus shifting) significantly predicted participants' time to fixate, as the participants took more time to fixate on subsequent stimuli when competing stimuli were present. As a result, both TD children and children with ASD showed a disengaging deficit, that is, slower times to fixate on subsequent stimuli for disengaging trials than for shifting trials. Specifically, participants took 0.081 s longer to fixate on subsequent stimuli when there was an overlap between stimuli (disengaging trials) versus a 'gap' between stimuli (shifting trials). This difference, however, was quite small relative to previous research. For example, in Landry and Bryson (2004), children with ASD, with Down syndrome, and TD children, took approximately 0.79 s longer to fixate on subsequent stimuli during disengage trials than shifting trials. Although the disengaging deficit in the current study was less pronounced than previous research, these findings provide further evidence that disengaging is more challenging than shifting, not just for children with ASD, but also for TD children.

For both groups, the nature of the shifting trials, or the 'gap' between stimuli, seems to facilitate participants' ability to disengage quickly and shift their attention. In shifting trials, the gap between stimuli may interrupt processing of the stimulus, enabling participants to shift and re-engage their attention more quickly. Conversely, time to fixate on disengaging trials may be slower, as participants are required first to notice the appearance of the stimulus and then purposefully disengage their attention from the current stimulus to the next stimulus. This process may be more demanding on the participants' cognitive load and other cognitive processes.

Although the current findings support evidence of a disengagement deficit, the overall number of fixations and durations per trial were similar on shifting and disengaging trials in both groups. This is the first study in which ongoing scanning of stimuli after the first fixation on a single new stimulus was examined. These latter, ongoing attention skills were investigated by examining the mean number of fixations and durations as the children continued to scan the displays. The lack of a disengagement deficit based on mean fixations and durations suggests that once participants have disengaged, shifted, and re-engaged in a new stimulus, their subsequent attention abilities and looking patterns may not be impacted by trial type.

Unexpectedly and inconsistent with previous research, the interaction between trial type and group was not significant. Research has previously found that there is a larger disengagement deficit in children with ASD compared to TD children and children with other neurodevelopmental disorders. For example, Landry and Bryson (2004) found that children with ASD on average took 2.164 s to initiate an eye movement to a peripheral stimulus when there was an overlap of stimuli compared to TD children (1.073) and children with Down syndrome (DS; 0.506). In addition to delays in fixating, they also found that children with ASD did not disengage their attention at all from the central stimulus to the peripheral stimulus more often than the TD children and children with DS. Stronger deficits in disengagement seen in children with ASD have been suggested to be due to higher-order processing abnormalities or weaknesses in the capacity to process stimulus cues to disengage (van der Geest, 2001).

The failure in this study to replicate the interaction between trial type and group found in previous research could be attributed to differences in measurement of the

dependent variable as well as the experimental design. More specifically, the current study utilized mean time to fixate on the peripheral stimulus when examining disengagement and shifting abilities, whereas previous research has determined disengagement abilities based on the time it takes participants to initiate an eye movement. Differences in the design of the trials, particularly the physical distance between stimuli, may also contribute to discrepancies between the current and past research. For example, Landry and Bryson (2004) presented stimuli on three adjacent computer screens – the central stimulus was present in the middle screen and the peripheral on the two outer screens – which is a far distance for participants to disengage and shift. Conversely, in the present study all stimuli were presented on a single, wide computer monitor in which the physical distance between stimuli was quite small. Larger physical distance between stimuli would negatively impact the time it would take participants' to disengage and shift, as participants may not see the peripheral stimulus once it is presented. Thus, this physical distance between stimuli may account for discrepancies between previous and current research.

Overall, the present findings are somewhat consistent with Hypothesis 2, as the findings suggest that disengagement abilities of both TD children and children with ASD showed a deficit. Unexpectedly both groups had more difficulties with disengaging than shifting attention trials. Despite previous evidence that this disengagement deficit contributes to a number of features associated with ASD, there is no evidence from the current research supporting a disengagement deficit among children and adolescents with ASD. Future research is needed to continue to determine the relationship between

disengagement abilities and group, in particular whether this deficit are displayed in other neurodevelopmental disorders.

Task-Specific Predictors

Stimulus type

Overall, stimulus type significantly predicted disengaging and shifting abilities in both groups. As expected (Hypothesis 3), the participants with ASD appeared to show more 'stickiness', as indicated by fewer fixations, to stimuli that included social and linguistic information compared to non-social, non-linguistic information. However, they had shorter times to fixate on subsequently presented stimuli when it contained social-linguistic information versus non-social, non-linguistic information. And unexpectedly, stimulus type was not a significant predictor of mean duration per fixation, in either group.

