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Gaze Patterns of Social and Nonsocial Stimuli: A Possible Early Marker for Autism Spectrum Disorder

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Gaze Patterns of Social and Nonsocial Stimuli:
A Possible Early Marker for
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Abstract

The push for early identification and diagnosis of Autism Spectrum Disorder (ASD) has led to new developments in this area of research. Eye tracking is a promising behavioral screening measure that has been heavily investigated for over a decade. Differences in eye gaze between typically developing (TD) children and children with ASD when viewing social and nonsocial videos have been observed, but only within videos of children playing as social stimuli and with geometric shapes as nonsocial stimuli (Pierce et al., 2016; Shaffer et al., 2017). In addition to social stimuli and geometric shapes, the current study expanded on previous research by including nonsocial inverted and blurred videos as stimuli. Participants were 15 TD children, ages 8 months to 5 years, and two children with ASD, ages 3 months and 3 years old. Each child was observed through a Tobii eye tracking system as they watched eight consecutive 10 second videos with video clips alternating between social and nonsocial conditions (geometric, inverted, or blurred). The two children with ASD looked for a similar amount of time and with a similar number of saccades for each video type; the same was also true within the TD children condition. The absence of a difference in looking time and saccade number calls into question what really accounted for the difference in gaze patterns found in the previous research. Further examination into the use of eye tracking as a screening measure must be conducted before a fully implementable measure is established.

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CHAPTER I

INTRODUCTION

The term "Autism" was first used by Leo Kanner in 1943, when he considered several cases of children with peculiar behaviors that differed from any other mental health disorder (Kanner, 1943). In the 1960's and 70's, Autism Spectrum Disorder (ASD) was thought to be an uncommon condition with an estimated prevalence of 5 in every 10,000 children (Christensen et al., 2012). It is apparent that ASD is no longer a rare disorder. Baio et al. (2014) reported that ASD is a highly prevalent disorder at a rate of 1 in 59 children diagnosed across the United States.

ASD is a disorder characterized by deficits in multiple areas of functioning including social skills, communication, and emotional regulation (Christensen et al., 2012; Elder, Kreider, Brasher, & Ansell, 2017; Shaffer et al., 2017). Current methods of diagnosis are only based on the presence of ASD symptoms. In order to find more objective methods of diagnosis, it is necessary to identify a behavioral measure of assessment (Elder et al., 2017).

To identify behavioral aspects of ASD, previous researchers have looked into joint attention (JA) and Theory of Mind (ToM) differences within children with ASD. JA is a rudimentary eye contact behavior that is typical of young children to share visual attention with another individual to an object or event. Lack of JA skills has been observed as a possible early symptom of ASD (Mundy & Crownson, 1997; Corkum & Moore, 1998; Neimy, Pelaez, Carrow, & Monlux, 2017). Theory of Mind is another area of social communication that is deficient in children with ASD. ToM describes the ability to understand thoughts, feelings, and intentions of oneself and others. Individuals with ASD are deficient in understanding the intentions, emotions, perspectives of other individuals (Hutchins & Prelock, 2008). ToM and JA deficits are characteristic of individuals with ASD.

Emphasis in JA and ToM research has led to the use of eye tracking procedures. Eye tracking is a possible objective measure for early diagnosis of ASD (Chita-Tegmark, 2016; Frazier, Klingemeir, & Beukemann, 2016). In previous research, participants are typically shown social videos of children moving around and playing as well as nonsocial videos that consist of geometric shapes floating around (Chawarska, Macari, & Shic, 2013; Franchini et al. (2016); Pierce, Conant, Hazin, Stoner, & Desmond, 2011; Pierce et al., 2016; Sekigawa-Hosozawa, Tanaka, Shimizu, Nakano, and Kitazawa, 2017; & Shaffer et al., 2017). Within these studies, the children with ASD have been found to prefer the geometric videos while the typically developing (TD) children have preferred the social videos. There are multiple possible confounding variables that could be attributing to the preference displayed by each group that this study attempted to control for. The current study included four different videos: geometric, social, inverted, and blurred.

The social video was altered to the inverted or blurred state to control for confounding variables and narrow down specifically what the children with ASD preferred in the previous research. The inverted video aligned with the "inversion effect" proposed by Yin in 1969. Featural and configural processing differences as defined by Bombari, Mast, & Lobmaier (2009) were controlled for in the blurred condition.

There were fifteen TD children and two children with ASD that participated in the current study. The Vineland Adaptive Behavior Rating Scales-Third Edition (Vineland-3; Sparrow, Cicchetti, & Saulnier, 2016) Parent/Caregiver form was administered to each child in order to gain an understanding of the general adaptive behavior skills that each child had achieved. Age was found to be similar across conditions and the Vineland-3 scores were consistent with what was expected for TD children and children with ASD.

The current study was conducted to add to the previous literature and to control for possible confounding variables that were present in the previous literature. Before reporting the results of the current study, there will be further examination of the topic of eye tracking. In the following literature review, there will be further exploration of the etiology and symptoms of ASD. The basis behind eye tracking research and theories that support the current study will also be explained in detail.

CHAPTER II

LITERATURE REVIEW

Autism Spectrum Disorder (ASD) is characterized by social, emotional, and communication impairments (Baio et al., 2014; Elder et al., 2017; Shaffer et al., 2017). The Autism and Developmental Disabilities Monitoring (ADDM) Network found that ASD occurs in one out of every 59 eight-year-old children within the United States (Baio et al., 2014). Within this ratio, the disorder is more common in males than females with a ratio of four to one. The ratio of boys to girls that are diagnosed with ASD has been stable since the ADDM Network began tracking ASD in 1998. Throughout the 1960's and 70's, ASD was thought to be an uncommon condition with an estimated prevalence of five in every 10,000 children (Christensen et al., 2012). It is apparent that ASD is no longer a rare disorder.

The Etiology of Autism Spectrum Disorder

The term "Autism", a Latin word meaning "self", was first used by Leo Kanner in 1943 when he observed 11 children who had symptoms that did not align with other diagnoses of his time (Kanner, 1943). Just one year later, in Austria, Hans Asperger identified a similar condition but with higher functioning individuals. The two had similar descriptions of the disorder and even used the same term, "Autism" (Boucher, 2009). Considering the language barrier, Kanner's paper was the most influential in the English-speaking countries, while Asperger's paper was popular in parts of Europe for 40 years after their initial findings. When Autism Spectrum Disorder was first identified, various groups of professionals attempted to explain the disorder in their own terms

(Boucher, 2009). Unfortunately, these descriptions of the disorder strayed from Kanner's original explanation. The psychoanalytical side insisted that ASD was a neurotic condition caused by a "disturbed mother-child relationship" (Boucher, 2009). The term "refrigerator mothers" was given to mothers of children diagnosed with ASD to blame them for supposed cold parenting style with lack of warmth for their child that caused their child's mental illness. Another proposed explanation for the disorder through the eyes of medical professionals claimed that ASD was a form of psychosis with a biological cause (Boucher, 2009). Based on this explanation, ASD was often referred to as childhood schizophrenia or childhood psychosis. After about 40 years, the inaccurate descriptions began to more closely reflect Kanner's original explanation. Today, Autism Spectrum Disorder is now believed to be a developmental disorder with genetic factors (Haney, 2013).

Autism Spectrum Disorder was first observed as a mental disorder in the 3rd revision of the Diagnostic and Statistical Manual of Mental Disorders in 1980 (Boucher, 2009). In 1981, Asperger's writings were translated into English and awareness of a higher-functioning type of ASD began to spread as well. The emergence of Asperger's paper in the English-speaking world led to greater reflection on the spectrum of different types of ASD.

The writing of Hans Asperger led the developers of the DSM-IV to reflect a more profound spectrum of possible ASD diagnoses within the group of Pervasive Developmental Disorders. The DSM-IV included major disorders that related to ASD, which were: Autistic disorder, Asperger disorder, and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS). Autistic disorder included social impairments, communication impairments, and restricted and repetitive interests and behaviors.

Asperger syndrome included similar aspects to an Autistic disorder diagnosis, except the individual developed language at the same rate as their typically developing peers. PDD-NOS meant that the individual was somewhere in between Autistic disorder and Asperger syndrome. The individual did not meet all the criterion for Autistic disorder, but their language skills were not advanced enough to meet criteria for Asperger syndrome.

Current Understanding

Today, the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) combines the previous three categories into what is now called Autism Spectrum Disorder. The criteria consist of two main defining symptoms: "persistent impairment in reciprocal social communication and social interactions" and "restricted, repetitive patterns of behavior, interests, or activities" (American Psychological Association, 2013). The symptoms must be evident in early childhood and have an impact on functioning in daily life. Current diagnosis is based on the presence of these symptoms; there is no identified objective method of evaluation (Elder et al., 2017).

Autism Spectrum Disorder is not seen as a homogenous disorder; there are varying levels of severity with each individual having varying abilities and preferences. The DSM-5 classifies the severity of disorder as three levels: Level 3 "requiring very substantial support, Level 2 "requiring substantial support", and Level 1 "requiring support".

An individual with a Level 3 label very limited function of verbal and nonverbal social communication skills which impacts the individual's ability to initiate and sustain conversation unless directly approached and prompted. In regard to the repetitive and restricted behaviors, individuals at this level are inflexible in their behaviors and have an extreme dislike of change of actions or routines.

