UNDERSTANDING ATTENTION AND INTERMODAL PROCESSING DIFFICULTIES IN CHILDREN WITH AUTISM SPECTRUM DISORDERS

MARIE HOOPER

A THESIS SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ARTS

GRADUATE PROGRAM IN PSYCHOLOGY
YORK UNIVERSITY
TORONTO, ONTARIO

September 2018

Abstract

Problems with social orienting, attention, and intermodal processing involving social events are considered to be important deficits in children with autism spectrum disorder (ASD). The present study aimed to better understand how difficulties in attention are associated with intermodal processing difficulties in children with ASD using a novel eye-tracking experimental task. Six- to 16-year- old children with ASD were compared to age- and cognitive ability- matched peers while engaging in a task involving intermodal processing and attentional experimental measures. Overall, results showed that attention may not be uniformly impaired in ASD in relation to intermodal processing abilities. However, for typically developing children, shifting attention performance and intermodal processing may be linked. Explaining the attentional differences in relation to intermodal processing difficulties will contribute to the field of ASD research in order to inform early interventionists, researchers, and clinicians in treating social deficits in this population.

Key words: ASD, autism, attention, disengaging attention, eye tracking, intermodal processing, selective attention, shifting attention, social orienting

Dedication

To my young children, you can do **anything** you put your mind to.

To my husband, who provided me with the stability and love I needed to keep working towards my goals, and for encouraging me not to give up (even when I felt like it).

Acknowledgements

First and foremost, I would like to sincerely thank my supervisor, Dr. James Bebko, for his support throughout this project. Thank you for taking me on (and always making me operationalize my variables against my will) and reminding me that I deserved to be in this program. Also, thank you for your unwavering support when it came to what was most important – my family.

A very special thank you to Dr. Mary Desrocher, who is not only on my thesis committee, but has been a mentor for me for the past several years. Your dedication to your students is *extraordinary* and I am so grateful to have you in my life for too many reasons to list here. You are the first person I turn to when I have good *or* bad news and I know no matter what the issue, I will have your support. I hope you know that you are *the* reason so many students excel professionally and personally. York is so very lucky to have you!

Dr. Carly McMorris, University of Calgary is lucky to have you! You are truly an inspiration. Since the first day I sat in your Cognition class to now, you have been (and continue to be) someone I look up to greatly. Your love for your work and your students radiates each time we talk. I am so thankful for all of your help getting me organized and mentoring me so much on this project. This project wouldn't have been possible without you and Lisa!

Dr. Lisa Alli, thank you for being available to me whenever I needed. Your ability to recall your project from memory blows me away! Thank you for all of your warmth, advice, and candour over the years as well. Thank you for the reminders that I can go at my own pace and that it will all work out. You probably aren't aware of how much I needed to hear that at the time and for that, I am *so* grateful.

Alex Porthukaran, my ‘work spouse’ and truly my best York friend, for really taking the time and helping me immensely through this process and over the last two years – no matter how busy you have been. I may not always want to hear what you have to say, but I appreciate the honesty, always. I don't know if this project would have ever been completed if you hadn’t been there to keep me on schedule!

To Melissa Ferland, thank you for always being willing to help and for your many (read: many!!) comments on my drafts. But most importantly, for all the chocolate motivators you donated to keep me going - I appreciate it so much (my stomach appreciates it a little less).

To Dr. Adrienne Perry, Lori, Barb, and Freda, thank you for all of the late-night email replies and the assistance on just about everything related to graduate school. Truly, there is no team like you and I am so grateful to have you in the grad office!

This thesis has been a ‘group effort’. They say it takes a village to raise children and in order to fulfill my dreams, my village really had to come through. I could not have done this without my village.

Mom, let me say this in writing – there is *no one* like you. Your support contributed to completing this endeavour and I am forever grateful for the love you have shown me and my young family. Thank you for showing me what it means to a mother.

Dad, thank you for always reminding me to slow down and to take a breath. This project has consumed me for the last while and all your offers to help have been so appreciated. Thank you for taking Sloane to dance class while I crunched data!

Sara, thank you for always believing in me and reminding me that I could do this – even when I really felt like I really couldn’t. Having a sister whom is my biggest cheerleader is truly a gift and a blessing.

To my in-laws, Dr. Sally Hooper and Peter Hooper, thank you for being such wonderful grandparents and being there whenever I needed you during this process. Charles and I really wouldn't have been able to go back to academia and fulfill our dreams without your steady support.

To the accomplishments I am **most** proud of - Sloane and Ashton. I know there have been times where I have had to sacrifice time with you in order to get this project done and I cannot thank you enough (even when Mommy had so much guilt over it). I love you both with every fibre of my being.

To my loving husband – Hooper – there are no words to describe how much your support and stability has allowed me to finish out this project. Thank you for taking the kids late nights or out on weekends so I could finish. Your love is second to none and without you this would only be a dream. Thank you for being my partner in crime. I love you.

Lastly, a huge thank you to the families who participated in the study and who generously gave of their time and experience.

Table of Contents

List of Tables

List of Figures

Literature Review

Autism spectrum disorder (ASD) is a neurodevelopmental disorder and an umbrella term used to describe several characteristics including deficits in social communication and interaction as well as restricted, repetitive patterns of behaviours, interests, or activities (American Psychiatric Association [APA], 2013). Children with ASD have challenges filtering and processing information from different sensory modalities simultaneously (Foss-Feig, et al., 2010). When a child has these multisensory processing challenges, combined with difficulties in selective attention (Bahrick & Todd, 2012), the development of pre-linguistic skills are negatively impacted (Patten, Watson, & Baranek, 2014).

Selective attention is vital to humans because we use this ability to perceive the world around us. It involves the process of being able to focus on an object, while filtering out distractors. Intermodal processing (IMP) is defined as the way in which the brain deals with multiple sources of information through multiple sensory systems (Meredith, 2012). Both intermodal processing skills and selective attention skills are observed soon after birth and further develop as the infant grows older. Infants of just a few days old begin to interact with the social world and involve skills such as social orienting and attention (Bahrick & Todd, 2012). However, these skills are found to be impaired in individuals with autism spectrum disorder (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998).

Selective attention

Selective attention plays a salient role in cognition and is controlled by two sets of cognitive processes: 1) *endogenous* which is a top-down goal-oriented process based on the individual; and 2) *exogenous* which is a bottom-up stimulus-driven process that is based on goal-driven behaviours (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014; Yantis, 1993). Posner and Petersen (1990) described three functionally independent networks of attention: 1) *Alerting* (attaining and upholding a high level of sensitivity to incoming information); 2) *Orienting* (selecting information from sensory input)*;* and *3) Executive attention* (encompassing mechanisms for monitoring and resolving conflict among cognitive thoughts and feelings). Orienting is implemented when a cue is presented that indicates where in space a target is likely to occur. In doing so, attention is directed to the cued location (Posner, 2012; Posner, 1980). While individuals with ASD experience challenges with all three networks (Keehn, Muller, & Townsend, 2013), the present study focuses on the orienting of overt attention. Orienting can involve both overt (accompanied with eye movements) or covert (no eye movements) movements of attention (Posner, 2012).

In infancy, the orienting network of selective attention is the first system babies use to explore the world around them. Posner and Cohen (1984) posited that there are three tenets of visual spatial attention when presented with an external cue: 1) *Disengagement of attention* which involves breaking away from visual attention; 2) *Shifting of attention* which involves moving attention from the original stimulus to a novel stimulus; and 3) *Engagement of attention* to the new stimulus. In order to selectively attend to a stimulus, one must be able to disengage from the initial stimulus, shift by moving from the first stimulus to the new stimulus, and then re-engage to a novel stimulus. In social development, the ability to disengage, shift, and engage again is critical for young babies and their caregivers for joint attention (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014). This ability is especially crucial when working with information from two different sensory modalities.

Intermodal processing (IMP): Integrating the senses

The human nervous system is capable of intricate, complex tasks such as integrating perceptual sensory modalities including visual, audio, tactile, taste, olfactory, and proprioceptive information. At a rudimentary level, the brain combines two separate, isolated sources of input (audio and visual information) by integrating the two modalities and creating one cohesive, central, perceptual unit. This current project specifically focuses on the joining and processing of audio and visual intermodal information.

Young babies are able to integrate these modalities as early as one day old and improve this skill across development (Alli, 2016; Bahrick & Hollich, 2017; Bahrick & Lickliter, 2000). An important intermodal processing (IMP) study by Wertheimer (1961) found that a newborn infant as young as 10 minutes old would respond to a toy cricket "clicking" in one ear or the other. The newborn responded with eye movements to just over half of the trials and when there were eye movements, the infant almost always oriented her head towards the sound (Arterberry & Kellman, 2016). Although the response to the sound was expected, researchers were surprised to see that the baby could coordinate movement to look towards the sound. The baby's response indicated that these complex perceptual skills begin developing soon after birth.

Consider another audio-visual example of an older child. When a child watches an actor on a television screen, she is hearing the words coming out of the actor's mouth and also watching the actor's mouth, integrating the synchronous information (what she hears matches the lips she is watching move), called temporal synchrony. Temporal synchrony is defined as changes in events that happen to the same moment in time, in this case, from different senses (Bahrick & Hollich, 2017; Bahrick & Todd, 2012). Children with ASD have difficulties when the modalities of information are asynchronous.