Although the participants with ASD in the current study had fewer fixations to social-linguistic stimuli, it is important to note that the TD participants showed the same pattern of attention abilities. In particular, the participants in both groups had fewer fixations and took less time to fixate to subsequent stimuli during social-linguistic trials than non-social, non-linguistic trials. A similar trend was found by Fischer et al. (2014) using a gap-overlap task, with which they found comparable reaction times between TD children and children with ASD when they disengaged from a non-social central stimulus to either a social or non-social stimulus. Taken together, these findings suggest that given the nature of the social-linguistic stimuli, participants may be more interested in the social-linguistic stimuli, thus resulting in faster times to fixate to new social-linguistic stimuli. Consistent with this idea, all the participants had fewer fixations to social-

linguistic information, indicating more stickiness once they engaged in the stimuli, and potentially more motivation to explore that stimulus when it was social in nature.

The present findings are inconsistent with a large body of research showing a strong negative relationship between social stimuli and disengaging and shifting abilities in children and adults with ASD (Bahrick & Todd, 2012; Baron-Cohen et al., 1998; Dawson et al., 1998; Sacrey et al., 2014). Using a variety of experimental paradigms (e.g., gap-overlap task, natural occurring scenes) and stimuli (e.g., pictures, scenes from old movies, and tactile toys and objects), children with ASD appear to have difficulty disengaging from stimuli that contains social information (Bahrick & Todd, 2012; Baron-Cohen et al., 1998; Dawson et al., 1998; Sacrey et al., 2014). In addition to deficits in orienting to visual social information, Dawson et al. (2004) determined that children with ASD have difficulty shifting to social auditory sounds in naturally occurring stimuli. During face-to-face interactions, children with ASD were presented with both social (e.g., humming), and non-social auditory stimuli (e.g., phone ringing) by one experimenter, while another experimenter interacted with the participant. Overall, the participants with ASD were less likely than the TD participants to orient toward social sounds than non-social sounds, indicating a social-auditory orienting deficit in this population.

Notably, previous research has involved a combination of social and non-social stimuli in the same trial, whereas in the current study, the same type of stimulus was used throughout each trial. Thus, difficulties may be more pronounced when participants are required to disengage, shift, and re-engage in a subsequent stimulus that is substantially different from the stimulus with which they are currently engaged, such as shifting and disengaging from a social-linguistic stimulus to a non-social, non-linguistic stimulus.

Overall, stimulus type appears to be an important factor when considering attention abilities among both groups. Most importantly, deficits in social processing frequently found in children with ASD did not appear to impact children's attention abilities, as indicated by shorter times to fixate. Although one would anticipate, based on previous research, that children with ASD would have more difficulty disengaging and shifting attention to social-linguistic information, the current findings do not support a specific social orienting deficit in children with ASD.

Role of complexity

Due to limited research examining the role of stimulus complexity on attention abilities, the present study aimed to determine whether aspects of the stimulus predicted attention difficulties. In particular, the current study examined stimulus motion, stimulus modality, and synchrony of the stimulus as predictors of attention. Overall, in both groups, whereas stimulus motion and synchrony were significant predictors of attention difficulties, the modality of the information was not.

Stimulus motion (Hypothesis 4a).

The TD participants displayed more fixations to static stimuli versus dynamic stimuli. While the participants with ASD also had more fixations to static stimuli, this discrepancy was less pronounced than among TD children. Additionally, both groups had shorter mean fixation durations during static stimuli than dynamic and took longer to fixate on subsequent stimuli during dynamic trials. Taken together, these finding indicate that both TD children and children with ASD are more 'sticky' to dynamic stimuli than static stimuli.

This is the first study to examine the impact that stimulus motion has on the exogenous attention abilities in children with ASD compared to TD children; thus, it is difficult to discern the reasons for these unexpected findings. Similar to the social-linguistic stimuli, participants in both groups may have been more engaged or interested in the dynamic stimuli (e.g., listening to the story, watching the nuts and bolts fall) than the static pictures, and therefore found it more challenging to disengage and shift. Additionally, the dynamic stimuli involved multiple components, including visual and auditory information. Thus, dynamic stimuli required more processing than the static stimuli and this 'stickiness' may be an artefact of increases on cognitive load.