Level 2 is described as the individual having less severe than Level 3 social communication deficits where they have limited verbal and nonverbal communication skills and their topics of discussion are limited to special interests of the individual. Within Level 2, the individual has marked difficulty with changes in actions and routines. The restricted, repetitive behaviors are also observable and interfere with functioning.

Level 1 is determined by the child having minimal interest in social interactions and noticeable deficits in social communication. At this level, individuals may seem odd to peers, and the forming of friendships is difficult. Within Level 1, the individual also has a difficult time changing between activities and has a deficit in planning and organizational skills.

Since 2002, the percentage of children diagnosed with ASD who also comorbidly qualified as having an Intellectual Disability (ID), an IQ of less than 70 and deficits in adaptive behavior skills, has decreased from one half to one third of the population of children diagnosed with ASD (Baio et al., 2014). The decrease of individuals diagnosed with ASD and comorbidly diagnosed with ID means that the identification of high functioning individuals with ASD has increased. Just as there is a spectrum of social communication deficits and rigidity of repetitive behaviors, there is a spectrum of intellectual functioning among individuals diagnosed with ASD. Individuals with Autism Spectrum Disorder may have anywhere from an extremely low to an average or above average IQ.

Special cases of extreme areas of genius have been found. Savant syndrome has been observed in one out of every ten individuals diagnosed with ASD (Treffert, 2014). Savant syndrome is a condition in which an individual has a specific area of genius. Some common areas of genius for individuals with Savant syndrome are “music, art, calendar calculating, mathematics, or mechanical/visual-spatial skills" (Treffort, 2014). Autism Spectrum Disorder is not a homogeneous disorder; there are varying levels of functioning within social communication and repetitive behaviors as well as differing intellectual abilities.

The percentage of children diagnosed with ASD and comorbidly diagnosed with ID is not the only statistic that changed during the 2014 ADDM Network review. As previously stated, ASD now has a prevalence of 1 in 59: which increased from the 2012 estimate of 1 in 68 and vastly increased from the 2002 estimate of 1 in 150 (Baio et al., 2014). There are reasons of why such a dramatic ascent in cases of ASD has occurred; the first, is the changing of diagnostic criteria. The DSM-III required stricter criteria for the diagnosis of ASD where the DSM-IV provided a wider range of ASD criteria (Haney, 2013). Increased awareness through campaigns of different organizations and the expansion of "child find" requirements of the 1997 revision of Individuals with Disabilities Education Act have also contributed to the rise in numbers. In addition to different criteria and more awareness, diagnostic tools have also become more efficient and reliable. Screening measures that were not as effective in the early 2000s now have the ability to identify children more accurately and at a younger age (Boucher, 2009).

Now that ASD has been identified and observed as a mental illness by the Diagnostic and Statistical Manual of Mental Disorders, researchers have set out to find the underlying causes of ASD. To investigate the differences between typically developing (TD) individuals and those diagnosed with ASD, researchers have begun to look for characteristics that are similar across individuals with Autism Spectrum Disorder. Two areas that have consistently been deficient for individuals with ASD are joint attention (JA) and Theory of Mind (ToM). JA is a rudimentary eye contact behavior that is lacking in individuals with ASD (Mundy & Crowson, 1997; Neimy et al., 2017). ToM differences align with the social and communication impairments that are associated with ASD (Baron-Cohen, Leslie, & Frith, 1985). Deficiencies in ToM and JA have led researchers to the use of eye tracking in ASD research. Eye tracking has the possibility of becoming a future early childhood mental health screener (Itti, 2015).

Social and Communication Differences

Profound developmental skills that involve social-emotional reciprocity have been observed to be deficient or different among individuals with ASD when compared to their typically developing (TD) peers or individuals with other disorders. In one of her books, Dr. Temple Grandin describes her struggle as a high school student:

> My big problems came in high school. That was my terrible time. Once kids started moving through puberty into adolescence, they are no longer interested in sails and kites and bike races and board games. Attention and interest turns to all things social emotional. For me, that spelled disaster. (Grandin & Barron, 2016, pp. 24)

One of the first nonverbal social communication behaviors that is displayed by a typically developing child is joint attention (JA), which starts to develop prior to the infants first birthday (Neimy et al., 2017) and is fully developed around 18 months of age (Boucher, 2009). Theory of Mind (ToM) then develops, which is a more advanced social communication skill that involves understanding the intentionality of another individual. ToM typically starts to develop around the 9th month of life and is fully developed before the age of five (Peterson, Wellman, & Liu, 2005). Both of these early social communication skills are essential to later development and are deficient or different among individuals diagnosed with ASD.

Discrepancies in Joint Attention (JA)

Joint attention skill level accounts for the discrimination of 80-90% of individuals with ASD from other developmental delays (Mundy & Crowson, 1997). "In infancy, JA to objects and events in the world provides the initial means whereby the child can share experiences with others and negotiate shared meanings" (Corkum & Moore, 1997). Joint attention is a rudimentary eye contact behavior that develops within the first year of life, but individuals with ASD have been observed to have difficulties with this skill (Neimy et al., 2017).

Prior to their first birthday, an infant will follow the gaze of others to find meaning within a situation. Most importantly, the infant will attempt to gain the attention of another and share an experience of a gaze (Tomasello & Carpenter, 2007). For instance, a child may want a toy that is out of their reach. The child may look at one's mother, then the toy, as if to say, "I want that toy". The mother may then grab the toy for the child. For joint attention to be effective, both parties must know that this sort of communication is occurring. The child must initiate attention, and the other party must notice this and participate.

To investigate JA in typically developing children Vaughen Van Heck et al. (2007) looked at differences in JA skills in 12-month-old infants to see if the early skills would later influence social behavior competence at 30 months. There was a difference found between the levels of JA skills and later social outcomes. They also stated that the difference in social competence could be observed in atypically developing infants as well. Joint attention skills do lead to a difference in social behavior competence later in development (Vaughen Van Heck et al., 2007; Neimy et al., 2017).

In addition to social behavior developing differently, the child's language skill development has been found to be impeded by a lack of JA in infancy (Baron-Cohen, Baldwin, & Crowson, 1997). It was investigated whether children with ASD used a "Speaker's Direction of Gaze (SDG)" strategy or a "Listener's Direction of Gaze (LDG) strategy" (Baron-Cohen et al., 1997); the SDG strategy is similar to joint attention abilities. If a child were using the SDG strategy, then when caregivers say a novel word, the child will shift one's attention to the object that the speaker is observing. For instance, if the caregiver said, "cup" and gaze directed at a cup, the child would then look at the cup and mentally note that the word "cup" means that object. For infants using the LDG strategy, they do not shift their gaze, but instead, relate the novel word to the object they are interested in at the time. In other words, instead of looking at the cup like the caregiver has directed, the child will continue to look at the object that the child is fixated on and incorrectly code that the object is a cup.

The research of Baron-Cohen et al. (1997) found that children diagnosed with ASD with a mean age of nine years and two months and a cognitive ability age of around two used the LDG strategy, while the other group of children of similar cognitive ability age with intellectual disabilities and no diagnosis of ASD preferred the SDG strategy. A second experiment was conducted with TD children whose ages matched the mental ages of the ASD group. This experiment found the same results where the TD children used the SDG strategy. The authors describe that using the LDG strategy can lead to deficits in vocabulary development and more error before learning correct names of objects. In order for the infant to engage in a shared topic, the infant must develop skills in joint attention (Baron-Cohen et al., 1997).

Fortunately, if caught early enough, delayed social development and JA can be improved. Koegal, Singh, Koegel, Hollingsworth, and Bradshaw (2014) identified three infants at four, seven, and nine months who demonstrated early social deficits that were associated with ASD. Pivotal Response Treatment (PRT) was used to assist in improving happiness and interest, eye contact, and the child's response to their own name. PRT is a play-based behavioral intervention that is used to improve social skills, communication, and behavior. PRT emphasizes the use of natural reinforcement procedures. For instance, if the child wants a toy that is out of reach and appropriately asks for help with reaching it, then the caregiver or interventionist provides natural reinforcement by giving the child the toy. From baseline sessions through intervention, all three areas improved for all three of the children.

Joint attention is a rudimentary eye contact behavior that is observable in children prior to their first birthday (Tomasello & Carpenter, 2007). The skill is highly associated with symptoms of ASD in early development (Mundy & Crowson, 1997) and has an impact on future social behavioral functioning (Colombi et al., 2009; Vaughen Van Heck et al., 2007). Fortunately, there are ways to improve the skill if identified early (Koegal et al., 2014). Eye tracking has great potential as a method of early identification because the child does not need any verbal or motor skills, one just need to watch a screen.

Theory of Mind (ToM)

Research has also focused on Theory of Mind (ToM) in relation to ASD. ToM means that, "the individual imputes mental states to himself and to others" (Premack & Woodruff, 1978). In broad terms, ToM describes the ability to understand thoughts, feelings, and intentions of self and others. This includes constructs such as desire and intention, affect recognition and causes of emotion, visual perspective taking, empathy, moral reasoning, distinguishing between lies and jokes, and metaphorical uses of language (Hutchins & Prelock, 2008). Peterson et al. (2005) found that ToM in typically developing (TD) children is often developed prior to the age of five. Individuals with ASD tend to be deficient in these areas of thinking throughout their life.