Intermodal processing and selective attention

Modalities that are temporally synchronous remain in harmony according to the *Intersensory Redundancy Hypothesis* (Bahrick & Todd, 2012). The intersensory redundancy hypothesis (IRH) is a model of selective attention that maintains that by receiving synchronous stimulation from two or more senses, amodal information becomes salient and redundant, and bimodal or unimodal information becomes nonredundant. For example, when a ball bounces on the ground, one can see the ball bouncing, but the rhythm, tempo, duration and intensity are temporally synchronized across visual and auditory sense modalities. Infant and early childhood researchers have found that when information is presented amodally (through several modalities simultaneously) such as hearing and seeing the ball bounce at the same time, this information is redundantly specified rather than if the information is presented unimodally. The IRH purports that when synchronous information is presented across several modalities, it strengthens and guides attentional selectivity (Bahrick & Lickliter, 2000; 2014). This is important because children orient towards intermodal information sources.

Preferential Looking Paradigm (PLP)

One of the most effective ways for researchers to examine selective attention when studying intermodal processing is to use the preferential looking paradigm (PLP). The PLP has had several variations, but the goal remains the same - to understand looking patterns. Researchers introduced a PLP by using a two-screen PLP task where one of the screens visually matched the audio (synchronous) being played and the other one was a mismatched (asynchronous) screen (Spelke, 1976; Walker-Andrews, 1986). The child should be able to discriminate intermodal differences between the two. If a child pays attention to one screen longer than the other, it is said that the child ‘prefers’ or notices that there is a difference between the two, measured by eye tracking technology. In more recent studies, four displays have sometimes replaced the two-screen method (Alli, 2016), but the interpretation remains the same. In children with ASD, children typically get fixated on certain aspects of the stimuli; therefore, studies of eye gaze and preferential looking are important in order to further understand social cognition and neuroscience in autism (Volkmar, Rogers, Paul, & Pelphrey, 2014).

ASD and 'sticky' attention

Visual orienting challenges begin in the first year of life for children with ASD (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014). Additionally, in high-risk siblings of children with ASD, this is the earliest reported visual orienting attentional deficit (Elsabbagh et al., 2009). The subject of deficits in attention disengagement, or 'sticky' attention, is controversial amongst researchers in the ASD field. Several studies show that attention disengagement abilities are intact in children with ASD (Fischer et al., 2014; Kawakubo et al., 2004; McMorris, 2015; Mosconi et al., 2009). 'Sticky' attention is the difficulty disengaging attention from one object in order to pay attention to another (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014). 'Sticky' attention has been observed using eye-tracking technology in typically developing infants from birth to one month old (Hood & Atkinson, 1993; Sacrey et al., 2014) and after that first month, the ability to disengage becomes increasingly easier and improves over development (McConnell & Bryson, 2005; Sacrey et al., 2014). Many children with ASD have a perseverative or repetitive interest such as spinning wheels on a car (Keehn, Muller, & Townsend, 2013; Sacrey et al., 2014) making it very difficult for the child to disengage from the task, similar to a "stickiness" of attention. From a developmental perspective, the difficulty in disengaging attention is problematic due to the possibility of its leading to deficits in social interaction, joint attention, and learning new information.

In a seminal study by Landry and Bryson (2004), 13 children with ASD, 13 children with Down syndrome and 13 typically developing (TD) children participated in a simple visual orienting attention task meant to engage them automatically on shifting and disengaging trials. Children sat in the centre of three computer monitors and were asked to look at the screens with no further instruction. For the shifting trials, a stimulus first appeared on the middle computer monitor and, once the child was engaged, the stimulus disappeared from the screen and another stimulus appeared on one of the peripheral monitors. That stimulus remained on the peripheral screen until the child made an overt eye movement, or after eight seconds had passed. The disengaging trials were somewhat analogous except that the central stimulus remained on the screen while the peripheral stimulus appeared. Not surprisingly, for the disengaging trials, the children with ASD had a difficult time disengaging their attention from the original, competing stimuli. For the disengaging trials, the children with ASD were four times slower than the children with Down syndrome and two times slower than the typically developing children. For the shifting trials, the children with ASD were three times slower than the children with Down syndrome and one-and-a-half times slower than the TD children. This study determined that children with ASD are slower in shifting and disengaging their attention which could underlie their difficulties in social relationships and rigid and repetitive behaviour (Bahrick & Todd, 2012).

In contrast, recent eye tracking studies have found that when compared to children with developmental delays or typically developing children, children with ASD do not differ much from children with developmental delays or typically developing children when presented with certain social stimuli; however, in even younger children, eye gaze patterns show significant differences when presented with the same stimuli (Chawarska, Macari, & Shic, 2012). More work is needed in order to elucidate the underlying mechanisms of gaze patterns and attention in younger children with ASD (Volkmar, Rogers, Paul, & Pelphrey, 2014).

Social orienting in ASD

Intermodal processing plays a critical role in the development of social orienting (Bahrick & Todd, 2012). Dawson and colleagues (1998) proposed the idea that children with ASD have difficulty orienting, shifting, and disengaging selective attention, and that these problems are particularly apparent when they are looking at social stimuli. The *Social Orienting Hypothesis* refers to the failure in young children to spontaneously orient towards naturally occurring social stimuli in the environment such as facial expressions or gestures of people they are familiar with (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Other researchers have found that the combined impaired attention functioning and the avoidance of social stimuli in turn limit the child's early social experiences (Kikuchi et al., 2011; Mundy & Neal, 2000; Osterling & Dawson, 1994).

In a breakthrough longitudinal study by Jones and Klin (2013), preferential selective attention and looking patterns were examined in infants, both typically developing and those who later went on to develop ASD. Using eyetracking technology, researchers had the infants watch videos of caregivers in naturalistic settings. They were able to capture what regions of the body the infants were attending to when engaging socially. The most significant finding was that, between two and six months of age, both TD and children who later went on to develop ASD had relatively stable looking patterns towards the eyes. As they aged, babies who went on to be diagnosed with ASD had a steady decline of visual fixations toward salient social information.

Orienting to a social stimulus is important in Posner's *Attentional Network* model. In cases of social stimuli, it is likely that children with ASD sometimes do not find the social stimulus (even though it is providing redundant information) reinforcing in and of itself. Because of this, children are less likely to orient to the social stimulus.

Young children need to master early socio-cognitive skills such as selective attention and social orienting in order to later develop skills in more complex social behaviours such as joint attention and theory of mind (Volkmar, Rogers, Paul, & Pelphrey, 2014). Children with ASD do not show the same pattern of preference as typically developing children when shown social versus non-social information. Additionally, they tend to get 'stuck' or fixate on information, such as non-social information, potentially limiting subsequent social development, a core deficit in children with ASD. Elucidating whether these attentional differences are related to intermodal processing difficulties will contribute to the field of ASD research in order to inform interventions in treating social deficits.

Present Study

Research objectives and hypotheses

Problems with social orienting, attention (disengaging and shifting), and intermodal processing involving social events are considered to be important deficits in children with ASD. In the extant literature, attention difficulties remain at the forefront of discussion, but how these impact intermodal processing deficits is less understood. The goal of this project was to better understand how difficulties with attention are associated with intermodal processing difficulties in children with ASD. The following research questions guided my hypotheses:

Research Question 1*:* Is the relationship between intermodal processing, (as measured by the performance on the IMP task) and attention (both the disengaging and shifting trials for both number of fixations and duration of fixations) associated with the type of trial (e.g., social or non-social)? These variables are defined in the data analysis portion. Are these relations the same for samples with and without ASD?

Hypothesis 1: I predicted that associations between performance on the IMP task and the attention measures would be found in some types of trials but not others. Specifically, they would be found in social trials but not non-social trials.

Research Question 2**:** What is the relationship between search strategies on the IMP task and performance on the attention task? These variables are defined in the data analysis portion.

Hypothesis 2: For the TD group, I predicted that there would be a positive association between utilizing more efficient search strategies and performance on the attention task. For the ASD group, there would be a negative association between utilizing efficient search strategies and performance on the attention task.

Exploratory Question 3: Is there are a relationship between parent reported attention skills and performance on the intermodal task or the attention task between the ASD and TD groups?

Methods

Participants

The current project utilizes previously collected data from an earlier joint project (Alli, 2016; McMorris, 2015). Children were recruited through collaborative agencies or through a previously established multi-site research registry (the Autism Spectrum Disorders - Canadian American Research Consortium; ASD-CARC). Children between the ages of 6 years, 3 months (75 months) and 15 years, 4 months (184 months) (M = 129.21 months, SD = 32.68 months) or their parents gave consent to participate in this study. The first group included 19 typically developing children and the second group included 14 children who were diagnosed with an Autism Spectrum Disorder based on the *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition* (DSM-IV-TR; APA, 2000). At the time of the study, the *Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition* (DSM-5; APA, 2013) was not yet in common use.

The ASD group was comprised of individuals who were diagnosed with Autistic Disorder (*n* = 3), ASD (*n* = 5), PDD-NOS (*n* = 6) and Asperger syndrome (*n* = 4). These four diagnostic groupings were formerly clustered under Pervasive Developmental Disorders in DSM-IV but are now subsumed under Autism Spectrum Disorder in DSM-5 (DSM-5; APA, 2013). For convenience and for future comparisons, this group will be referred to as the group with ASD. To confirm diagnosis, participants and their parents participated in the *Autism Diagnostic Interview-Revised (*ADI-R; Le Couteur, Lord, & Rutter, 2003) or the *Autism Diagnostic Observation Schedule* (ADOS; Lord, Rutter, DiLavore, & Risi, 2002). The original researchers asked for a pediatric or psychological report to confirm diagnosis if the families were not available to participate in the diagnostic measures. Due to the nature and importance of hearing and vision of the task, families were asked to report on hearing and vision. All children had normal or corrected-to-normal hearing and vision and no neurological impairments were reported. Proficiency in English was also required.