Stimulus modality (Hypothesis 4b).

Unexpectedly, regardless of group and trial type, stimulus modality did not predict number of fixations, mean fixation durations, or mean time to fixate. The hypothesis that stimuli that included both visual and auditory information would facilitate exogenous attention abilities was not supported.

Stimulus synchrony (Hypothesis 4c).

The degree of synchrony between the visual and auditory information of the stimuli only predicted number of fixations, with both groups having more fixations to synchronous than asynchronous stimuli. As expected, synchrony appears to facilitate attention among both TD participants and participants with ASD. Although these findings are consistent with the present study hypotheses, they are partially inconsistent with research showing that children with ASD have difficulties with detecting synchrony. In particular, using preferential looking paradigms, Bebko et al. (2006) found that for social-linguistic stimuli children with ASD, compared to TD children, do not show a preference

for stimuli in which the auditory and visual information is synchronous. Given that children with ASD fail to perceive the differences between synchronous and asynchronous social-linguistic stimuli, previous researchers have suggested that children with ASD have impaired inter-sensory perception for social-linguistic stimuli (Bahrick & Todd, 2012).

Although stimulus synchrony significantly predicted the mean number of fixations in both groups, it did not predict mean duration per fixation and mean time to fixate. Furthermore, none of the interactions between stimulus synchrony and group was significant. Taken together, these findings suggest that exogenous attention abilities might not be impacted by difficulties in inter-sensory perception. Notably, this study did not directly examine attention abilities when both synchronous and asynchronous information was present in the same trial. Therefore, difficulties with inter-sensory perception may impact disengaging and shifting abilities when both types of stimulus are present at the same time.

In summary, stimulus synchrony and motion predicted some aspects of exogenous attention abilities in children with ASD and TD children, whereas modality of the stimulus did not predict any of the attention outcomes. However, from the current findings is unclear if this pattern of results can be solely attributed to these factors individually, or rather the combination of these factors. Further, given the substantial overlap between the different aspects of the stimuli (dynamic, multimodal, and synchronous), it is challenging to isolate which aspects of the stimulus lead to difficulties with disengaging and shifting. Rather, the amalgamation of these factors may best predict autogenous and exogenous attention abilities.

Role of engagement

When evaluating attention type (autogenous and exogenous), trial type (shifting and disengaging), and group, engagement in the task predicted some of the dependent variables and not others. More specifically, consistent with Hypothesis 6, the participants who were less engaged in the trial displayed fewer fixations and shorter mean durations when controlling attention type (exogenous and autogenous). Conversely, when accounting for trial type (disengaging and shifting) and group, engagement in the trial significantly predicted the number of fixations; however, it did not predict fixation durations or time to fixate.

In the only other study of the role of engagement in attention abilities of individuals with ASD, van der Geest et al. (2001) compared exogenous attention abilities of high functioning adolescents with ASD to chronological age and IQ-matched TD peers. Utilizing a gap-overlap task, they found that children with ASD had a smaller gap effect, or the difference between shifting (gap) trials and disengaging (overlap) trial, than TD adolescents. Van der Geest et al. (2001) concluded that this smaller gap effect in children with ASD was not due to difficulties with the attention system; rather, they argued that it could be attributed to lower levels of engagement to the central stimulus prior to presentation of the peripheral stimulus.

It is not surprising that engagement is positively associated with mean number of fixations and subsequently mean durations per fixations in the present study, given how engagement was determined. That is, if individuals are less engaged in the task, they would likely display fewer fixations and possibly shorter mean durations per fixations, leading to a degree of circularity in terminology.

While the present study continues to highlight the importance of examining how engagement impacts attention, a number of gaps in the literature still exist. For example, it is unknown if the amount of time that participants are engaged in the central stimulus impacts participants' disengaging and shifting abilities to subsequent stimuli. Additionally, in previous research, the central fixation or stimulus has been presented for a variable amount of time (i.e., 200-100 ms). However, the appropriate presentation time to ensure engagement is unknown.

Individual Clinical and Demographic Variables

Attention and ASD symptomatology.

Given that deficits in disengaging and shifting have been hypothesized to underlie the core deficits of ASD, difficulties in social-communication and repetitive or rigid behaviours were expected to be positively associated with fewer fixations, shorter mean durations, and slower times to fixate. As expected in hypothesis 5, parent-reported social-communication difficulties and repetitive and rigid behaviours predicted performance on the attention task, but only when group was excluded from the models. Specifically, when group was included in the model, no variance remained for the questionnaires to account for because the participants with ASD had much higher parent reported social-communication difficulties and repetitive and rigid behaviours than the TD group.