A prime example of a ToM deficit was seen in Baron-Cohen et al. (1985). Their experiment consisted of TD four- and five-year-old children, ten- and eleven-year-old children diagnosed with Down's syndrome, and eleven-year-old children diagnosed with ASD. The scenario illustrated two dolls, Sally and Anne, playing with a marble. Sally placed the marble in her basket, then left. While Sally was gone, Anne moved the marble to her basket. When Sally came back, the child was asked where Sally would first look for the marble. The TD children and children with Down's syndrome said that Sally would first look in her box because that is where the marble was before she left. Children with ASD replied that Sally would look in Anne's box because that is where the marble ended up being. They did not account for Sally not knowing that the marble moved. The marble example describes how children with ASD lack the understanding of another person's thinking. It can also explain the difficulty that individuals with ASD have with understanding social cues that others display such as affect and empathy. ToM describes an area of social communication that is difficult for individuals with ASD.

The development of ToM is essential for the development of social cognition within young children (Happé & Frith, 2013; Mazza et al., 2017). Mazza et al. (2017) investigated the social information processing differences in five- to thirteen-year-old TD children and children diagnosed with ASD. They utilized two measures of social cognition: Social Information Processing Interview (SIPI) and the Comic Strip Task. The SIPI involved reading a series of vignettes to the child and scoring them based on competence in composing an answer on the intentions of others within the vignette and construction of a response to each situation. The Comic Strip Task involves reading a comic strip about an everyday social situation and then evaluating the beliefs, intentions, and emotions of characters within the comic strip.

Within the SIPI, Mazza et al. (2017) found that the children in the ASD group had more trouble than TD children in repeating the story back to the narrator, which means they had difficulty taking in the social situation. They also struggled with forming a response of what they would do in the specified situation and evaluating whether what the character in the story did was right or wrong. Within the Comic Strip Task, the children with ASD struggled more than TD children in describing the characters beliefs and emotions for the comic strip. These skills are related to ToM because the child is supposed to think like the person in the story. This study did not directly represent the formation of social cognition but provides examples of how individuals ages five to thirteen with ASD take in social information differently than TD children who have developed ToM.

Joint attention (JA) allows the infant to socially share experiences with another individual. Joint attention and eye contact differences have led to eye tracking research to identify a possible objective measure of early diagnosis. Theory of Mind and joint attention form the basis of eye tracking research as they describe the observable social interaction difference between the child and parent. Deficiencies in ToM and JA have led researchers to the use of eye tracking in ASD research. Eye tracking has the possibility of becoming a future early childhood mental health screener (Itti, 2015).

Repetitive Patterns of Behavior, Interests, and Activities

In addition to social and communication differences, individuals with ASD also display restricted and repetitive patterns of behavior, interest, and activities. These types of behaviors are typically the first symptom observed by caregivers (Haney, 2013) and persist into adulthood (Crane, Goddard, & Pring, 2009). Bryson et al. (2007) observed multiple different types of patterns of behaviors and interests in six-month-old infants until they were diagnosed with ASD. They observed behaviors and interests included: looking at hands, distress when water is running, hand flapping, interest in the vacuum cleaner, and specific food preferences. Tactile preferences, such as types of fabric and the feeling of skin products like lotion, can also be present in an individual with ASD (Thompson, 2009).

The need for rituals and resistance to change in situations is also related to ASD. Thompson (2009) describes a child at Thanksgiving dinner whose grandmother made a chocolate cake just for him. The child refrained from eating the cake and became upset until the grandmother realized that she put the cake on the wrong colored plate. The need for "sameness" is often used in the literature to describe the individual's need for rituals and resistance to change. Other types of rituals that may be present in a child with ASD could be collection or hoarding of objects, lining up or creating a pattern of objects, or repetitive verbal rituals (Thompson, 2009).

Some of the preferences that children with ASD develop are based on a fear or phobia. Children with ASD have a higher number of fears than TD children and children diagnosed with Downs Syndrome (Evans, Canavera, Kleinpeter, Maccubbin, & Taga, 2005). Whether the need for rituals and preferences is developed through fears or just personal preference, children with ASD typically enjoy "sameness" in their daily lives.

Benefits of Early Identification

Despite advances over the past two decades in the identification and awareness of Autism Spectrum Disorder the mean age of diagnosis of 53 months (four years, five months) has remained stable since the ADDM Network began tracking ASD in 1998 (Baio et al., 2014). "ASD is an urgent public health concern that could benefit from enhanced strategies to help identify ASD earlier; to determine possible risk factors; and to address the growing behavioral, education, residential, and occupational needs of this population" (Baio et al., 2014).

Benefits for the Child

As noted earlier, deficits in joint attention and Theory of Mind abilities effect the child's ability to develop social behavioral and communication competence (Colombi et al., 2009; Happé & Frith, 2013; Mazza et al., 2017; Vaughen Van Heck et al., 2007). Early diagnosis and intervention provide social, communication, and behavioral benefits for the child (Elder et al., 2017; Keogel, 2000; Koegel et al., 2014; Leekam, Nieto, Libby, Wing, Gould, 2007; Lovaas, 1985). Lovaas (1985) was one of the first individuals to devise an effective intervention for individuals with ASD that allowed 47% of the treatment group participants to achieve typical developmental and educational functioning. The intervention was intensive at 40 hours per week for two years and consisted of reducing self-stimulatory behaviors and noncompliance, teaching imitation of caregivers and teachers, increasing engagement in play with peers, and development of expressive language. Lovaas' therapy was groundbreaking in that it was more effective than other therapies at the time that lacked maintenance and generalization of abilities.

Since the days of Lovaas, numerous other intervention strategies have been found effective. Koegel (2000) stated that children who receive intervention prior to the age of five have a large probability of using language as their primary mode of communication rather than augmentative and alternative forms of communication. They also found that communication interventions early in life provide the individual with skills to effectively monitor and regulate behavior as well as develop communicative and social competence.

Cohen, Dickens, and Smith (2006) also found promising results for children under 48 months from early intervention using early intensive behavioral treatment (EIBT) 35-40 hours per week for three years. The comparison, control group received a less intensive intervention. The children in the intervention group gained an average of 25 IQ points compared to the control group with a mean gain of 14 points. Both groups made gains in IQ score with the early intervention, and more intense intervention made more improvement. Early intervention is clearly beneficial for the child by improving their social behavior and communication competence.

Benefits for the Family

Past research has also indicated that early identification of ASD is beneficial for the interactions between the parent and child. Evidence exists that parents of children with ASD experience more stress than parents of typically developing (TD) children and parents of children with any other disorder (Hayes & Watson, 2013). Folkman and Lazarus (1985) described that stress occurs when a family has trouble restoring functioning after the occurrence of a stressor, such as a difficult behavior or tantrum. When the parents have not learned proper coping mechanisms, the family has trouble moving on from difficult situations. The increased amount of stress makes it difficult for the family to effectively cope with future situations. Early identification of ASD allows for improved outcomes for the individual and their parents because appropriate stress coping mechanism can be taught (Elder et al. 2017; Suma, Adamson, Bakeman, Robins, & Abrams, 2016; Zwaigenbaum et al., 2015). When appropriate coping mechanisms are taught, stress may be reduced through improved interactions between the child and parent.

Ziv, Hadad, and Khateeb (2013) studied the social information processing patterns of TD children and children with ASD. They found that children with ASD encoded, interpreted, and produced a response that was not consistent with the social interaction. Children with ASD would often perceive a situation as threatening when no evidence supported this perception. When interventions are implemented prior to age four, there are improvements in cognitive skills, language, and adaptive behavior compared to those that begin interventions after that age (Elder et al., 2017).

Clearly, early intervention is beneficial for the child and their families, but current diagnosis does not occur until the child is about 53 months old (Baio et al., 2014). Identification of symptoms can occur early on. Typically, 80% of parents identify a discrepancy between typical and achieved developmental milestones in their child before the age of two (Chawarska et al., 2013). Identification is critical because early intervention provides social, communication, and behavioral benefits for the child (Elder et al., 2017; Keogel, 2000; Koegel et al., 2014; Leekam et al., 2007; Lovaas, 1985). In addition, parents of children receiving a greater number of intervention hours for ASD reported higher quality parent-child interactions (Suma et al., 2016).

Current Screening Methods

Early identification is clearly optimal, but current methods of initial identification are based on parental reports of their child's behavior. Common screening measures are the Modified Checklist of Autism in Toddlers (M-CHAT; Robins, Fein, & Barton, 2009) and Screening Tool for Autism in Two-Year-Old's (STAT; Stone, McMahon, & Henderson, 2008). The M-CHAT is a 23 item "yes" or "no" questionnaire that is used to identify ASD in 16- to 30-month-old children. Various skills it assesses are language, social skills, and joint attention. The STAT is a 12-item measure that is used to screen for ASD in children ages 24 to 36 months. It involves activities that assess communication, play, requesting behaviors, and joint attention. Both of these screening measures are quick to administer, less than 20 minutes, and have a goal of identifying ASD in toddlers by looking at similar domains of language, social abilities, and joint attention. The issue is that both of these screening tools rely on parental report of behavior and do not identify issues until the child is already developmentally behind TD peers.