Inclusion criteria for typically developing (TD) children and youth included: a) a Full-Scale Intelligent Quotient (FSIQ) over 70 and b) no history of a social disability (as indicated on the Social Communication Questionnaire). The group with ASD was matched to the TD group based on chronological age (CA), Verbal Cognitive Ability (VCA), and Nonverbal Cognitive

Ability (NVGCA) as measured by one of two cognitive batteries of the *Differential Ability Scales,* 2nd Edition (DAS-II; Elliott, 2007) depending on their chronological age: *The Early Years Cognitive Battery* or the *School-Age Cognitive Battery.* Descriptive statistics are summarized in Table 1.

Table 1

Descriptive statistics of participants chronological age and cognitive skills

Clinical Variables	**Total Sample** (N = 33)	**ASD Group** (*n* = 14)	**TD Group** (*n* = 19)
	Mean *(SD)* Range	Mean *(SD)* Range	Mean *(SD)* Range
Chronological Age (Months)	128.08 *(31.01)* 75 - 183	136.14 *(28.09)* 90 - 183	122.00 *(32.40)* 75 - 175
DAS-II: Verbal Cognitive Ability Standard Score (VCA)	*99.16 (17.48*) 34 - 133	94.77 *(24.25)* 34 - 133	102.16 *(10.53)* 86 - 126
DAS-II: Nonverbal Cognitive Ability Standard Score (NVCA)	100.79 *(14.77)* 64 - 128	97.86 *(19.14)* 64 - 128	102.95 *(10.56)* 76 - 120

Note. Autism Spectrum Disorder (ASD); Typically Developing (TD); Differential Ability Scale, 2nd Edition (DAS-II); Verbal Cognitive Ability (VCA); and Nonverbal Cognitive Ability (NVCA).

Clinical Measures

Child measure.

Cognitive measure. The Differential Abilities Scale, 2nd Edition (DAS-II; Elliott, 2007) is a standardized measure designed to assess cognitive abilities of children and adolescents from two years, six months through eleven years, eleven months. There is limited information on the reliability and validity of the DAS-II; however, the DAS-II has been used with special populations such as those with autism spectrum disorders or developmental disabilities because of its reduced verbal instruction, fewer timed tasks, and calls for less social engagement than other cognitive measures.

Parent-report measures.

Repetitive Behavior Scale-Revised (RBS-R). To better understand the relationship between performance on the attention task and participants' difficulties with repetitive or rigid behaviours, 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. Scores range from 1 to 100 on the RBS-R and higher scores indicate repetitive behaviours typically associated with autism. Authors report high internal consistency (α=.78-.91) and acceptable inter- rater reliability (67%) across the six subscales: stereotyped behaviour, self-injurious behaviour, compulsive behaviour, ritualistic behaviour, sameness behaviour, and restricted behaviour (Alli, 2016).

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. Higher scores on the Conners also indicate more severe symptomatology as reported by parents. T-scores above 65 are considered elevated. The Conners is recommended for use with children between six and 18 years of age and has been shown to have strong reliability as well as good predictive and construct validity (Conners et al., 2008). 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. The SCQ is a brief parent-report questionnaire used with children and adolescents with a mental age above 2 years who may have ASD. Scores higher than 15 on the SCQ typically warrant a further autism evaluation. Additionally, the SCQ was used to ensure individuals in the TD group did not show clinical symptoms consistent with an ASD diagnosis. The SCQ 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 (McMorris, 2015).

Autism diagnostic measures.

Autism Diagnostic Interview-Revised. 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 has strong psychometric properties, including internal consistency, inter-rater reliability, and test- retest reliability (Lecavalier et al., 2006).

Autism Diagnostic Observation Schedule. The ADOS is a standardized semi-structured observation schedule designed to help diagnose individuals with ASD. Using several 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. As reported in the ADOS manual (Lord et al., 2002), intraclass correlations are as follows: interrater reliability ranged from .82 to .93 and test-retest reliability over 1 to 2 weeks ranged from .59 to .73 (Lord et al., 2000).

Experimental Tasks

Stimuli. There were two types of trials employed in this study: 1) Preferential looking trials or intermodal trials, where four stimuli were shown in four quadrants of a computer screen throughout the trial, and one quadrant had a synchronous audio and visual track and the rest were asynchronous; and 2) Attention trials or exogenously cued trials, where stimuli were presented on the screen sequentially across the four quadrants. These tasks are described further below.

The Tobii eye-tracker measured the participants' eye movements indicating their attention behavior during both types of trials. When typically developing (TD) children are presented with social linguistic information, they orient their attention to the eyes of the person speaking in the social scene, whereas children with ASD tend to look at the mouth (Jones & Klin, 2013). In this study, one non-social stimulus and three different types of complex social stimuli were included:

1) SL - Social Linguistic: a woman telling a fictional story.
2) SNLO - Social Non-Linguistic Oral: a woman making various sounds (e.g. kissing, raspberry sounds, clucking, etc.).
3) SNLC – Social Non-Linguistic Clap: a woman clapping.
4) NSNL – Non-Social Non-Linguistic: a hand playing a piano and a string attached to nuts and bolts being lifted up and dropped.

Intermodal task. All trials used the four-screen preferential looking paradigm (PLP-4) with all four videos present, one in each quadrant of the screen (Alli, 2016; McMorris, 2015).

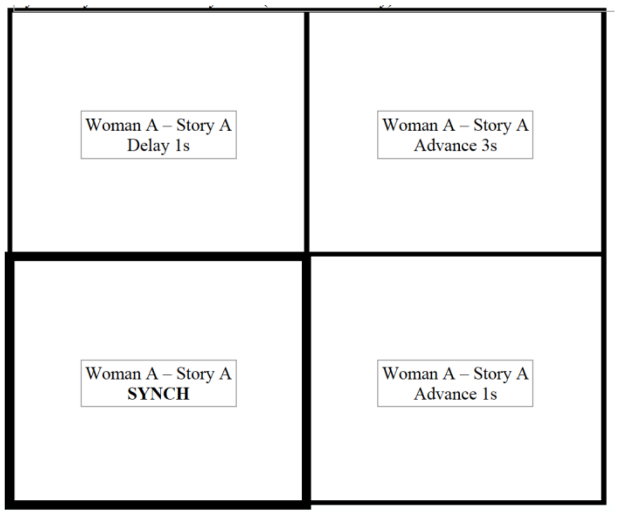

Figure 1. In this social linguistic trial, the woman's voice synchronous to the video is in the lower left quadrant. The videos in each of the other quadrants are identified by the level of synchrony with the auditory track (advance or delay) (Alli, 2016; McMorris, 2015).

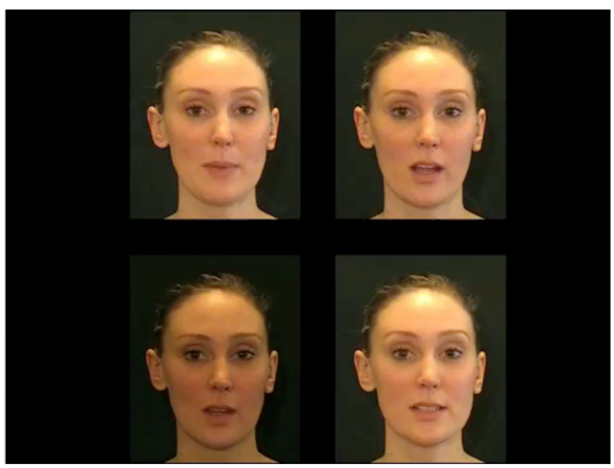

Figure 2. Example of a social linguistic trial (Alli, 2016; McMorris, 2015).

In the trial, one of these quadrants had a synchronous audio and visual track, while the other three were asynchronous. This type of trial is called preferential looking since all the stimuli are present, and participants must determine where to look. Preferential looking paradigm research suggests that participants focus on the stimuli that are synchronous (Patten, Watson, & Baranek, 2014). The presentation of these stimuli is similar to those used in standard preferential looking paradigms, other than having four stimuli present rather than two. The duration of time spent looking at each quadrant was recorded, including differences between the one synchronous stimulus and the other stimuli.

Attention task. Due to the need for precision in describing the difference between the shifting and disengaging trials, the following section is extracted directly from McMorris (2015) with permission:

> All trials lasted approximately 12 s, with shifting trials lasting slightly longer (12.09s; 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 (McMorris, 2015, p. 33).

Number of fixations, duration of fixations, and time to fixate was recorded for each stimulus. These are operationalized in the data analysis portion of this paper.

Experimental Procedure

To garner an interest in the task and gain comfort with the apparatus, the paradigm began with a centrally-presented cartoon using the Tobii program. After the cartoon, a nine-point calibration took place. Once the calibration was deemed successful and the participant felt comfortable, there was a four-screen familiarization task in which four identical video clips were shown, all synchronous with the audio track. The testing trials for both the intermodal and attention task then followed.

Intermodal trials. To examine preferential looking, a total of 16 trials were presented (four of each kind of stimulus: SL, SNLO, SNLC, NSNL). Each trial began with a cartoon picture or video (central fixation) presented in the middle of the screen, which remained on the screen for three seconds.