The present findings are consistent with past research identifying a strong link between exogenous attention abilities and the social and behavioural characteristics typically seen in individuals with ASD. For example, Bryson et al. (2007) found that infants at risk for ASD (i.e., those who have weaker disengaging and shifting abilities than TD infants) are more likely to have difficulties with social interactions and

relationships in the future. That is, 'sticky' attention may lead to symptoms such as problems in social reciprocity and taking part in the back and forth of conversations, which are both experienced by individuals with ASD. Exogenous attention deficits are also hypothesized to underlie repetitive and rigid behaviour typically experienced in children with ASD, such as becoming fixated on single objects, failure to respond to their own name, and narrow focus and interests (Fisher et al., 2014; Nadig et al., 2007; Turner, 1999). Additionally, similar to the diagnostic criteria of ASD, disengaging and shifting attention abilities could be conceptualized on a spectrum, with varying degrees of impairment. The developmental trajectories of exogenous attention abilities in individuals with ASD are unknown, and whether this association with social-communication and repetitive, rigid behaviours changes over the lifespan.

Demographic and clinical predictors

Specific demographic and clinical characteristics were examined to determine which variables best predicted attention abilities in TD children and children with ASD, in addition to social-communication and repetitive and rigid behaviours. Overall, it was anticipated (exploratory hypotheses) that if 'sticky' attention is not a core deficit of ASD, then there might be other clinical characteristics which predict attention difficulties, such as sex, chronological age, inattention, impulsivity, hyperactivity, and executive functioning.

Regardless of attention type, trial type, and group, chronological age predicted mean time to first fixate. That is, across groups, as children get older they become less 'sticky' as indicated by shorter mean times to fixate. This result is consistent with a

number of studies showing that shifting and disengaging abilities are intact among adolescents and adults with ASD (Kuhn et al., 2010).

Shorter mean time to fixate was also associated with stronger verbal cognitive abilities, which is consistent Chawarska et al's (2010) finding that deficits in disengaging are associated with cognitive functioning abilities. Evidence of a disengagement deficit in children and adolescents with ASD has either failed to control for IQ (Elsabbagh et al., 2013; Zwaigenbaum et al., 2005), or have only examined attention abilities in individuals with ASD who have below average cognitive functioning abilities (Landry & Bryson, 2004). Studies that have compared exogenous abilities in age- and IQ-matched TD children with children with ASD have also found no differences in disengaging and shifting skills (Fisher et al., 2014). However, previous research has failed to identify which area of IQ is associated with attention difficulties. Verbal cognitive abilities, rather than nonverbal cognitive abilities or general abilities, were found to best predict attention abilities, which is a unique contribution to the field.

Unexpectedly, no other clinical variables significantly predicted attention abilities. However, clinical variables were based on parent-report questionnaires rather than standardized assessment measures. Future research examining predictors of attention abilities should utilize standardized assessment tools that evaluate children's and adolescents' attention and executive functioning skills to supplement information gathered in parent questionnaires.

Strengths, Limitations, and Future Directions

  Methodological advancements

   The current study utilized eye-tracking software, a novel attention task, and advanced statistics to examine attention abilities in children with ASD to determine if 'sticky' attention is a core deficit of ASD. In particular, the present study was distinct from previous research in a number of ways, both conceptually and methodologically. In particular, the present study was the first of its kind to investigate a novel conceptualization of attention, autogenous attention, in children with ASD. Given that autogenous attention is self-directed and internally driven, comparing these abilities to exogenous abilities allows researchers to understand the extent to which attention abilities are impaired in children with ASD. Similarly, there is only limited research examining attention abilities of children with ASD using eye-tracking software. Compared to previous research that has utilized behavioural observations of eye fixations, using eye-tracking software allows richer data and more accurate analyses.

   The attention task of the current study was distinct from previous research, specifically related to the design of the trials. Unlike past research, the present study had longer trials (approximately 12 s), which provided participants multiple opportunities to shift, in contrast to a single shift paradigm used in earlier studies. As mentioned above, the stimuli in the present study varied in terms of complexity and therefore may be more representative of participants' everyday attention skills. Lastly, utilizing multilevel modeling provided the opportunity to examine trial-level and participant-level predictors simultaneously, while considering the nesting of trials within participants, which is a novel and robust approach to investigating these attention abilities in children with ASD.