Having screening tools that are solely based on parental report of their child's behavior can be unreliable and lead to under or over-identification of ASD based on the screening measure. Zwaigenbaum et al. (2005) noted that parental report is vulnerable to incorrect memory recall, distortion of events, and memory bias. Karp, Ibañez, Warren, and Stone (2017) found parental report was sensitive to the parent's stress level and mood. Parents who were more stressed tended to express less concern for their child's well-being, leading to under-identification of those children. Conversely, some parents with higher well-being scores over-identified their child with developmental issues. These studies are prime examples of how parental report can be inconsistent. They provide further evidence that an objective behavioral screening measure for ASD is needed. Identifying screening methods that do not rely solely on parental report of behavior, requires investigators to look into the biological and neurocognitive discrepancies between TD children and children with ASD (Kylliäinen, Jones, Gomot, Warreyn, & Ytter, 2014).

An Alternative to Current Screening Methods

Camarata (2014) discussed how the current methods of screening are insufficient in accurately identifying ASD in children under the age of five. He noted this is partly due to toddlers displaying ASD symptoms (e.g., repetitive hand motions) as part of their typical development stages. Common current screening measures, such as the STAT and M-CHAT, also only assess unmet developmental milestones after the child is already behind their TD peers. Taylor, Mayberry, and Whitehouse (2014) expanded on the writings of Camarata (2014) stating a solution to this problem is the identification of biomarkers in children with ASD because these indicators are more reliable and accurate than current methods.

Taylor et al. described various methods of research that have the potential to confirm neurocognitive symptoms of ASD. One type of research described was a large-scale longitudinal study that compared high-risk (infants with an older sibling diagnosed with ASD) to low-risk infants when shown pictures of faces versus objects. The high-risk infants typically responded more quickly to the objects than faces, which was conversely true for the low-risk infants (McCleery, Akshoomoff, Dobkins, & Carver, 2009). Another longitudinal study looked at differences in gaze shifting between high- and low-risk infants when viewing still images compared to dynamic videos (Elsabbagh et al. 2012) and found the gaze pattern of an infant to be a predictor of later diagnosis of

ASD. Although strong support exists for a gaze difference in infants that are later diagnosed with ASD, there is insufficient research to support clinical utility of the findings.

Since early identification has been shown to improve outcomes for individuals with ASD, it is becoming a prominent motivation in ASD research. The discovery of implementable measures is an area of high public health priority (Pierce et al., 2011). To identify a measure, investigators have looked at neurological discrepancies between TD children and children with ASD, applying these ideas as a basis for eye tracking.

Symptoms of ASD are often observed in the child's first two years of life (Chawarska et al. 2013), but there is a large gap between observation of the first symptoms and official diagnosis at about 53 months old (Baio et al., 2014). This is largely due to screening measures relying on observing deficits after a delay in development is present. A proactive approach to the identification of ASD is necessary. Eye tracking simply requires that the child observe a screen. Since there is no need for language or gross motor abilities, eye tracking can be used to assess suspected ASD in children early in their development.

Previous Eye-Tracking Research

Eye tracking is influencing the future of mental health screening (Itti, 2015). Eye tracking has the possibility of becoming a future objective behavioral measure of ASD (Chita-Tegmark, 2016; Frazier et al., 2016). The use of eye tracking in ASD research has become common in recent years (Chawarska et al., 2013; Franchini et al., 2016; Franzier, 2016; Nakano et al., 2017; Nele, Ellen, Petra, & Herbert, 2015; Pierce et al., 2011; Pierce et al., 2016; Rice, Moriuchi, Jones, & Klin, 2012; Sassoon & Touchstone, 2013; Sekigawa-Hosozawa, 2017; & Shaffer et al., 2016). A common method in the previous research of assessing gaze preferences in children with ASD has been to present the children with geometric versus social stimuli.

Geometric as Nonsocial Versus Social Stimuli

In most previous research, social stimuli have been videos of children playing or doing activities, while the nonsocial videos contain geometric shapes moving around. Children diagnosed with ASD showed a significant preference for geometric images over social images (Pierce et al., 2016). Pierce et al. (2011) and Pierce et al. (2016) used the number of saccades as a measurement of preference. A saccade is a quick change in fixation points. When a participant produces fewer saccades, it means one is fixated on certain parts of the video or image for a longer portion of time. When viewing the geometric images, children with ASD produced fewer saccades than any other condition (Peirce et al., 2011; Peirce et al., 2016).

Sekigawa-Hosozawa et al. (2017) examined very preterm infants (a gestational period of 28 weeks or less) and their risk for social difficulties later in life compared to TD children and children with ASD. They found that some of the infants viewed the social situations more than others. The one's who avoided the social situations had gaze patterns consistent with ASD, while the infants who attended to the social stimuli had TD gaze patterns. The majority of infants who averted their eyes to the social situations were later diagnosed with ASD.

Chawarska et al. (2013) observed that six-month-old infants later diagnosed with ASD showed a preference in gaze for the nonsocial images. This was observed to be conversely true for low-risk infants. Shaffer et al. (2017) used the Tobii eye tracker to compare total looking times of social and geometric stimuli for TD children and individuals with ASD. They used a large age span of five to seventeen years. This study was based on the findings of Chita-Tegmark (2016) where they found that gaze preference was maintained throughout life. It was observed that individuals with ASD preferred the nonsocial stimuli across age groups. Kylliäinen et al. (2014) stated limited research exists with preschool children for eye-tracking studies; most of the studies use school-aged and adolescent participants. The current study attempted to replicate the findings of Shaffer et al. (2017) using a smaller age range and younger participants.

Previous research most commonly investigated gaze preference by presenting social and nonsocial stimuli (Franchini et al., 2016; Peirce et al., 2011; Peirce et al., 2016; Shaffer et al., 2017). Franchini et al. (2016) found that TD children also showed an inclination for biological motion slides. Peirce et al. (2011) and Peirce et al. (2016) discovered that individuals with ASD attended to the geometric images more than the social images. This inclination was observed in participants through adulthood (Nakano et al., 2017) and in individuals as young as one year of age (Peirce et al., 2011; Peirce et al., 2016). The current study expanded on this finding by included participants as young as five-months-old.

The former research has typically defined social as children playing and doing activities while the nonsocial is the geometric shapes floating around with a dark background. There are multiple confounding variables within the videos that may account for the preferences such as color, contrast, and number of objects on the screen. To further investigate the specific social aspects of static images and dynamic videos when viewed through eye tracking software, the current study attempted to find a more precise explanation of why there is a preference between the two videos. This was done by changing parts of the videos to narrow down the parts of the "social" videos that may have been responsible for the previous findings.

Nele et al. (2015) investigated regions of interest (ROI's) where infants were shown their mother's face, a stranger's face, and geometric objects. There were two gaze patterns in which the faces were presented: direct and indirect. TD individuals and children with ASD both showed an equal preference for their mother's face. The major difference was seen in the type of gaze the children with ASD attended to. The infants with ASD preferred to maintain eye contact when the indirect gaze was present; the opposite occurred for the TD infants. To better control for extraneous variables related to the social aspects of the videos, the current study altered the social stimuli by having one condition with inverted videos and another with faces blurred.

Vineland Adaptive Behavior Rating Scales

The Vineland-3 is an individually administered, norm-referenced instrument that assesses adaptive behavior in individuals from birth through 90-years-old. It can be administered in comprehensive or domain-level forms. The Vineland-3 can also be administered in different ways based on the type of data and informant desired. The Interview form is completed by the professional through a discussion with the desired informant. The Vineland-3 Parent/Caregiver and Teacher forms are rating scales completed by the parent, caregiver, or teacher. The informant may rate a certain skill as being observed in the child never (0), sometimes (1), or usually (2). If the child displayed the skill at a younger age but has outgrown it, then the informant rates the at a two.

The Adaptive Behavior Composite provides an overall view of the child's adaptive behavior functioning level. The domain level scores (Communication, Daily Living Skills, and Socialization) combine various pertinent subdomains to determine their scores. The Communication domain asks questions related to how well the child listens and understands what other people are saying as well as how well the child communicates their needs and wants to others. The Daily Living Skills domain includes questions related everyday tasks of living that are required of someone at the specified age level. The Socialization domain considers skills related to the forming of relationships, participation in play and leisure activities, and how well the child copes in various situations. The subdomain levels provided information on a child's abilities of a specific skill.

The Receptive subdomain determines the child's ability to receive and understand information that is being provided from the communicator. Expressive assesses the child's ability to communicate information to a conversation partner through words and sentences. These processes relate to the communication deficits of ASD. Interpersonal Relationships assesses the child's ability to form relationships with others, including friendships, and how well they communicate in a socially appropriate manner. Lastly, Play and Leisure looks at the child's ability to engage in play and other activities with others. All of the subdomains directly relate to the development of joint attention (JA) and Theory of Mind (ToM). Restricted and repetitive behaviors may also lead to deficits in any of these areas. Receptive, Expressive, and Interpersonal Relationship subdomain competence requires that the child engage in the social back and forth that occurs when JA and ToM are being developed or have been developed. Any of these subdomains may have a deficit when the child displays restricted and repetitive behaviors because their social topics are limited, and they may not engage in play with others due to fixations of interest.