Attention trials. To examine exogenously-cued attention, both shifting and disengaging abilities were examined. Children participated in 32 exogenous attention trials lasting approximately 12 seconds each, (16 trials assessing participants' shifting and the remaining trials examining disengaging again with four of each kind of stimulus). Each trial began with a cartoon picture or video (central fixation) presented in the middle of the screen, which remained for three seconds.

General procedure

Prior to participating in the study, the participants and their parents completed informed consent and assent forms. Once the consent forms were signed, participants were situated at the computer between 64 ± 13 cm from the display screen and Tobii eye-tracker. Before the task, a moving ball appeared on the computer screen to ensure proper calibration of eye fixations and movements. The attention and intermodal task (PLP-4) took 20 minutes to complete, with a short break halfway through the task. Upon completion, the participants were administered the DAS-II that lasted 45-60 minutes.

While the children were participating in the experimental procedure, parents were given the parent-report measures to fill out. They were also asked to provide documentation to confirm an ASD diagnosis. If the document was unavailable or the parent was unwilling to provide the report, the child was asked to participate in the ADOS. If there was not enough time, the parents were then contacted to partake in the ADI-R over the phone to confirm a diagnosis of ASD.

Upon completion of the experimental procedure and cognitive measure, participants and their parents were debriefed. An opportunity to ask questions was offered to all parties and they were then presented with a gift card to a book store and a certificate for participating.

Data Analyses

Tobii software was employed to analyze the attention portion of the task as well as the intersensory processing part. Statistical analyses were conducted using SPSS. In general, Tobii software calculates each participants' eye movements based on each quadrant per trial and exports the gaze data and looking patterns.

Variables.

Attention. Participants' disengaging and shifting attention abilities were measured by the time it took for a participant to fixate (*time to fixate*), *total duration of fixations* and *number of fixations* per trial.

Time to fixate is operationalized as the time it took for a participant to move attention from one stimulus to the next. Specifically, *time to fixate* indicates the mean amount of time it took a participant to look at a specific quadrant (i.e., second stimulus) from the onset of that stimulus. The *mean time to fixate* was used in the analyses and refers to the average speed of shifting or disengagement performance across all fixations.

The *total duration of fixations* is defined as the degree to which the participants were involved, engaged, or interested in the task stimuli. Specifically, the longer the participants looked at the computer screen (i.e., overall four-image array of the 12 second trial), the more engaged they were, resulting in a higher total duration of fixation. Lastly, the *total number of fixations* is defined as the sum of number of times a participant made a fixation across all quadrants on a trial. *Time to fixate, total duration of fixations* and *total* *number of fixations* per trial were exported in Tobii for each participant.

Intermodal performance. In regards to the IMP portion of the analyses, two different descriptions of analysis were used as described below. Tobii software was employed to calculate the duration of looking time to the quadrants and were analyzed on a per trial basis to calculate the proportion of time spent looking at specific Areas of Interest (AOI)s. These AOIs included the upper right quadrant (UR), upper left (UL), lower right (LR) and lower left (LL). The *proportion of looking time* (proportion of fixation duration) was operationalized as the proportion of time spent looking at a specific AOI. This is important to determine where the participant was preferentially looking. In order to ascertain preference in looking patterns, *preferential looking* was operationalized as the participants' preference for stimuli measured by the time they spent looking at each stimulus.

The second part of the analysis included measuring gaze patterns. Sequences of looks were coded as 'efficient' or 'inefficient' based on the gaze shift pattern. Here, AOI's were defined by more precise areas within the quadrants. Each participant was coded to employ an 'efficient' search strategy if their gaze shifted from an AOI (mouth) to another AOI. 'Inefficient' search strategies were coded for any other gaze patterns. Once the data were coded, the proportion of efficient transitions was calculated by dividing the number of efficient transitions / total number of transitions for each trial.

Analyses. The data were analyzed across both the ASD and TD groups. Below are the research questions and descriptions of analyses.

Research Question 1. Are strong intermodal processing abilities (as measured using a preferential looking paradigm) associated with attention (disengaging and shifting abilities) and the type of trial (e.g., social or non-social)? These data were analyzed by conducting Pearson correlations. Correlations revealed the associations between performance on the IMP portion (i.e., the extent, or the duration, that they demonstrated preferential looking to the synchronous stimulus) and performance in the attention portion (as measured by the number of fixations, duration of fixations, and time to fixate) of the task. Further, IMP and attention shifting and disengaging abilities were examined by diagnostic group and type of trial (e.g., TD versus ASD social and TD versus ASD non-social).

Research Question 2. What is the relationship between search strategies on the IMP task and performance on the attention task? These data will be analyzed by looking at the associations between efficient search strategies and performance on the attention task, for only the social linguistic (SL) and for social non-linguistic oral trials (SNLO) for simplicity. Efficient search strategies are defined as the proportion of looks towards the mouth (meaningful area) that provide information about temporal synchrony which were coded using areas of interests (AOI's) placed on these areas.

Research Question 3. Is there are a relationship between parent reported attention skills and performance on the intermodal task or the attention task? Relationships between parent reported Conners-3 subscales of inattention and executive functioning as well as the attention and IMP measures (i.e. those variables described in hypothesis 1) were examined through correlational analyses.

Results

Attention trials

Independent samples *t*-tests revealed that in the disengaging trials there were no significant differences in the number of fixations $t(31) = 1.88$, $p = .07$ or time to fixate $t(31) = -1.57$, $p = .13$ between TD and ASD groups. These results indicate that participants with ASD disengaged at the same speed as the TD participants. There was a significant difference in the total duration of fixations per trial, *t*(31) = 3.02, *p* = .01. See Table 2 for results.

Table 2

Performance on attention disengagement trials by group

	Total Sample (N = 33)	**ASD Group** (*n* = 14)	**TD Group** (*n* = 19)
Disengaging	Mean *(SD)*	Mean *(SD)*	Mean *(SD)*
Total number of fixations per trial	17.84 *(5.18)*	15.94 *(4.96)*	19.24 *(5.00)*
Total duration of fixations per trial (sec)	6.92 *(2.26)*	5.63 *(2.34)*	7.86 *(1.71)*
Time to fixate (sec)	.53 *(.17)*	.59 *(.19)*	.49 *(.15)*

In the shifting trials, there were no significant differences in the number of fixations, *t*(31) = 1.58, *p* = .12. However, there was a significant difference in the time to fixate, *t*(31) = -2.36, *p* = .03 as well as total duration of fixations per trial, *t*(31) = 2.87, *p* = .01. See Table 3 for a summary of results.

Table 3

Performance on attention shifting trials by group

Shifting	**Total Sample** (N = 33) Mean *(SD)*	**ASD Group** (*n* = 14) Mean *(SD)*	**TD Group** (*n* = 19) Mean *(SD)*	*p*
Total number of fixations per trial	18.78 *(5.52)*	17.04 *(6.00)*	20.05 *(4.92)*	>.05
Total duration of fixations per trial (sec)	7.19 *(2.43)*	5.91 *(2.64)*	8.12 *(1.80)*	.01
Time to fixate (sec)	.46 *(.21)*	.56 *(.28)*	.40 *(.11)*	.03

Overall, the participants in the TD group were quicker to shift than the participants in the ASD group. Further, the TD group had longer duration of fixation times per trial than the ASD group.

Parent Reported Questionnaires

Parents completed the *Social Communication Questionnaire – Lifetime Form* (SCQ), the *Repetitive Behavior Scale-Revised* (RBS-R), and the *Conners - 3rd Edition* (Conners-3). Independent sample *t*-tests were conducted to test group differences. There were significant group differences on the reported measures: RBS-R $t(29) = -6.71$, $p < .001$, the SCQ questionnaires $t(31) = -4.76$, $p < .001$, the Conners Inattention Symptom Subscale, $t(31) = -5.01$, $p < .001$, and the Conners Executive Functioning Symptom Subscale, $t(31) = -3.93$, $p < .001$. Overall, parents of the children in the ASD group reported more difficulties with social communication, repetitive behaviours, attention, and executive functioning than parents of TD children. Descriptive statistics are summarized in Table 4.

Table 4

Descriptive statistics: Parent-reported questionnaires

Clinical Variables	Total Sample (N = 33)	ASD Group (*n* = 14)	TD Group (*n* = 19)
	Mean *(SD)* Range	Mean *(SD)* Range	Mean *(SD)* Range
SCQ: Total Raw Score	9.84 *(9.99)* 0 - 30	18.29 *(8.97)* 3 - 30	2.88 *(2.80)* 0 - 8
RBS-R: Total Standard Score	9.27 (13.43) 0 – 54	19.29 *(15.66)* 1 – 54	1.89 *(2.80)* 0 – 11
Conners: INT Subscale T-Score	57.73 *(15.34)* 38 - 87	69.50 *(10.53)* 56 - 87	49.05 *(12.28)* 38 - 84
Conners: EF Subscale T-Score	56.36 *(14.24)* 38 - 88	65.79 *(10.90)* 44 - 82	49.05 *(12.45)* 38 - 88

Note. SCQ = Social Communication Questionnaire – Lifetime Form; RBS-R = Repetitive Behavior Scale-Revised; Conners INT = Conners Inattention Symptom Subscale; Conners EF = Conners Executive Functioning Symptom Subscale

Hypothesis 1: The Relationship between Intermodal Processing Abilities and Attention Abilities by Trial Type

Intermodal performance (IMP) was defined as the extent, or the duration, to which participants demonstrated preferential looking to the synchronous stimulus. Shifting and disengaging attention abilities were measured by the total number of fixations, total duration of fixations, and time to fixate to the non-social stimulus (NSNL) and three different types of complex social stimuli (SL, SNLO, and SNLC). For both groups, the correlations between IMP and attention shifting and disengaging abilities were examined by social linguistic and non-social non-linguistic trial types.