Methodological limitations and future directions

Participants.

Despite the various strengths of the currently study, there are a number of limitations. In particular, the current sample consisted of 18 children diagnosed with ASD who were age- and IQ-matched to TD children. Although the groups were matched based on IQ and age, the ASD participants were quite high functioning, which could contribute to some of the discrepancies between the current findings and past research. Additionally, given that previous research has frequently identified 'sticky' attention as a core deficit of ASD, it would be important to examine such abilities in children with other neurodevelopmental disorders, including attention deficit hyperactivity disorder (ADHD), learning disability (LD), and ID. The present study's sample included children and adolescents between the ages of 10 and 16 years, and thus future research is needed to examine such abilities across childhood and adolescence to determine if and how attention abilities develop into adulthood in individuals with ASD compared to TD individuals.

Attention task.

Overall, despite the innovative and novel attention task used in the current study, there were a number of limitations to the experimental design that may restrict the generalizability of the current findings. First, increasing the complexity of the stimulus, although original, limited the number of trials that were utilized in the current study. More specifically, as children with ASD typically experience difficulties with focusing their attention for long periods of time, the attention task was designed to be less than 15 min to maximize children's attention to the task. Consequently, there were only a limited

number of trials in each stimulus category. Second, although the design of the current attention task was based on previous literature in the field, it is possible that there were other factors that may also be impacting performance on this task. In particular, factors such as processing speed and self-stimulatory behaviour may have impacted attention abilities by distracting participants from the task; however, were not specifically measured or considered in the present study.

Another limitation of the present study involves the design of the trials. In particular, as mentioned previously, the distance between stimuli in the current study was quite small relative to previous research in which stimuli were presented on three different side-by-side computer screens. This shortened distance may have facilitated disengagement and shifting in the current sample. Specifically, when the 'peripheral stimulus' was presented in the present study, it may appear in the participants' visual field, taking them less time to disengage and shift. However, in previous research where the distance was greater between stimuli, the appearance of the peripheral stimulus may have been outside of the participants' field, resulting in slower times to fixate.

A final limitation of the present study pertains to the engagement abilities in children with ASD and how engagement directly impacts attention. The present study's experimental paradigm limited the degree to which engagement was examined. The present study along with others has established engagement with the central fixation prior to the presentation of the peripheral stimulus observationally. Thus, it would be important to incorporate a fixation contingency in which participants were required to fixate on the central stimulus for a specific length of time, and only then would the target stimulus be presented.

Conclusion and Clinical Implications

Overall, the current research findings not only provide insight into the attention abilities of children with ASD, but also identify individual and task variables that predict attention abilities in this population. The present study does not support previous research indicating inferior disengaging and shifting abilities in children with ASD, as attention abilities in the present study vary based on attention type (exogenous versus autogenous), as well as other task-dependent variable. Although few individual factors predicted performance on the current study's attention task, level of engagement in the trial was associated with attention abilities, regardless of group. Given the numerous variables that predicted disengaging and shifting abilities among children with ASD, the current study does not provide clear support for the hypothesis that 'sticky' attention is a core deficit in children with ASD, and thus its potential as a diagnostic marker in this population is questionable, or, at best, limited to very specific stimulus parameters. Further, the current study highlights that although children with ASD may have some impaired attention difficulties, these difficulties do not appear to be the underlying cause of the core symptoms of ASD. Rather, other cognitive processes, such as executive functioning, may contribute to the social-communication deficits and repetitive, rigid behaviours seen in children and adolescents with ASD. Thus, not only is future research needed to continue to examine the impaired and intact attention processes in children with ASD, but also whether other clinical populations may have similar attention profiles, whether additional demographic and clinical factors not measured here may predict attention in children with ASD, and whether difficulties in disengaging, shifting, and re-engaging lead to other characteristics or comorbidities that are prominent in children and adolescents with ASD.

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APPENDICES

Appendix A: Informed Consent for TD Parents

INFORTMATION LETTER

**Information Processing in Autism Spectrum Disorders: Understanding
Attention and Intersensory Processing as Core Deficits**

Dear Parent,

Purpose of the Study

Two abilities are thought to help people interact socially: 1) attention (shifting your attention from one person or object to another); and 2) combining together what we see with what we hear (intersensory processing). Both attention shifting and intersensory processing are impaired in many children and adolescents with Autism Spectrum Disorders (ASD). Although these difficulties together could lead to other impairments in making sense of the world around us, there has only been limited research on how they work together. We are asking for your and your child's assistance in a research study to look at how they work together and how they impact on social understanding and communication in ASDs.