Typically, the Vineland-3 is used to assist in the diagnosis of various developmental disorders. The Vineland-3 has not only been used as a diagnostic measure; throughout the literature various editions of the Vineland Adaptive Behavior Rating Scale has also been utilized by researchers (Cohen, Amerine-Dickens, & Smith, 2006; Franchini et al., 2016; Pierce et al., 2011; Pierce et al., 2016; Salomone, Shephard, & Milosavljevic, 2018).

Through a longitudinal study, Salomone et al. (2018) tracked cognitive and adaptive behavior changes from seven months to seven-years-old in high risk children eventually diagnosed with ASD, high-risk but not diagnosed with ASD, and low-risk and no diagnosis of ASD groups. Over time, the score gap between low-risk and high-risk groups on the Vineland-II were widened, whereas the cognitive skill gap stayed consistent. Scores within the Adaptive Behavior Composite (ABC) as well as the Socialization, Communication, and Daily Living Skills domains were significantly different between the three groups at 84-month testing time. Low-risk children had the highest scores, followed by high-risk children who did not develop ASD, and the lowest average scores for the ABC, Socialization, Communication, and Daily Living Skills.

Associations between ABC scores have been found between intervention and comparison groups (Cohen et al., 2006). Cohen et al. (2006) utilized an Early Intensive Behavioral Treatment (EIBT) based on Lovaas' model. Children started at less than two years of age at the beginning of treatment and received 35-40 hours of intervention per week for three years. The intervention group increased their adaptive behavior abilities, while the comparison group decreased. This association was also found within eye tracking research on gaze preference between children with ASD and TD children. Previous eye-tracking research has associated gaze preference with VABS-II ABC scores

(Franchini et al., 2016; Pierce et al., 2011; Pierce et al., 2016). Children with a lower ABC score (Pierce et al., 2011) as well as lower scores in the Communication, Daily Living Skills, and Social domains (Pierce., 2016) preferred the geometric images compared to children who obtained higher scores.

Franchini et al. (2016) observed differences between children with ASD; in addition to gaze discrepancies between TD children and children with ASD. For the children with ASD, only half of them showed a gaze aversion of the social stimuli. The preference of stimuli of the ASD group correlated with the Vineland Adaptive Behavior Scale 2nd edition (VABS-II). Children who scored with a more severe rating on the VABS-II were the children who showed a preference for the nonsocial, geometric images.

The VABS-II has been used as a screening measure for multiple previous studies (Franchini et al. (2016); Pierce et al. (2011); Pierce et al., 2016). For the current study, the updated version of the VABS-II was administered, which is the Vineland Adaptive Behavior Rating Scales-Third Edition (Vineland-3; Sparrow, Cicchetti, & Saulnier, 2016). The Vineland-3 allowed the investigators to check the adaptive behavior development of the TD children and get a sense of adaptive behavior skills that the children with ASD had developed. The scores also enabled researchers to further look into the gaze differences between children at various levels of the spectrum.

For the current study, the scores we were most interested in were the ABC score; the Communication, Socialization, and Daily Living Skills domains; as well as the subdomains of Receptive, Expressive, Interpersonal Relationships, and Play and Leisure. Previous research (Cohen et al., 2006; Franchini et al., 2016; Pierce et al., 2011; Pierce et al., 2016; Salomone et al., 2018) has been most concerned with and compared their results to the ABC and domain level scores. The Vineland-3 (Sparrow et al., 2016) manual also displays differences in these scores between TD children and children diagnosed with ASD. In addition, the Vineland-3 manual reports distinctive differences between scores of the Receptive, Expressive, Interpersonal Relationships, and Play and Leisure subdomains. To be consistent with the recommended scores previously associated with an ASD diagnosis, the current study was most interested in these scores.

Discrepancies in Facial Processing in Eye-Tracking Research

Featural and Configural Processing

Rice et al. (2012) found that infants with ASD focused less on the eyes and mouth regions and more on the body and object regions. Conversely, TD infants focused more on the eyes and mouth regions. This finding aligns with the explanation of featural and configural processing by Bombari et al. (2009). Featural processing deals with information from parts of the face such as color of the eyes, shape of the eyes and nose, or hair color. Configural processing refers to the ordinal and cardinal spatial interrelationships between features such as distance in centimeters between the eyes, the eyes being above the nose, and the measured distance between the mouth and nose. Bombari et al. (2009) explained that configural processing is where one takes in the entire face to identify an individual, while featural processing consists of taking in certain aspects of a person's face to identify them. An association was found between the number of saccades, quick changes in fixation points, and the type of processing that the individual used. When the individual had a higher number of saccades, then they were using configural processing because they were taking in the entire face. When a lower number of saccades were recorded, then the participant used featural processing because they focused on a smaller number of facial aspects. This study followed the scanpath patterns of young adults and found that both methods were used when interpreting typical, inverted, and blurred faces.

The research by Rice et al. suggests that children with Autism Spectrum Disorder tend to rely more on featural processing rather than configural because they focus more on outer facial features. Pierce et al. (2011) and Pierce et al. (2016) also supported this notion. They found that children with ASD produced fewer saccades when viewing images, which is a characteristic of featural processing. This study attempted to directly examine the featural and configural processing methods by including a blurred and inverted condition.

The Inversion Effect

The "inversion effect" was first identified by Yin in 1969. He suspected that facial recognition was often done configurally, where one examines the face in its entirety. When the face was then inverted, this process was disrupted, and the individual must identify the face in pieces known as featural processing. To control for confounding variables of previous research, this study tested the inversion effect by including a condition where the video was turned upside-down.

In a matching task, children with ASD were observed having a more difficult time matching identity, gaze, and emotional expression than gender and lip-reading (Deruelle, Rodnan, Gepner, & Tardif, 2004). Identity, gaze, and emotional expressions are components of configural processing; where the latter is related to featural processing. TD children use the featural processing strategy during the matching task. This suggests a configural processing impairment in children with ASD. Children with ASD have also shown a significantly lower preference than TD children when observing low spatial frequency and upright faces. The children with ASD had more trouble identifying faces configurally than TD children (Kikuchi, Senju, & Hawsegawa, 2012). This study hoped to disrupt this process, so then the individuals with ASD might increase looking time to the inverted faces.

Blurred Faces

The last video modification used was one with blurred faces. White and Li (2006) investigated the matching abilities of adults when presented with typical, pixelated, and blurred faces. They found it was the most difficult to match individual faces when the images were blurred. This study only incorporated adult participants and the current study focused on children under the age of five. George, Hole, and Scaife (2000) presented six-year-old TD children with two faces and asked them to identify which person looked old based on the person's face. They used four conditions: features-only, skin-blurred, original, and overall-blurred. It was found that the ability to discriminate the age difference was not hindered by the altered face presentations for TD children.

Deruelle, Rodnon, Salle-Collemiche, Bastard-Rosset, and Da Fonséca (2008) studied the effects of high pass (blurred) versus low pass (slightly blurred) filtered faces on the facial recognition abilities of TD children and children with ASD. They found that children with ASD were significantly better at matching blurred faces than the TD children. Children with ASD relied more on local (featural) processing of information rather than configural information like the TD controls.

The interruption of typical facial recognition methods controlled for the social information compared to the geometric shape video clips. Instead of only using purely non-social clips to contrast the social situation clips, we changed part of the social information that the children receive. By doing this, the children with ASD might look at the inverted social situations and blurred face social situations clips for a longer duration, and with different regions of interest (ROI's), than in the social situation clips. If a preference for blurred face and inverted videos were found, then this would imply there is something else about the standard social videos from previous research, other than how social it is, that could be attributed to the geometric video gaze preference of children with ASD.

Purpose of the Current Study

The symptoms of ASD are often present within the first two years of life (Chawarska et al., 2013), but diagnosis does not occur until the child reaches an average age of 53 months (Baio et al., 2014). Current screening methods are vulnerable to inaccuracies due to parental stress (Zwaigenbaum et al., 2005; Karp et al., 2017). The most popular current screen measures, M-CHAT and STAT, do not identify ASD until the child is at least 16 months. These measures do not identify ASD until key developmental milestones have already been missed. The current methods of screening are insufficient (Camarata, 2014) and an objective method of early screening must be identified. Eye tracking could become a proactive measure of screening for ASD in very young children because it simply requires that the child sit in front of a screen.

The previous research has identified a preference in children with ASD for geometric over social videos (Franchini et al., 2016; Peirce et al., 2011; Peirce et al., 2016; Sekigawa-Hosozama et al., 2017; Shaffer et al., 2017). Confounding variables may attribute to this preference, so the current study included two different variations of "social": blurred and inverted. The purpose of the current study is to add to the previous literature on using eye tracking as a screening method for ASD by controlling for the confounding variables and further narrow down what the children with ASD specifically prefer in the videos.

It was predicted that individuals with ASD would have a significantly higher percentage of looking time when viewing geometric over social situation videos, as shown by the multitude of previous research. Within the social situation videos; it was predicted that participants with ASD would show a significantly higher percentage of looking time for the inverted social situations and blurred face social situations when compared to the social situation videos. This preference was suspected because children with ASD have been found to more easily identify blurred and inverted faces compared to their TD peers. This is attributed to the idea that children with ASD more commonly utilize the configural rather than featural method when identifying faces. It was also predicted that the children with ASD would produce a higher number of saccades than the TD children. This prediction aligns with the previous findings that children with ASD produce fewer saccades when observing videos.