Social Linguistic IMP Performance

Disengaging. For the ASD participants, there were no significant relationships between the IMP performance and disengaging attention abilities. For the TD participants, there were two positive associations that approached significance. Results are shown in Table 5.

Table 5

Correlations between disengaging attention abilities and preferential looking performance conditions by groups

	Preferential Looking Performance		
Stimulus	**SL**	**SNLO**	**SNLC**
Disengagement Task Variable			
ASD Group			
Number of fixations per trial	-.21	-.16	.34
Duration of fixations per trial	-.13	.01	.27
Time to fixate	.29	-.02	.01
TD Group			
Number of fixations per trial	.05	.26	$.41^{+}$
Duration of fixations per trial	$.40^{+}$	.32	.30
Time to fixate	-.03	-.13	-.11

Note. SL (Social Linguistic), SNLO (Social Non-Linguistic Oral), and SNLC (Social Non-Linguistic Clap)
$^{+}p < .10$ approaching significance

Shifting. For the ASD participants, there were no significant relationships for any of the shifting attention abilities for the social trials. However, the SNLC condition approached significance.

For the TD participants, there were several significant findings in the shifting attention abilities and the social linguistic trials suggesting that those in the TD groups had longer fixation times and took less time to fixate in all of the social trials than the ASD group. Duration of fixations for the SL condition, $r(17) = .53$, $p < .05$, SNLO condition, $r(17) = .47$, $p < .05$, and the

SNLC condition, $r(17) = .49$, $p < .05$ were all positively correlated. Time to fixate was negatively correlated in all three social conditions: SL $r(17) = -.56$, $p < .05$, SNLO $r(17) = -.65$, $p < .01$, and SNLC $r(17) = -.60$, $p < .01$ These results are summarized in Table 6.

Table 6

Correlations between shifting attention abilities and preferential looking conditions by groups

	Preferential Looking Performance		
Stimulus	**SL**	**SNLO**	**SNLC**
Shifting Task Variable			
ASD Group			
Number of fixations per trial	-.36	-.33	$.49^{+}$
Duration of fixations per trial	-.31	-.29	.38
Time to fixate	.27	.19	-.35
TD Group			
Number of fixations per trial	.14	.37	$.45^{+}$
Duration of fixations per trial	$.53^{*}$	$.47^{*}$	$.49^{*}$
Time to fixate	$-.56^{*}$	$-.65^{**}$	$-.60^{**}$

Note. SL (Social Linguistic), SNLO (Social Non-Linguistic Oral), and SNLC (Social Non-Linguistic Clap)
$^{*}\,p < .05$; $^{**}p < .01$; $^{+}\,p < .10$ approaching significance

For both ASD and TD groups, on both shifting and disengaging stimulus type, there were no significant relationships with any of the Non-Social Non-Linguistic (NSNL) trial types. Results are reported in Table 7.

Table 7

Correlations between disengaging and shifting stimuli and non-social non-linguistic intermodal processing trials by group

	Non-Social Non-Linguistic Trials (NSNL)	
Stimulus	ASD Group	TD Group
Disengaging Task Variable		
Number of fixations per trial	.24	-.18
Duration of fixations per trial	.11	.20
Time to fixate	-.22	-.07
Shifting Task Variable		
Number of fixations per trial	.11	-.13
Duration of fixations per trial	.05	.12
Time to fixate	-.03	.12

Note. NSNL = Non-Social Non-Linguistic

Hypothesis 2: Efficient Search Strategies and Performance on the Attention Measures

Efficient search strategies are defined as proportion of looks towards meaningful areas that provide information about temporal synchrony, such as the mouth. The mouth is informative for telling apart temporal synchrony especially when using social stimuli. Proportion of looking time was expected to differ between groups for both the disengaging and shifting attention task. A correlational analysis was used to explore the association of proportion of looking at the mouth and attention variables separately for SL and SNLO conditions.

Disengaging. In the TD group, there were no statistically significant relationships between efficient looks in the social linguistic and non-linguistic conditions and disengaging attention abilities (number of fixations, duration of fixations and time to fixate).

For the ASD group, within the SNLO condition, significant association between efficient looks and disengaging attention abilities, duration of fixations $r(14) = .66$, $p < .01$, and time to fixate was also found, $r(14) = -.84$, $p < .001$.

The findings indicate an association between disengaging attention abilities and efficient search strategies (only SNLO) among ASD participants. More specifically, on the attention tasks, longer duration of fixations and less time to fixated are associated with efficient search strategies for ASD participants. Results are summarized in Table 8.

Table 8

Correlations between disengaging attention abilities and efficient search strategies (SL and SNLO)

Stimulus	**Proportion of Looking (Mouth)**			
	ASD Group		TD Group	
	SL	**SNLO**	**SL**	**SNLO**
Disengaging				
Number of fixations per trial	.28	.42	.02	-.002
Duration of fixations per trial	.37	$.66^{*}$	.19	.30
Time to fixate	$-.49^{+}$	$-.72^{**}$	-.10	-.22

Note. SL = Social Linguistic; SNLO = Social Non-Linguistic Oral
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$; $^{+}p < .10$ approaching significance

Shifting. In the TD group, there were statistically significant associations between efficient search strategies in the SNLO condition and shifting attention abilities, duration of fixation, $r(19) = .47$, $p < .05$. This positive correlation indicates that strategic search patterns are associated with more fixations and longer time to fixate.

In the ASD group, the strategic looking in the SNLO condition and shifting attention abilities was found to be statistically significant, duration of fixations, $r(14) = .60$, $p < .05$. Results are summarized in Table 9.

Table 9

Correlations between shifting attention abilities and efficient search strategies (SL and SNLO)

Stimulus	**Proportion of Looking (Mouth)**			
	ASD Group		TD Group	
	SL	**SNLO**	**SL**	**SNLO**
Shifting				
Number of fixations per trial	.09	$.50^{+}$	-.09	.26
Duration of fixations per trial	.16	$.60^{*}$	.22	$.47^{*}$
Time to fixate	-.17	-.30	-.20	-.02

Note. SL = Social Linguistic; SNLO = Social Non-Linguistic Oral
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$; $^{+}p < .10$ approaching significance

Hypothesis 3: Relationship between Parent Reported Attention Abilities and Performance on the IMP or Attention Task

Often, behavioural measures of attention do not correlate with standardized reports of attention (Toplak, 2013). As a result, it was unclear whether there would be any correlations between parent reported measures on the Conners and the shifting and disengaging attention measures used in this study.

Shifting. In the TD group, time to fixate is significant. In the ASD group, there were several relationships between parent report and attention measures. Overall, for shifting attention abilities, and for both social linguistic and social non-linguistic trials, almost all results were significant indicating that standardized reports of attention are correlated when shifting attention is measured behaviourally. These results are summarized in Table 10.

Table 10

Correlations between the Conners inattention and executive functioning symptoms subscales scores and shifting attention abilities

Shifting Attention	ASD Group Conners Symptom Subscale		TD Group Conners Symptom Subscale	
	INT	**EF**	**INT**	**EF**
SL Search Strategies				
Number of fixations per trial	$-.55^{*}$	$-.51^{*}$	-.06	-.01
Duration of fixations per trial	$-.62^{*}$	-.41	-.24	-.13
Time to fixate	$.64^{*}$	$.48^{*}$	.29	.21
SNLO Search Strategies				
Number of fixations per trial	$-.58^{*}$	-.01	.05	.14
Duration of fixations per trial	$-.62^{*}$	-.18	-.04	.07
Time to fixate	$.52^{+}$	.04	$-.45^{+}$	$-.46^{*}$

Note. INT = Inattention; EF = Executive Functioning
$^{*}p < .05$; $^{**}p < .01$; $^{+}p < .10$ approaching significance

Disengaging. In the TD group, there were no significant results. However, in the ASD group, there were several significant results. Overall, for disengaging attention trials, and the proportion of looking on the SL trials, almost all results were significant indicating that standardized reports of attention are correlated when disengaging attention is measured behaviourally. Results are summarized in Table 11.

Table 11

Correlations between the Conners inattention and executive functioning symptoms subscales scores and disengaging attention abilities

Disengaging Attention	**ASD Group** Conners Symptom Subscale **INT**	**ASD Group** Conners Symptom Subscale **EF**	**TD Group** Conners Symptom Subscale **INT**	**TD Group** Conners Symptom Subscale **EF**
SL Search Strategies				
Number of fixations per trial	$-.56^{*}$	$-.54^{*}$	-.01	.04
Duration of fixations per trial	$-.69^{**}$	$-.48^{+}$	-.14	-.06
Time to fixate	$.57^{*}$	$.51^{+}$	.22	.19
SNLO Search Strategies				
Number of fixations per trial	-.41	-.36	.08	.13
Duration of fixations per trial	-.42	-.13	-.10	-.02
Time to fixate	$.50^{+}$	.07	.36	.31

Note. INT = Inattention; EF = Executive Functioning
$^{*}p < .05$; $^{**}p < .01$; $^{+}p < .10$ approaching significance

IMP Performance. There were very few correlations between IMP performance and the parent-reported measures of attention (e.g., inattention and executive functioning symptoms) indicating that parent-reported attention measures and are not related to IMP performance. Results are presented in Table 12.