A better understanding of the nature of information processing abilities, specifically attention and intersensory processing, will help us better understand the normal course of development in children and adolescents.

What will Participation Involve?

This study will involve children between the ages of 6 and 16 years of age who have been diagnosed with an Autism Spectrum Disorder (ASD). In order to participate, individuals must: a) have at least a 2-year-old verbal ability in English; b) normal or corrected-to-normal hearing and vision; c) no known neurological issues (epilepsy, brain injury, etc.), and d) a previous diagnosis of an ASD by a psychologist or psychiatrist according to DSM-IV-TR criteria. Children will be asked to watch a short video and some pictures that have been created specifically to understand how children attend to and understand what they see and what they hear. The images and video that children will see include a woman telling a story, a woman making voice sounds, a piano being played, and some animated cartoons. During the session, the child's eye movements will be video recorded and tracked using eye-tracking equipment.

Along with this there will one cognitive (thinking) activity examining children's problem solving skills (e.g., working with puzzles) and one language activity (e.g., looking at pictures). Additionally, the Autism Diagnostic Observation Scale (ADOS), a structured observation scale children and adults with ASD will be administered. Overall, the experiment should take no longer than one and a half hours for your child.

Parents will also be asked complete several questionnaires about a range of skills and characteristics of your child. These include thinking skills, self-control, communication and social skills, repetitive and sensory-type behaviours. An additional questionnaire will ask about your experiences obtaining a diagnosis for your child and any previous diagnoses that may have been given. We will also ask you to provide a copy of the diagnostic report for clarification. Parent involvement should take approximately 60 to 90 minutes.

Are there any Risks Involved?

All of the parts of this study have been reviewed and there are no risks involved. All information that is collected will be kept strictly confidential to the fullest extent possible by law. To ensure confidentiality, paper data will be stored in a locked cabinet, and other data will be stored on an external hard drive in an encrypted file that will be kept at the Child Learning Projects Lab at York University. The lab is also locked and only accessible by project personnel. All children will be given a participant number by which they will be identified. Data and audio-video recordings will be stored for an extended period after the study to enable comparison and combination with data in future studies. Once all projects in this line of research have been completed, all data and recordings will be destroyed (paper materials will be shredded and video will be destroyed). In the event that the results are published or presented, only grouped data will be used to guarantee anonymity. Any individual or personal information will be kept confidential. You will be provided with a small gift in appreciation for your participation. In addition, we will offer modest compensation for your travel, parking or transit, if you choose. This study is being conducted under the supervision of Dr. James Bebko, a professor at York University and a Clinical Psychologist.

Withdrawal from the Study: Participation is completely voluntary, *you or your child can withdraw from the study at any time* and it will not affect any of the services that you may currently be receiving. If you decide to stop participating, you will still be eligible to receive the promised compensation for agreeing to be in this project. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Please read and sign the attached consent form indicating whether your child may or may not participate. Please feel free to ask me any questions or if you would like more information. Thank you for your interest and participation in this study, it is greatly appreciated!

Sincerely,

Carly McMorris   Lisa Hancock
Doctoral Candidate   Doctoral Candidate
Psychology Department   Psychology Department

INFORMED CONSENT FORM

**Information Processing in Autism Spectrum Disorders: Understanding
Attention and Intersensory Processing as Core Deficits**

By signing this form, I agree that I have read and understood the description of the study, and that I allow my child to participate. I understand that the information collected about my child during this study will remain completely confidential within the limits of the law and that we may choose to stop participating at any time. I understand that participation in this study will in no way affect any services that we are receiving now or in the future. I agree to have my child's participation and eye-movements video-recorded for purposes of later analyzing looking patterns.

Parent/Guardian Name (please print) _____

Parent/Guardian Signature _____   Date_____

Relationship to the minor who is participating in this study:_____

Child's Name (please print): _____

Child's Date of Birth (d/m/y): _____

Child's current age (in years): _____

Principal Investigator Signature_____   Date _____

Questions about the Research? If you have questions about the research in general or about your role in the study, please feel free to contact us using the contact information below. You may also contact my Graduate Program – the Psychology Department Graduate office. This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics.