If it is found that the children with ASD have a higher percentage of looking time and fewer saccades for the blurred or inverted videos over the geometric video, then the findings of existing research would be challenged. Further examination would need to be conducted on the existence of confounding variables within the conditions of the previous research to find the reason that children with ASD preferred the geometric over "social" video. What the children with ASD actually prefer would also need to be identified to assist in using eye tracking gaze preference as a possible future screening measure for ASD.

If it were found that the children with ASD prefer the blurred and inverted videos over the standard social video, then this preference would align with the previous research of configural and featural processing preferences. The finding would also further support the previous research on the ease of facial identification of children with ASD when videos have blurred faces or are inverted.

CHAPTER III

METHODS

Participants

The research was conducted in a lab at a university in a midsized, midwestern city. Eighteen typically developing children and three children with Autism Spectrum Disorder were recruited from early intervention centers and the community. Participants were excluded from analysis if the eye tracker did not track the child's gaze for longer than 40% of the time, a proper calibration could not be obtained, or if the child was noncompliant with the task. After exclusionary criteria were determined there were 18 total participants. Fifteen typically developing children (n =11 males, n =4 females) participated as well as one male, Jack (pseudonym), who was three years and seven months old with a previous diagnosis of ASD and one male, Bobby (pseudonym), who was three months old and highly suspected of receiving a diagnosis based on having two older siblings with the disorder. Within each condition, there were five children for the TD group. The mean age for the Standard (social and geometric videos) TD condition was 3.3 (SD = 1.6), 4.0 (SD = 2.1) for the Inverted (social and inverted videos) TD condition, and 2.6 (SD = 1.0) for the Blurred (social and blurred videos) TD condition.

In the ASD group, Bobby participated in the blurred condition, and Jack participated in the inverted condition. Bobby was highly suspected of receiving an ASD diagnosis due to having two older brothers being previously diagnosed. Jack received a diagnosis at two years and five months due to slow language development. Jack had a typically developing twin sister who participated in the Blurred condition. Analysis of gaze differences within this set of twins will be investigated later.

Overall, 61.11% of parents were between 25 and 34 years old, 33.33% were between 35 and 44 years old, and 5.56% were between 45 and 54 years old. The majority of participants came from a home where the parents were married (83.33%). Within the sample, 88.89% of the participants were Caucasian, and 11.11% were African American. All activities within the study were approved by the Minnesota State University Moorhead's Institutional Review Board.

This study had three conditions to which each participant was randomly assigned. In each condition, every child observed the social videos and the nonsocial videos that correlated to their condition (geometric, inverted, or blurred). The Standard condition consisted of alternating social and geometric videos. For example, in the Standard condition a child would watch the videos in the following order: social, geometric, social, geometric, social, geometric, social, geometric. The same pattern of videos was also used in the Inverted and Blurred conditions. In the Inverted condition, the children watch the social and inverted videos, and in the Blurred condition the children watched the social and blurred face videos.

Materials

Apparatus

Eye position and number of saccades were monitored with a Tobii X120 remote infrared eye-tracking system (Tobii Technology; Falls Church, VA). The system contains control and calibration software, Tobii Studio, which runs on a separate Intel Core computer using Windows 7.

Measure

The Comprehensive Parent/Caregiver Form of the Vineland Adaptive Behavior Scales, Third Edition (Sparrow et al., 2016) was administered to all participants to check for any adaptive behavior deficits in the TD condition and gain a sense of the adaptive behavior skills that the children with ASD had acquired. The Vineland-3 is a standardized, norm-referenced parent questionnaire that was administered online, through Q-Global, for 16 of the participants and one was administered by hand. The Vineland-3 Comprehensive Parent/Caregiver Form scaled scores within the subdomains have a mean of 15 and a standard deviation of 3, while the standard scores for the composite and domain scores have a mean of 100 and a standard deviation of 15. The questionnaire calculates an Adaptive Behavior Composite (ABC); provides domain level information in Communication, Daily Living Skills, and Socialization; and provides subdomain scores in Receptive, Expressive, Interpersonal Relationships, and Play and Leisure.

For the purpose of this study, we are concerned with the standard scores of the Adaptive Behavior Composite and domain level scores of Communication, Daily Living Skills, and Socialization. We are also interested in the subdomain scaled scores of Receptive, Expressive, Interpersonal Relationships, and Play and Leisure. The emphasis was decided based on suggestions from the Vineland-3 manual (Sparrow et al., 2016) and previous research (Cohen et al., 2006; Franchini et al., 2016; Pierce et al., 2011; Pierce et al., 2016; Salomone, Shephard, & Milosavljevic, 2018).

Stimuli

Nonsocial geometric versus social images have been widely used as stimuli in autism eye-tracking research (Franchini et al., 2016; Klin, Lin, Gorrindo, Ramsay & Jones, 2009; Nakano et al., 2017; Pierce et al., 2011; Pierce et al., 2016; Sasson & Touchstone, 2014; Shaffer et al., 2017). For the current study, we incorporated one type of social video and three types of nonsocial videos to control for confounding variables that have existed in the previous research. We used four different types of videos as stimuli: social and three types of nonsocial (geometric, inverted, and blurred). All children observed the social videos and observed the nonsocial video that correlated with the condition they were assigned. The inverted and blurred conditions utilized the same video as in the social situation, but the picture was inverted or the faces were blurred out. It was hypothesized that alterations made to the social videos might affect gaze patterns between social and non-social stimuli by allowing us to explicitly test the typical configural and featural facial processing procedure.

A repeated measures design was used where each participant was presented eight consecutive ten-second video clips. The video clips alternated between the social control or nonsocial type (geometric, inverted, blurred) based on the assigned condition of the participant: social and geometric, social and inverted, or social and blurred face. The videos were obtained from a Sesame Street activity (https://www.youtube.com/watch?v=gN594DSOWHU) and an effective teaching documentary (https://www.youtube.com/watch?v=2Hw0DbxOmJQ). The audio had been eliminated, and the social clip had been modified for the inverted and blurred conditions.

Procedure

The current study utilized a 2 (TD versus ASD) X 2 (social versus nonsocial videos) X 3 (Standard versus Inverted versus Blurred) mixed measures design. The within-subjects variables were the condition type of Standard, Inverted, or Blurred. The between-subjects variables were the participant type and the social versus nonsocial types of videos. Prior to the eye-tracking session, the participant was randomly assigned a condition of Standard(social and geometric), Inverted (social and inverted), or Blurred (social and blurred) and the parent of the child completed the Vineland-3 Parent/Caregiver Form; either online using Q-global or completed an in-person administration. Upon arrival to the eye-tracking session, parental consent was first obtained for each child participant followed by completion of a brief demographic form. The consent and demographic forms are displayed in Appendix A and B. After the consent and demographic forms were completed, the child was seated on the parent's lap approximately 65 cm from the monitor. The monitor, parent, and child were in a three-sided enclosure to minimize distractions. The experimenter then displayed a brief cartoon clip, if needed, to gain the attention of the child.

Each trial was initiated when the child fixated on a central point on the screen. The attention was then directed toward the center using an attention-getting happy face stimulus.

When calibration was completed, the Tobii eye-tracking system sent eye position data to the computer using TCP/IP protocol. Tobii displayed data on eye position, regions of interest (ROI's), and saccades. There were eight, consecutive ten-second videos were used as stimuli, but each participant only saw the social and one of the conditions repeatedly. For example, Jake saw social then blurred, social then blurred, social then blurred, social then blurred. The videos alternated between social and geometric, social and inverted, or social and blurred face depending on experimental condition. In one window Tobii Studio superimposed the eye positioning data upon an image of the stimulus being viewed by the child. This allowed the experimenter to monitor the child's gaze and progress throughout the experiment. In another window, Tobii Studio also presented a video image of the child from a USB camera mounted just above the eye tracker. In a third window, Studio presented a graphic representation of the tracking quality and the infant's viewing distance. A third Macintosh laptop computer was also connected to the VGA switch allowing brief cartoons to be presented to the child before and between experiments.

When the eye-tracking procedure was completed, the parent and child were debriefed on the experiment. The child then received a small toy or book for participating.

The eye tracker calculated the percentage of time that the child looked at the videos and the number of saccades produced for each of the clips. Because of the variability in the data from the eye tracker, a secondary measure of timing was used. While the participant was viewing the videos, a camera was positioned to see the child's face and whether the child was looking at the video. Lab assistants observed the video and recorded the looking times of each participant using a stopwatch. Looking time was recorded for each of the eight video clips on a form with the participant's condition assignment. To increase interobserver reliability, prior to the beginning of data collection, each lab assistant was trained using an operational definition of looking behavior and two practice videos.

CHAPTER IV

RESULTS

The current study utilized a 2 (TD versus ASD) X 2 (social versus nonsocial) X 3 (Standard versus Inverted versus Blurred). There were three independent measures that were analyzed in this study. The independent measures were the classification of subjects as ASD or TD; the video type (social and nonsocial); and the condition type of Standard (social and geometric), Inverted (social and inverted), Blurred (social and blurred). These independent measures were analyzed against the dependent measures of percentage of looking time and number of saccades.