Table 12

Correlations between the Conners inattention and executive functioning symptoms subscales scores and IMP performance

IMP Performance	ASD Group Conners Symptom Subscale		TD Group Conners Symptom Subscale	
	INT	**EF**	**INT**	**EF**
SL performance	-.17	-.16	-.17	-.02
SNLO performance	-.49*	-.35	.11	.17
SNLC performance	-.33	-.28	-.17	.00
NSNL performance	-.21	-.16	-.16	.02

Note. INT = Inattention; EF = Executive Functioning
IMP performance is reported as SL (Social Linguistic), SNLO (Social Non-Linguistic Oral), and SNLC (Social Non-Linguistic Clap).
*$p < .05$

Discussion

Our world is a continual source of incoming stimuli and it is impossible for a person to process and attend to all of the incoming information simultaneously. The brain has the tremendous ability to sift through or filter this information. In order to filter all of the ‘noise’ coming our way, selective attention, such as social orienting, allows us to focus on salient information and these attention abilities are believed to be developed early. In general, attentional deficits have their roots in early infancy development (Atkinson & Braddick, 2012); however, disruptions in these early attentional processes are well documented in ASD research.

Selective attention and intermodal processing are essential to perform higher-order cognitive tasks and deficits is these areas can lead to cascading deficits in development (Bahrick & Todd, 2012; Posner & Rothbart, 2007; Rueda, Posner, & Rothbart, 2005). As indicated, past research has shown that children with ASD have unusual patterns of intermodal processing and selective attention when compared to typically developing children (Bahrick & Todd, 2012).

Using a novel eye tracking paradigm, this is the first study to examine together shifting and disengaging attention abilities and intermodal processing in order to help us specifically understand the deficits that are present in ASD as well as the general structure of attention. It has been well documented that the smallest of differences in developmental timing can significantly impact developmental outcomes (Alli, 2016; Bahrick & Todd, 2012; McMorris, 2015; Mundy & Burnette, 2005), making this study a valuable addition to the literature.

The *Attentional Network* model posits that the attention system is anatomically separated from the processing systems – emphasizing the attentional influences themselves, rather than the processing systems that could be affected by the attentional processes (Posner & Peterson, 1990; Petersen & Posner, 2012). To illustrate, it is important to remember that attention is understood to be divided into three parts: (1) *Alerting;* (2) *Orienting;* and (3) *Executive control*. The alerting (i.e., arousal) network prioritizes sensory input and orienting involves the shifting of attention to selected information in the environment. The executive control system is responsible for higher-order complex executive functioning (Petersen & Posner, 2012; Posner & Petersen, 1990). Disengaging and shifting of attention (alerting and orienting) are a central part of the attention components of the present study. However, intermodal processing involves these attention mechanisms as well as higher order processing, particularly to resolve discrepancies between modalities, such as when they are not in synchrony.

Posner was primarily interested in visual perception involving unimodal information (i.e., one modality). He posited that once a person is cued or alerted (i.e., arousal) to a cue in the environment, he or she must now attend (i.e., orient) to the new stimulus (i.e., engage) by first disengaging what he is doing. In order for this to happen, he must stop looking (i.e., disengage) at the first cue and move focus (i.e., orient) to the new one. In the case of intermodal stimuli, when the intermodal stimuli are in synchrony, then Posner's model might be adequate, because the amodal properties of the vision and sound signals can be interpreted as being a redundant stimulus, perhaps as if it were a visual stimulus, with an auditory stimulus superimposed. However, when they go out of synchrony, the data suggests that participants search out synchrony in the various quadrants, which implies a higher order level of processing. In other words, the participants searched out strategies to try to resolve the conflict between the disagreement of the auditory and visual signals so this goes beyond simply attention, and certainly visual attention. Perhaps one modality (i.e., visual) impacts another (i.e., audio), resulting in a reinforcement of the attention system. In future research, Posner's model warrants expansion when there are multiple modalities.

The Relationship Between IMP Abilities and Attention Abilities by Trial Type

To better understand the relationships between IMP and attention, I examined the trials and groups separately (i.e., IMP and attention abilities by trial type). In the disengaging task for the TD group, no correlations were found suggesting that, in normal development, there is no relationship between disengaging abilities and intermodal processing. It is possible that in typical, healthy development, the alerting system impacts disengagement. A better understanding of selective attention (i.e., disengaging) is needed to elucidate conflicting findings on disengaging attention in general.

In the TD group in the shifting condition, IMP and shifting attention abilities were correlated. Therefore, it is possible that such connections and associations exist between shifting attention abilities and intermodal processing in typical development. Based on the results, this broad construct that we call attention likely incorporates both IMP and the orienting system when the stimulus is multi-modal. Moreover, the results for the stimuli in this study suggest that this relationship was only true in particular cases – social situations and for the TD group. In contrast, for the ASD group, there were no associations on the social tasks. In either group, there were no correlations in the non-social tasks. Similar patterns have been shown in other studies comparing TD and ASD children. For example, Klin and colleagues (2002) presented a scene of *Who's Afraid of Virginia Wolf?* to a young ASD and TD sample. The eye-tracker recorded the looking time to the AOIs as the youngsters watched the video clips of complex, dynamic stimuli. The AOIs focused on social (i.e., eyes, mouth, and bodies) and non-social scenes (i.e., objects) and it was found that the children with ASD focused more on the mouth, bodies and non-social objects than the typically developing children. However, it is possible that the non-social objects were not salient enough for those on a normal developmental trajectory. Several years later, Jones (2008) replicated the study finding by presenting two-year-old TD and ASD children with 10 videos similar to those used in the present study. Toddlers with ASD focused more on non-social objects than did their TD counterparts, suggesting that these looking behaviours begin quite early in development.

Bahrick and Hollich (2017) noted that as early as 4 to 6 months, TD infants can associate specific faces and voices following just a couple minutes of familiarization, indicating early intermodal abilities. Researchers assessing the distribution of attention (between social and non-social information) have found that infants with autism have a specific deficit in attending to social stimuli (Swettenham et al., 1998).

Inconsistent with the majority of current research, the present study found no correlations on the social trial types between disengaging or shifting and IMP for individuals with ASD. The results suggest that the actual impairments in individuals with ASD are more important than the cascading deficits. In other words, neither shifting nor disengaging abilities are associated with

IMP. These results suggest that a child with an ASD could have an impairment in *either* IMP *or* attention or could have impairments in *both*, but it is not conclusive that if IMP is impaired, then alerting attention would be and vice versa.

Many eye-tracking studies have investigated facial processing and attentional allocation in social situations. A recent meta-analysis included 68 peer-reviewed research articles comparing eye-tracking measures of attention in children with ASD and TD controls. The review examined whether individuals with ASD allocate their attention to social stimuli atypically and found that overall, individuals with ASD were characterized more by an increased attention to non-social objects (Chita-Tegmark, 2016). This supports Tager-Flusberg’s (2010) notion that individuals with ASD should be characterized by a heightened motivation to engage with non-social objects, rather than a prominent current theory that holds that individuals with ASD are characterized by loss of motivation in engaging with the social world.

Additionally, it is also plausible that there is so much heterogeneity in individuals with ASD, that it may be difficult to detect specific deficits. This is due to greater statistical variance in the ASD group overall. Several factors may contribute to this variance such as comorbidities, age and gender, early intervention, social skills training and overall genetic variability to name a few.

Efficient Search Strategies and Performance on the Attention Measures

Current research in the area of efficient search strategies, as measured by gaze pattern, has been mixed as well. However, for the present study, there were no correlations in the TD group for disengaging and IMP performance. However, their attention-shifting performance and IMP were correlated indicating that they likely understood that in order to determine speech synchronicity or discrimination, they knew to look at the mouth. In the ASD sample, some children had efficient search strategies, and some did not. Children who had better disengaging abilities and *some* shifting abilities also were more likely to have efficient search strategies. Past research has found that, in preferential looking studies, children with ASD do not show preferential looking for social linguistic synchronous stimuli, as compared to typically developing children (Bebko et al., 2006; McMorris, 2015). In future, further research is necessary to better understand efficient search strategies and the relationship to attention.

In the current literature on children with ASD, results are inconsistent and a consensus on mouth-looking as an efficient search strategy in relation to selective attention is unclear. As noted earlier, children with ASD are at a disadvantage in that their attention does not appear to orient to the most salient aspects of linguistic communication, reducing the benefit hypothesized from the IRH (Patten, Watson, & Baranek, 2014). Reduced attention to social cues can seriously impact the development of social cognitive skills and learning (Klin, Jones, Schultz, & Volkmar, 2003).

Norbury and colleagues (2009) predicted that TD and ASD teenagers who had a diagnosis of language impairment, represented by a current score of -1.25 SD on the Recalling Sentences subtest of the Clinical Evaluation of Language Fundamentals (CELF-3UK: Semel, Wiig, & Secord, 2000), would spend less time looking at the mouth while watching videos of their peers in social situations. They argued that the language impaired children would have difficulty understanding the literal and social messages being presented. They found that for both groups, increased fixation times to the mouth for social linguistic stimuli were correlated with stronger communication and linguistic abilities, aligned with past research. That is, those who scored higher on the language measure, also had longer fixation durations on the social stimuli as opposed to the non-linguistic stimuli. This is important to understand for early intervention, seeing as communicative competence continues to be problematic into the teenage years.