Carly McMorris	Lisa Hancock	Dr. James Bebko
Doctoral Student	Doctoral Student	Supervising Professor
York University	York University	York University

_____

Additional Information *(please complete the following information)*

Child's first language_____ Child's most frequently used language_____

By the age of **3**, was your child's language the same as typically developing children? ☐ YES ☐ NO

My child's hearing: Estimated test date_____

☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:

_____

My child's vision: Estimated test date_____
☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:

_____

Has your child **ever** received Intensive Behavioural Therapy (IBI: at least 20 hours of behavioural therapy a week)? (Please note: This question is only to help us understand your child's previous experiences)
☐ YES ☐ NO

* Limited compensation for your travel, parking or transit is available, if you wish; would you like to receive $10.00 to partially cover these costs? ☐ YES ☐ NO

1. Do you wish to receive a brief summary of the grouped findings of this study? (*Please note that it may be 12 months after completion of the study before all the results have been analyzed*) ☐ YES ☐ NO

2. Are you willing to be contacted for participation in future studies (no obligation)? ☐ YES ☐ NO

If you answered **YES** to either of the two above questions, please provide:

Name: _____

Mailing Address: _____

Telephone: _____   Email:_____

Appendix B: Informed Consent for Parents of Children with ASD

INFORMATION LETTER

Information Processing in Autism Spectrum Disorders: Understanding Attention and Intersensory Processing as Core Deficits

Dear Parent,

Purpose of the Study

Two abilities are thought to help people interact socially: 1) attention (shifting your attention from one person or object to another); and 2) combining together what we see with what we hear (intersensory processing). Both attention shifting and intersensory processing are impaired in many children and adolescents with Autism Spectrum Disorders (ASD). Although these difficulties together could lead to other impairments in making sense of the world around us, there has only been limited research on how they work together. We are asking for your and your child's assistance in a research study to look at how they work together and how they impact on social understanding and communication in ASDs.

A better understanding of attention and intersensory abilities will help us identify central difficulties in ASD that may aid in the earlier detection of ASD. It may also provide insight into other characteristics of ASD, such as repetitive and rigid behaviours (for example, over selectivity/'narrow' focus), and social difficulties (e.g., joint attention, face-processing).

What will Participation Involve?

This study will involve children between the ages of 6 and 16 years of age who have been diagnosed with an Autism Spectrum Disorder (ASD). In order to participate, individuals must: a) have at least a 2-year-old verbal ability in English; b) normal or corrected-to-normal hearing and vision; c) no known neurological issues (epilepsy, brain injury, etc.), and d) a previous diagnosis of an ASD by a psychologist or psychiatrist according to DSM-IV-TR criteria. Children will be asked to watch a short video and some pictures that have been created specifically to understand how children attend to and understand what they see and what they hear. The images and video that children will see include a woman telling a story, a woman making voice sounds, a piano being played, and some animated cartoons. During the session, the child's eye movements will be video recorded and tracked using eye-tracking equipment.

Along with this there will one cognitive (thinking) activity examining children's problem solving skills (e.g., working with puzzles) and one language activity (e.g., looking at pictures). Additionally, the Autism Diagnostic Observation Scale (ADOS), a structured observation scale children and adults with ASD will be administered. Overall, the experiment should take no longer than one and a half hours for your child.

Parents will also be asked complete several questionnaires about a range of skills and characteristics of your child. These include thinking skills, self-control, communication and social skills, repetitive and sensory-type behaviours. An additional questionnaire will ask about your experiences obtaining a diagnosis for your child and any previous diagnoses that may have been given. We will also ask you to provide a copy of the diagnostic report for clarification. Parent involvement should take approximately 60 to 90 minutes.

Are there any Risks Involved?

All of the parts of this study have been reviewed and there are no risks involved. All information that is collected will be kept strictly confidential to the fullest extent possible by law. To ensure confidentiality, paper data will be stored in a locked cabinet, and other data will be stored on an external hard drive in an encrypted file that will be kept at the Child Learning Projects Lab at York University. The lab is also locked and only accessible by project personnel. All children will be given a participant number by which they will be identified. Data and audio-video recordings will be stored for an extended period after the study to enable comparison and combination with data in future studies. Once all projects in this line of research have been completed, all data and recordings will be destroyed (paper materials will be shredded and video will be destroyed). In the event that the results are published or presented, only grouped data will be used to guarantee anonymity. Any individual or personal information will be kept confidential. You will be provided with a small gift in appreciation for your participation. In addition, we will offer modest compensation for your travel, parking or transit, if you choose. This study is being conducted under the supervision of Dr. James Bebko, a professor at York University and a Clinical Psychologist.