The percentage of looking time at each of the video clips was calculated by the eye tracker. Because of the lower tracking percentages and high variation in the data from the eye tracker a lab assistant also kept track of looking time using a stopwatch. This was the primary method of data that was collected for percentage of looking time. From the stopwatch data, the percentage of looking time was calculated by comparing the recorded looking time to the video length. For instance, the video may be 10 seconds long and the child was looking for 9 seconds, which would be a total looking time percentage of 90%. The number of saccades were automatically determined by the eye tracker, and number of saccades were compared between conditions.

The current analysis is exploratory in nature and caution should be used in the interpretation of the results described below. It was difficult to recruit young children with Autism Spectrum Disorder (ASD), which led to a small number of participants used in the following analysis. Because of the small number of participants, assumptions involved in conducting an ANOVA were considered. Throughout the analysis, the assumptions were not perfectly met. The research design utilized in this study would work well for an ANOVA, but caution should be used in interpretation because of the small number of participants.

Average Percentage of Looking Time

Considering the small number of participants, an examination of normality and skewness of the distribution of data was conducted. Examination of the data in the children with ASD condition was not possible because there were only two participants, so only the typically developing (TD) children distributions were included. Kurtosis in percentage of looking time was typical within the nonsocial (inverted, blurred, and geometric) data at 0.80 but a high peak existed in the social (4.81) data. Recall that Kurtosis measures the sharpness of the peak in the distribution compared to the normal distribution with acceptable values between negative two and positive two.

The nonsocial (-1.28) data was within the acceptable range, but the social (-2.12) data was slightly negatively skewed. Recall that skewness is how much the distribution has been distorted to the left or right from the normal distribution with acceptable values between negative two and positive two.

A three-way mixed ANOVA was calculated to examine a preference in percentage of looking time. The between-subject variables were subject classification (TD or ASD) and condition of Standard (social and geometric), Inverted (social and inverted), or Blurred (social and blurred). The within-subject variable was video type (social and nonsocial) because all participants watched social and nonsocial categories of videos within each condition. A significant interaction effect for preference was not found for social or nonsocial videos between conditions within all participants, $F_{(1,12)} = 0.17$, $p = 0.69$, $\eta^2 = 0.01$. No difference was found in percentage of looking time for social or nonsocial videos within the children with ASD, $t_{(1)} = 1.35$, $p = 0.41$, or TD children group, $t_{(14)} = 1.68$, $p = 0.12$. Between both groups, there was no overall preference for social or nonsocial videos across conditions.

Collective looking times at both the social and nonsocial videos between TD children and children with ASD were analyzed through an independent samples *t*-test. No significant difference was found between overall percentage of looking time to the videos between TD children ($M = 93.15$, $SD = 8.25$) and children with ASD ($M = 86.39$, $SD = 8.43$), $t_{(32)} = 1.54$, $p = 0.13$. Both groups of participants observed the videos for a similar length of time, which can be observed in Figure 1. All of the children, with the exception of Bobby, observed the videos for at least 85% of the time.

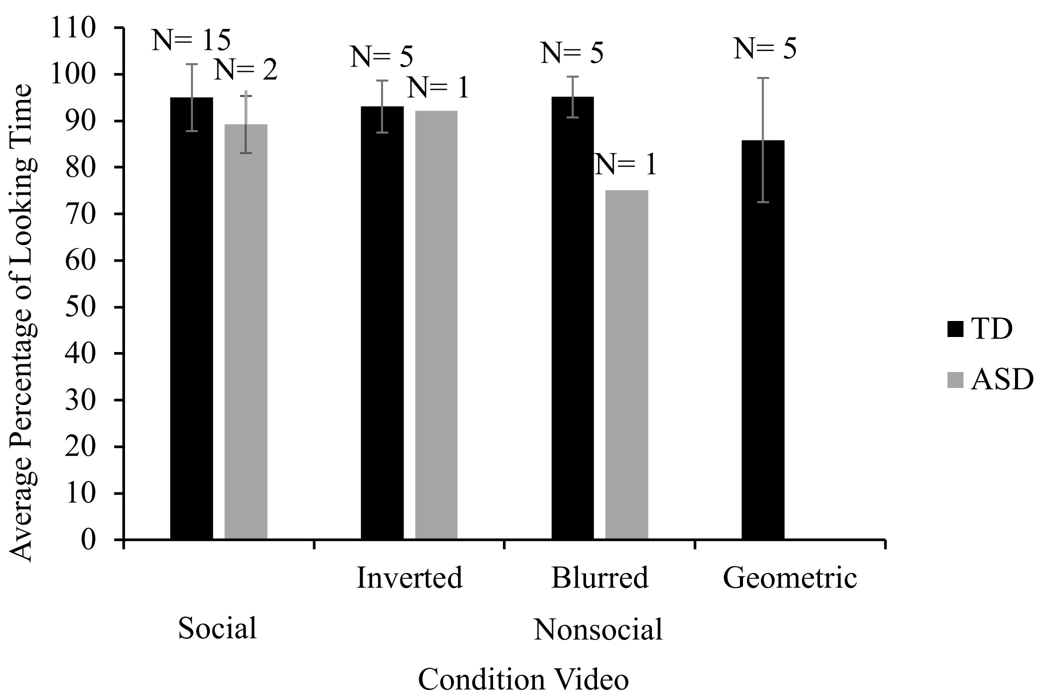

Figure 1. Average percentage of looking time within each condition for TD and ASD groups.

In Figure 1, it should be noted that the absence of data for the geometric condition for children with ASD does not mean that the child observed for zero percent of the time. We did not have a child with ASD participate in this condition, which is why there is no data.

Percentage of looking time was further investigated against the specific conditions within the TD children and children with ASD groups. Figure 1 displays no overall differences in percentage of looking time for the children with ASD group while viewing social and nonsocial videos when compared to all TD children, $F_{(1,15)} = 0.10$, $p = 0.76$, $\eta^2 = 0.01$, with no violation in the equal variances assumption. This was also true when just Jack's data, $F_{(1,14)} = 0.13$, $p = 0.73$, $\eta^2 = 0.03$, and just Bobby's data, $F_{(1,14)} = 0.13$, $p = 0.73$, $\eta^2 = 0.03$, were compared to all TD children.

Examination of differences between each of the videos was also conducted. All participants observed the social video within their specified condition. Only participants in the specific conditions observed a different type of nonsocial video (inverted, blurred, and geometric). No significant differences occurred within the TD children group for percentage of looking time between the social ($M = 94.97$, $SD = 7.19$), inverted ($M = 93.04$, $SD = 5.59$), blurred ($M = 95.09$, $SD = 4.38$), or geometric ($M = 85.85$, $SD = 13.34$) videos, $F_{(3,26)} = 1.77$, $p = 0.18$, as seen by the dark bars in Figure 1. Equal variance in this analysis was violated the Levene statistical value at 0.05. Also no difference occurred in percentage of looking time between any of the social ($M = 89.19$, $SD = 6.13$), inverted ($M = 92.08$), or blurred ($M = 75.10$) conditions for the children with ASD, $F_{(2,1)} = 2.33$, $p = 0.42$, as seen by the lighter bars in Figure 1. Violation in the variance assumption could not be calculated for the ASD group due to the low number of participants.

Violation of the variance assumption through Levene's test was found in only a few of the ANOVA's for percentage of looking time, but visual inspection of the variance is cause for concern. Variance for the social (51.71) and nonsocial (82.03) video data was high.

Considering the age range of the participants, differences in gaze preferences were also inspected based on participant age in the TD group. A significant difference was found in percentage of looking time between the younger and older participants. The younger participants (M = 89.72, SD = 10.53) observed the videos for a smaller percentage of time than the older participants (M = 96.15, SD = 3.85), $t(28) = -2.28$, p = 0.03. The difference in percentage of looking time did not create an interaction effect within video and condition by age, $F_{(2,9)} = 1.67$, $p = 0.24$, $\eta^2 = 0.27$. Overall looking times differed between the two age groups, but this effect did not extend into the conditions.

In this study, a set of twins were also included. The TD twin was in the inverted condition while Jack was in the blurred condition. A paired samples *t*-test was conducted to examine a difference in their percentages of looking time. There was no difference in percentage of looking within the set of twins, $t_{(1)} = 11.58$, $p = 0.06$. Both twins observed the videos for a similar amount of time. Also no effect occurred between the twins when viewing the social or nonsocial videos, $F_{(1,6)} = 0.02$, $p = 0.90$, $\eta^2 = 0.00$.

Average Number of Saccades

An examination of normality and skewness of the distribution of data was conducted. Examination of the data in the children with ASD condition was not possible because there were only two participants, so only the TD children distributions were included. Kurtosis in number of saccades was typical for both the social (1.87) and nonsocial (-0.14) video data. Analysis of skewness was also conducted within the number of saccades data. Both the social (0.10) and nonsocial (-0.11) data were within the acceptable range of skewness.

A Three-Way ANOVA was conducted in the same way as for percentage of looking time. The Three-Way ANOVA revealed that there was a similar number of saccades produced between the TD children and children with ASD groups for social and nonsocial videos as well as videos in each of the conditions. No difference between social or nonsocial videos were found within conditions between all participants, $F_{(1,11)} = 0.80$, $p = 0.78$, $\eta^2 = 0.01$. A paired samples *t*-test revealed no saccade differences within the TD children, $t_{(14)} = 0.77$, $p = 0.46$, or children with ASD groups, $t_{(1)} = 2.75$, $p = 0.22$. Both groups of participants had a similar number of saccades within and between the groups.