Relationship between Parent Reported Attention Abilities and Performance on the IMP or Attention Task

Toplak and colleagues (2013) conducted a review hypothesizing that performance-based measures of attention (as seen in laboratory settings) and paper ratings of executive function (parent or self-report) would be highly positively correlated. They found that, in fact, performance-based and parent or self-reported ratings of executive functioning do not capture the same level of analysis, possibly measuring two different constructs on several different measures. In applying this finding to my data, there were no significant results for the TD group, indicating that there were no correlations between parent report attention abilities and IMP performance. For the ASD group, results showed that parent reported measures of inattention on the Conners 3 are related to social linguistic shifting attention abilities for children with ASD. That is, for the children who performed poorly on the SL shifting task, their parents reported high levels of inattention and executive dysfunction on the paper-based parent reports. One explanation for these findings is that it is possible that the non-clinical TD group likely did not have extensive attention difficulties, so there was little variance in the ratings by their parents of their attention ratings. As a result, it would be difficult to find significant correlations, versus for the ASD sample where greater variability would be expected.

Limitations

The current study had many strengths; however, there were several limitations. It should be noted that this was a small sample size. Obtaining a larger sample size would increase the power of the study. Additionally, this study only reported *p*-value significance, it would be useful to report effect size in order to report on the magnitude of their effects in future studies.

While ASD affects four times more males than females (Werling & Geschwing, 2014), there also were more males than females in the study. Participants were matched on IQ and age, not gender. More recent studies are finding early sex differences (Chawarska, Macari, Powell, DiNicola, & Shic, 2016); therefore, future studies should be matched on gender as well. Additionally, it is important to understand that these participants were high functioning individuals and results should not be presumed generalizable to all individuals.

Also, these findings included a large age range (6 to 16 years of age) from childhood to adolescence. Cognitive abilities grow rapidly during this time period, and it may be that the present results are quite specific to this age range. As a result, the findings from this study should not be generalized to a younger or older population. It would be ideal to get a profile for each broad age range (i.e., infant, toddler, preschooler, school age, adolescent, emerging adult, and older adult) in order to capture changes in attention and IMP across the lifespan.

The study was designed to measure children's selective attention, so the study needed to be designed in a way to engage and maintain the participants' focus. In order to do so, the original researchers limited this portion of the study to 15 minutes (in order to increase the complexity of the stimuli), making the inclusion of a large number of trials difficult. While the study is believed to have ecological validity, it is important to note that there were a number of factors that could be attributed to the children's performance on the attention portion such as the time of day (i.e., fatigue), a child having greater than expected attentional issues (i.e., not reported by parents), processing speed, self-stimulatory behaviours as well as boredom. These were not accounted for in the current study.

It should also be noted that, unlike past studies by other researchers, this study used a novel approach in that each trial was longer, giving the participants ample time to shift and disengage between stimuli. The limitation is that the distance between the stimuli was smaller than older research. In other words, because the screens were so close together, when it came time to shift and disengage, the appearance of 'peripheral stimulus' should be interpreted with caution as the peripheral stimuli may not have been outside the participants' visual field.

The parent-report attention measures captured important data in regards to observable attentional behaviours as seen by the parent. However, some of the parent report questions were related to internal experiences (e.g., sensory discomfort, attention, etc.), and the parents are prompted to make their best guesses with regard to their child's internal experiences. In a study by Alli (2016), the attentional parent-reports were found useful; however, the author noted potential lack of sensitivity in the parent report measures as a limitation. In future, given the IQ and ages of the participants, it would be useful to collect self-report measures when available.

Clinical Implications

The overarching goal of this study was to begin to understand selective attentional abilities (i.e., disengaging and shifting) and intermodal processing. Moreover, this type of research is needed in order to aid researchers in understanding the deficits that are present in ASD as well as learning more about the general structure of attention. Explaining the attentional differences in relation to intermodal processing difficulties will contribute to the field of ASD research in order to inform early interventionists, researchers, and clinicians in treating social deficits in this population.

Decreased attentional allotment and reduced social orienting in a social world can seriously negatively impact a developing child. Because these challenges are understood to be general cognitive processes, the adverse impact can spread across several smaller areas of development. For example, a child that is not able to selectively attend and perceive intermodal information may miss salient cues in his or her environment. In the early years, this may be detrimental to learning social skills or early language abiliites, all critical for a healthy developmental trajectory. Childcare centres and schools will be instrumental in faciltiating the interventions needed to help foster and shape these early skills.

Conclusions and Future Directions

Given psychology's shift towards neuroscience and the advancements in neuroscientific technology, it would be useful to combine and integrate findings with other fields (i.e., biopsychology) examining intermodal processing from a neuroscientific perspective in order to make use of the substantial data collected.

Eye-tracking measures of disengaging and shifting attention and the relationship to intermodal processing abilities in children with ASD must continue to be researched in order to elucidate the connections between them. As noted in the present study, attention *may not* be uniformly impaired in ASD as the results are mixed – particularly when it comes to intermodal processing.

While the findings contribute to the field and offer some food for thought, due to the correlational nature of the present study as well as the small sample size, results are to be approached with caution and causal interpretations cannot be made. Consequently, future research is needed in to order to better understand how selective attention abilities, specifically shifting attention, and intermodal processing impact one another. While more work is needed, this study serves as a first step in developing a deeper understanding of the relationships between intermodal processing and attention.

References

Alli, L. N. (2016). *A multi-method analysis of intersensory perception of social information in children and adolescents with autism spectrum disorder* (Unpublished doctoral dissertation). York University, Toronto, ON.

American Psychiatric Association (2000). *Diagnostic and Statistical Manual of Mental Disorders,* Fourth Edition, Text Revision. Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: Author.

Arterberry, M. E., & Kellman, P. J. (2016). *Development of perception in infancy.* New York: Oxford University Press.

Atkinson, J., & Braddick, O. (2012). Visual attention in the first years: Typical development and developmental disorders. *Developmental Medicine and Child Neurology, 54*, 589-595.

(2000). Intersensory redundancy guides attentional selectivity and perceptual learning in infancy. *Developmental Psychology*, *36*(2), 1-22.

Baranek, G. (1999). Autism during infancy: A restrospective video analysis of sensory-motor and social behaviors at 9-12 months of age. *Journal of Autism and Developmental Disorders, 29*(3), 213-281.

Barenek, G., Woynaroski, T., Nowell, S., Turner-Brown, L., DuBay, M., Crais, E., & Watson, L. (2017). Cascading effects of attention disengagement and sensory seeking on social symptoms in a community sample of infants at-risk for a future diagnosis of autism spectrum disorder. *Developmental Cognitive Neuroscience, 29,* 1-10.

Baron-Cohen, S. (1998). Social and pragmatic deficits in autism: Cognitive or affective? *Journal of Autism and Developmental Disorders, 18,* 379-402.

Bebko, J. M., Weiss, J. A., Demark, J. L., & Gomez, P. (2006). Discrimination of temporal synchrony in intermodal events by children with autism and children with developmental disabilities without autism. *Journal of Child Psychology and Psychiatry, 47*(1), 88-98.

Birmingham, E., Smith, J., & Iarocci, G. (2017). Spontaneous gaze selection and following during naturalistic social interactions in school-aged children and adolescents with autism spectrum disorder. *Canadian Journal of Experimental Psychology, 71*(3), 243-257.

Bodfish, J., Symons, F., Parker, D., et al. (2000). Varieties of repetitive behavior in autism: 181 comparisons to mental retardation. *Journal of Autism and Developmental Disorder, 182* (30), 237-243.

Brock, J., Brown, C. C., Boucher, J., & Rippon, G. (2002). The temporal binding deficit hypothesis of autism. *Development and Psychopathology, 14*, 209-224.

Brooks, R., & Meltzoff, A. (2005). The development of gaze following and its relation to language. *Developmental Science, 8*(6), 535-543.

Chawarska, K., Macari, S., Powell, K., DiNciola, L., & Shic, F. (2016). Enhanced social attention in female infant siblings at risk for autism. *Journal of the American Academy of Child & Adolecsent Psychiatry, 55*(3), 188-195.

Chawarska, K., Macari, S., & Shic, F. (2012). Context modulates attention to social scenes in toddlers with autism. *Journal of Child Psychology and Psychiatry, 53*(8), 903-913.

Chawarska, K., Macari, S., & Shic, F. (2013). Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders. *Biological Psychiatry, 74,* 195-203.

Chita-Tegmark, M. (2016). Attention allocation in ASD: A review and meta-analysis of eye-tracking studies. *Journal of Autism and Developmental Disorders, 3,* 209-223.

Chukoskie, L., Westerfield, M., & Townsend, J. (2017). A novel approach to training attention and gaze in ASD: A feasibility and efficacy pilot study. *Developmental Neurobiology, 78*(5)*,* 546-554.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201-215.

Courchesne, E., Townsend, J., Akshoomoff, N. A., Saitoh, O., Yeung-Courchesne, R., Lincoln, A. J., . . . Lau, L. (1994). Impairment in shifting attention in autistic and cerebellar patients. *Behavioral Neuroscience, 108*(5), 848-865.

Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disabilities, 28*(6), 479-485.

Dawson, G., Toth, K., Abbott, R., Osterling J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting joint attention, and attention to distress. *Developmental Psychology, 40*(2), 271-283.

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioural and electrophysiological studies. *Developmental Neuropsychology, 27,* 403-424.

Durkin, K., & Conti-Ramsden, G. (2007). Language, social behavior, and the quality of friendships in adolescents with and without a history of specific language impairment. *Child Development, 78,* 1441–1457.

Elliott, C. D.;. (2007). *Differential Ability Scales - Second Edition (DAS-II).* San Antonio, TX: Psychological Corporation.

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

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

Falck-Ytter, T., Bolte, S., & Gredeback, G. (2013). Eye tracking in early autism research. *Journal of Neurodevelopmental Disorders, 5*(28), 1-28.