Withdrawal from the Study: Participation is completely voluntary, *you or your child can withdraw from the study at any time* and it will not affect any of the services that you may currently be receiving. If you decide to stop participating, you will still be eligible to receive the promised compensation for agreeing to be in this project. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Please read and sign the attached consent form indicating whether your child may or may not participate. Please feel free to ask me any questions or if you would like more information. Thank you for your interest and participation in this study, it is greatly appreciated!

Sincerely,

Carly McMorris   Lisa Hancock
Doctoral Candidate   Doctoral Candidate

INFORMED CONSENT FORM

**Information Processing in Autism Spectrum Disorders: Understanding
Attention and Intersensory Processing as Core Deficits**

By signing this form, I agree that I have read and understood the description of the study, and that I allow my child to participate. I understand that the information collected about my child during this study will remain completely confidential within the limits of the law and that we may choose to stop participating at any time. I understand that participation in this study will in no way affect any services that we are receiving now or in the future. I agree to have my child's participation and eye-movements video-recorded for purposes of later analyzing looking patterns.

Parent/Guardian Name (please print) _____

Parent/Guardian Signature _____ Date_____

Relationship to the minor who is participating in this study: _____

Child's Name (please print): _____

Child's Date of Birth (d/m/y): _____

Child's current age (in years): _____

Principal Investigator Signature_____ Date _____

Questions about the Research? If you have questions about the research in general or about your role in the study, please feel free to contact us using the contact information below. You may also contact my Graduate Program – the Psychology Department Graduate office. This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics.

Carly McMorris	Lisa Hancock	Dr. James Bebko
Doctoral Student	Doctoral Student	Supervising Professor
York University	York University	York University

_____

Additional Information *(please complete the following information)*

Child's first language_____ Child's most frequently used language_____

By the age of **3**, was your child's language the same as typically developing children? □ YES □ NO

My child's hearing: Estimated test date_____

□ has not been tested
□ has been tested and no problems were found
□ has been tested and the following difficulties were found:

_____

My child's vision: Estimated test date_____
□ has not been tested
□ has been tested and no problems were found
□ has been tested and the following difficulties were found:

_____

Has your child **ever** received Intensive Behavioural Therapy (IBI: at least 20 hours of behavioural therapy a week)? (Please note: This question is only to help us understand your child's previous experiences)
 □ YES □ NO

* Limited compensation for your travel, parking or transit is available, if you wish; would you like to receive $10.00 to partially cover these costs? □ YES □ NO

1. Do you wish to receive a brief summary of the grouped findings of this study? (*Please note that it may be* <u>12 months</u> *after completion of the study before all the results have been analyzed*) □ YES □ NO

2. Are you willing to be contacted for participation in future studies (no obligation)? □ YES □ NO

If you answered **YES** to either of the two above questions, please provide:

Name: _____

Mailing Address: _____

Telephone: _____   Email:_____

Appendix C: Assent Form

ASSENT FORM

**Information Processing in Autism Spectrum Disorders: Understanding Attention
and Intersensory Processing as Core Deficits**

Why are we doing this study?
We would like to learn more about how people think about information and how they pay
attention to and understand the things they see and hear.

What will happen during the study?
You will see some pictures and some special videos of people talking and some cartoons.
We will use a computer to show us where you were looking and we will make a video
recording of you while you are watching so we can see what you are looking at. After
that we will do some activities where we will ask you to build things, tell us about some
words, look at some books, make a puzzle, and play with some toys. When we are
finished you will be given a small gift.

Are there good or bad things about the study?
Most kids like to watch this video and think the study is fun. We don't think that there are
any bad things about the study.

Who will know about what I said or did in the study?
If you are part of this study, your name will not be given to anyone. We won't tell anyone
about what you said or did. We will not show the videotape of you to anyone and will
erase the video once the results are of no more use for us. Also, we will destroy any
papers that we used in the study.

Can I decide if I want to be in the study?
You can decide if you want to be in the study. It is O.K. if you do not want to be part of
the study. It is O.K. if you say yes now and change your mind later. Your parents know
about the study and have said that you can be in it. Please ask questions that you have at
any time.

Assent:
The study has been explained to me. I know that I can ask questions about the study at
any time. I know that I can decide to stop at any time. I have been told that all of the
videos and other information collected will not be given to anyone. It will only be seen by
the research team.

_____   _____
NAME   SIGNATURE

_____   _____
Carly McMorris (Researcher) or   DATE
Lisa Hancock (Researcher)