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

Fletcher-Watson, S., Leekam, S., Benson, V., Frank, M., & Findlay, J.M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder. *Neuropsychologia, 47,* 248–257.

Foss-Feig, J. H., Kwayke, L. D., Cascio, C. J., Burnette, C. P., Kadivar, H., Stone, W. L., & Wallace, M. T. (2010). An extended multisensory temporary binding window in autism spectrum disorders. *Experimental Brain Research, 203*(2), 381-389.

Franchini, M., Glaser, B., Wood de Wilse, H., Gentaz, E., Eliez, S., & Schaer, M. (2017). Social orienting and joint attention in preschoolers with autism spectrum disorders. *PLos One, 12*(6), 1-14.

Guillong, Q., Hadjikhani, N., Baduel, S., & Roge, B. (2014). Visual social attention in autism spectrum disorder: Insights from eye tracking studies. *Neuroscience and Biobehavioral Reviews*, *42*, 279-297.

Guthrie, W., Swineford, L. B., Nottke, C., & Wetherby, A. M. (n.d.). Early diagnosis of autism spectrum disorder: Stability and change in clinical diagnosis and symptom presentation. *Journal of Child Psychology and Psychiatry, 54*(5), 582-590.

Hollich, G., Newman, R. S., & Jusczyk, P. W. (2005). Infants' use of synchronized visual information to separate streams of speech. *Child Development, 76,* 598-613.

Iarocci, G., & McDonald, J. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders, 36*(1), 77-90.

Johnson, M. H., Posner, M. I., Rothbart, M. K. (1991). Components of visual orienting in early infancy: contingency learning, anticipatory looking, and disengaging. *Journal of Cognitive Neuroscience, 3,* 335-344.

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2– to 6-month-old infants later diagnosed with autism. *Nature, 504* (7480), 427-31.

Jones, E., Venema, K., Earl, R., Lowy, R., & Webb, S. (2017). Infant social attention: An endophenotype of ASD-related traits? *Journal of Child Pscyhology and Psychiatry, 58*(3), 270-281.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child, 2*, 217-250.

Keehn, B., Muller, R.-A., & Townsend, J. (2013). Atypical attentional networks and the emergence of atuism. *Neuroscience and Biobehavioral Reviews, 37*, 164-183.

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

Kleberg, J., Thorup, E., & Falck-Ytter, T. (2017). Reduced visual disengagement but intact phasic alerting in young children with autism. *Autism Research, 10*(3), 539-545.

Klin, A. (2008). Three things to remember if you are a functional magnetic resonance imaging researcher of face processing in autism spectrum disorders. *Biological Psychiatry, 64,* 549-551.

Klin, A., & Jones, W. (2008). Altered face scanning and impaired recognition of biological motion in a 15-month-old infant with autism. *Developmental Science, 11,* 40-46.

Klin, A., Jones, W., Schultz, R. Volkmar, F. & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59,* 809-816.

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year olds with autism orient to non-social contingencies rather than biological motion. *Nature, 459,* 257-261.

Klin, A., Sparrow, S. S., de Bildt, A., Cicchetti, D. V., Cohen, D. J., & Volkmar, F. R. (1999). A normed study of face recognition in autism and related disorders. *Journal of Autism & Developmental Disorders, 29,* 499-508.

Landry, R., & Bryson, S. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry, 45*(6), 115-1122.

Le Couteur, A., Lord, C. & Rutter, M. (2003). *Autism Diagnostic Interview-Revised.* Los Angeles, CA: Western Psychological Services.

Lewkowicz, D. J. (1986). Developmental changes in infants' bisensory response to synchronous durations. *Infant Behavior & Development, 9*(3), 335-353.

Lickliter, R., Bahrick, L. E., & Honeycutt, H. (2002). Intersensory redundancy facilitates prenatal perceptual learning in bobwhite quail embryos. *Developmental Psychology, 38,* 15-23.

Lickliter, R., Bahrick, L. E., & Honeycutt, H. (2004). Intersensory redundancy enhances memory in bobwhite quail embryos. *Infancy, 5,* 253-269.

Lord, C., Rutter, M., DiLavore, P.C., & Risi, S. (2002). *Autism Diagnostic Observation Schedule: ADOS manual.* Los Angeles, CA: Western Psychological Services.

Marco, E. J., Hinkley, L. B., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in autism: a review of neurophysiologic findings. *Pediatric Research*, *69*, 48R-54R.

McMorris, C. A. (2015). Disengagement, shifting and engagement of attention in children and adolescents with autism spectrum disorder (ASD). (Unpublished doctoral dissertation). York University, Toronto, ON.

Meredith, M. A. (2012). Multisensory convergence: Where it all begins. In B. E. Stein, *The New Handbook of Multisensory Processing* (pp. 3-11). Cambridge, MA: MIT Press Books.

Mundy, P., & Burnette, C. (2005). Joint attention and neurodevelopmental models of autism. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, Vol. 1: Diagnosis, development, neurobiology, and behavior (3rd ed.)* (pp. 650–681). Hoboken, NJ: John Wiley & Sons.

Mundy, P., & Neal, A. R. (2000). Neural plasticity, joint attention, and a transactional social-orienting model of autism. *Mental Retardation and Developmental Disabilities Research Reviews, 23*, 139-168.

Oram Cardy, J. E., Flagg, E. J., Roberts, W., & Roberts, T. P. (2008). Auditory evoked fields predict language ability and impairments in children. *International Journal of Psychophysiology, 68,* 170-175.

Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism and Developmental Disorders, 24*, 247-257.

Patten, E., Watson, L. R., & Baranek, G. T. (2014). Temporal synchrony detection and associations with language in young children with ASD. *Autism Research and Treatment*, *2014*, *44*(10), 2413-2428.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, *32*(4), 249-261.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Posner, M. I. (1982). Cumulative development of attentional theory. *American Psychology, 32*, 53-64.

Posner, M. I. (1988). Structures and functions of selective attention. In T. Boll, & B. K. Bryant, *Clinical neuropsychology and brain function: Research, measurement, and practice* (pp. 169-202). New York, NY:American Psychological Association.

Posner, M. I. (2012). *Attention in a social world.* New York: Oxford University Press.

Posner, M., & Rothbart, M. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58,* 1-23.

Righi, G., Tenenbaum, E., McCormick, C., Blossom, M., Amso, D., & Sheinkopf, S. (2018). Sensitivity to audio-visual synchrony and its relation to language abilities in children with and without ASD. *Autism Research, 11*, 645-653.

Rueda, M., Posner, M., & Rothbart, M. (2005) The development of executive attention: Contributions to the emergence of self-regulation, *Developmental Neuropsychology, 28* (2), 573-594.

Rutter, M., Bailey, A., & Lord, C. (2003). *The social communication questionnaire: Manual*. Western Psychological Services.

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

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

Semel, E., Wiig, E., & Secord, W. (2000). Clinical Evaluation of Language Fundamentals (3rd UK edn). London: Harcourt.

Soskey, L., Allen, P., & Bennetto, L. (2017). Auditory spatial attention to speech and complex non-speech sounds in children with autism spectrum disorder. *Autism Research, 10*, 1405-1416.

Suarez, M. (2016). Senosry processing in children with autism spectrum disorders and impact on functioning. *Pediatric Clinics of North America, 59*(1), 203-214.

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., Rees, L., & Wheelright, S. (1998). The frequency and distribution of spontaneous attention shifts between social and nonsocial stimuli in autistic, typically developing, and nonautistic developmentally delayed infants. *Journal of Child Psychology and Psychiatry, 39*(5), 747-53.

Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and communication in autism. In F. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), Handbook of autism and pervasive developmental disorders (3rd ed., pp. 335–364). New York: Wiley.

Thye, M., Bednarz, H., Herringshaw, A., Goodman, E., & Kana, R. (2017). The impact of atypical sensory processing on social impairments in autism spectrum disorder. *Developmental Cognitive Neuroscience, 29*, 151-167.

Toplak M., West, R., & Stanovich, K. (2013). Practitioner review: Do performance-based measures and rating of executive function assess the same construct? *Journal of Child Psychology and Psychiatry*, *54,* 131-143.

Unruh, K., Sasson, N., Shafer, R., Whitten, A., Miller, S., Turner-Brown, L., & Bodfish, J. (2016). Social orienting and the attention is influences by the presense of competing nonsocial information in adolescents with autism. *Frontiers in Neuroscience*, *10,* 1-12.

Volkmar, F. (2016). From infantile autism to autism spectrum: Evolution of the diagnostic concept. In C. J. McDougle, *Primer on autism spectrum disorder* (pp. 1-18). USA: Oxford University Press.

Volkmar, F. R., Rogers, S. J., Paul, R., & Pelphrey, K. A. (2014). *Handbook of autism and pervasive developmental disorders (4th Ed.)* (Vol. 1). Hoboken, NJ: John Wiley & Sons.

Werling D., & Geschwing, D. (2013). Sex differences in autism spectrum disorders. *Current Opinion in Neurology, 26,* 146–153.

Wertheimer, M. (1961). Psychomotor coordination of auditory and visual space at birth. *Science*, *134*(3491), 1692.

Zwaigenbaum, L., Bryson, S. E., Rogers, T. S., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neurosciences, 23,* 143-152.

APPENDICES

Appendix A
Informed Consent for TD Parents 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 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
Doctoral Candidate
Psychology Department

Lisa Hancock
Doctoral Candidate
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* <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 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 Doctoral Candidate	Lisa Hancock 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)