Composite numbers of saccades for both the social and nonsocial videos between TD children and children with ASD were analyzed through an independent samples *t*-test. There was a significant difference between overall number of saccades while observing the videos between TD children ($M = 16.10$, $SD = 6.29$) and children with ASD ($M = 9.5$, $SD = 1.74$), $t_{(32)} = 2.07$, $p = 0.05$. The children with ASD produced fewer saccades when viewing the videos than the TD children.

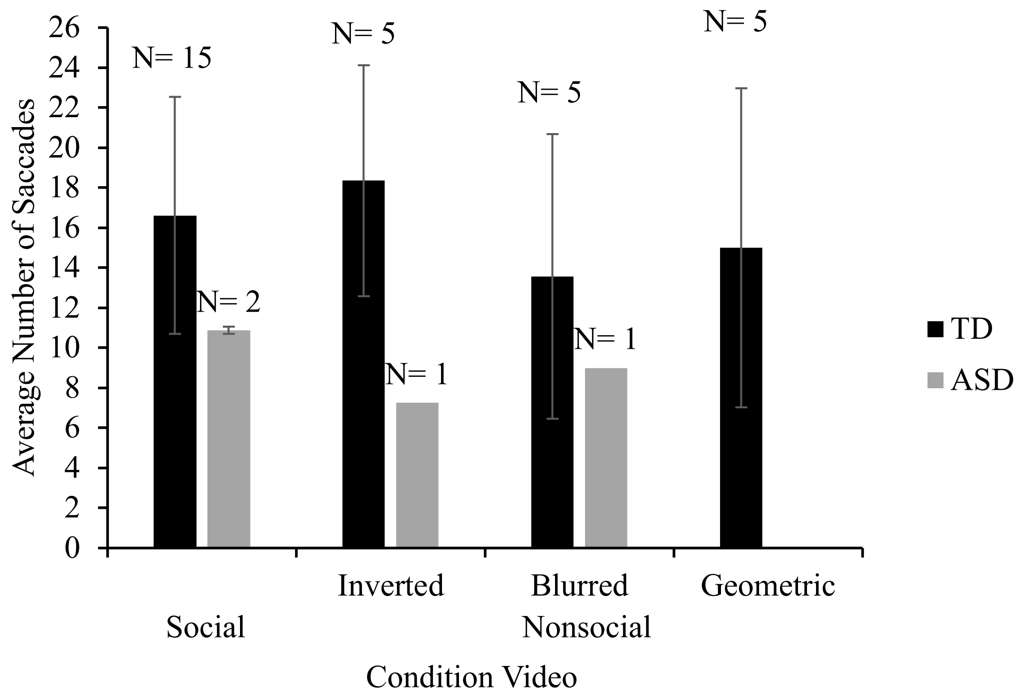

Figure 2. Average number of saccades within each condition for TD and ASD groups.

Just as with the percentage of looking time data, Figure 2 does not show the child with ASD produced zero saccades while viewing the geometric video. We did not have a child with ASD participate in this condition, which is why there is no data.

Saccade number within the ASD group was further investigated against the overall TD group and specific conditions. As shown in Figure 2, the participants in the children with ASD group did not differ significantly in saccade number while viewing social and nonsocial videos when compared to the overall TD children group $F_{(1,15)}$ = 0.24, p = 0.63, η^2 = 0.02, and no violation in the equal variance assumption was found. Within the inverted condition, there was no significant interaction effect in the number of saccades between Jack and the TD children group, $F_{(1,4)}$ = 1.08, p = 0.36, η^2 = 0.21; this finding can be observed when viewing the social and inverted columns of Figure 2. The same results were found within the blurred condition. No significant interaction effect was found in the number of saccades between Bobby and the TD children group, $F_{(1,4)}$ = 1.67, p = 0.27, η^2 = 0.29; this finding can be observed by viewing the social and blurred columns of Figure 2.

Just as with the percentage of looking time, differences between each of the videos was also conducted. The darker bars within Figure 2, display that within the TD group, there were no significant differences in saccade numbers when watching the social (M = 16.62, SD = 5.92), inverted (M = 18.35, SD = 5.77), blurred (M = 13.57, SD = 7.11), or geometric (M = 15.00, SD = 7.97) videos, $F_{(3,26)}$ = 0.54, p = 0.66; no violation of equal variance was found. No differences in saccades numbers existed between the children with ASD while watching the social (M = 10.88, SD = 0.18), inverted (M = 7.25), or blurred (M = 9.00) videos, $F_{(2,1)}$ = 145.50, p = 0.06; which can be seen by the lighter bars in Figure 2. Violation of equal variance could not be examined for the children with ASD because of the low number of participants.

Violation of the variance assumption through Levene's test was not found in the ANOVA's for number of saccades, but visual inspection of the variance is cause for concern. Variance for the social (35.05) and nonsocial (46.40) video data was high.

Differences in number of saccades were also investigated across age in the TD group, finding no significant difference between younger and older participants. Younger (M = 12.85, SD = 5.36) participants displayed fewer saccades than older (M = 18.54, SD = 6.37) while observing all the videos $t_{(28)}$ = -2.49, p = 0.02. There was no interaction effect between condition, video type, and age of the participant, $F_{(2,10)}$ = 0.64, p = 0.46, η^2 = 0.10.

A comparison between the twins through a paired samples *t*-test was also calculated for number of saccades produced. A difference was not found between the number of saccades that the TD twin ($M = 22.05$, $SD = 1.84$) or the twin with ASD ($M = 9.13$, $SD = 2.65$) produced, $t_{(1)} = 4.07$, $p = 0.15$. Both of the twins produced a similar number of saccades. There was also no effect difference in number of saccades between the twins when viewing the social and nonsocial videos, $F_{(1,6)} = 0.02$, $p = 0.90$, $\eta^2 = 0.00$.

Adaptive Behavior

Within the TD group, a one-way ANOVA was calculated and found there was no significant difference between ages of participants within the distributions of ages across each condition, ($F_{(2,12)} = 0.90$, $p =.434$).

The Vineland-3 Parent/Caregiver form was administered online through Q-Global for 16 of the participants and completed by hand for one participant. Mean scores and standard deviations for the typically developing group and scores of each of the children diagnosed with Autism Spectrum Disorder are listed in Table 1 below.

The average scores for children within the TD group align with average scores that a typically developing child would usually receive when rated using the Vineland-3. Within the TD group, a one-way ANOVA was calculated to determine if there was a difference between ratings within each condition of standard, inverted, and blurred. The scores obtained by participants did not significantly differ between each condition: ABC ($F_{(2,12)} = 0.82$, $p = 0.46$), Communication ($F_{(2,12)} = 0.09$, $p = 0.92$), Daily Living Skills ($F_{(2,12)} = 1.40$, $p = 0.29$), Socialization ($F_{(2,12)} = 0.74$, $p = 0.50$), Receptive ($F_{(2,12)} = 0.80$, $p = 0.47$), Expressive ($F_{(2,12)} = 2.11$, $p = 0.16$), Interpersonal Relationships ($F_{(2,12)} = 1.91$, $p = 0.19$), and Play and Leisure ($F_{(2,12)} = 0.56$, $p = 0.59$).

Table 1

Vineland Adaptive Behavior Ratings for Typically Developing Children and Children with Autism Spectrum Disorder

Adaptive Behavior Area	Typically Developing *M* (*SD*)	ASD Inverted Condition (Jack)	ASD Blurred Condition (Bobby)
Adaptive Behavior Composite	96.60 (8.93)	59	129
Communication Domain	97.07 (6.60)	47	126
Receptive	14.87 (1.73)	2	21
Expressive	15.07 (1.16)	3	17
Daily Living Skills	98.13 (10.72)	60	123
Socialization Domain	98.40 (8.68)	60	125
Interpersonal Relationships	14.53 (1.55)	8	18
Play and Leisure	14.87 (1.77)	9	19

Within the ASD inverted video condition, the scores suggest that the individual has a more moderate form of ASD. The scores of the TD children were compared to the child in the inverted ASD condition and a significant difference was found between all domain, subdomain, and ABC scores: ABC, $F_{(1,14)} = 16.63$, $p = .00$; Communication, $F_{(1,14)} = 54.02$, $p = .00$; Daily Living, $F_{(1,14)} = 11.86$, $p = .00$, Socialization, $F_{(1,14)} = 18.37$, $p = .00$; Receptive, $F_{(1,14)} = 52.07$, $p = .00$; Expressive, $F_{(1,14)} = 100.94$, $p = .00$; Interpersonal Communication, $F_{(1,14)} = 16.61$, $p = .00$; and Play and Leisure, $F_{(1,14)} = 18.57$, $p = .00$. This is to be expected between the TD group and Jack (Sparrow et al., 2016). Bobby's scores were above the average scores for a typically developing child, which is not what is expected of a child with ASD. Further explanation of Bobby's scores will be rationalized later.

CHAPTER V

DISCUSSION

The purpose of this study was to add to the previous literature on using eye tracking as a screening method for Autism Spectrum Disorder (ASD) by controlling for the confounding variables to further narrow what children with ASD specifically prefer in videos compared to typically developing (TD) children. This study controlled for confounding variables by including variations of the nonsocial video. It was predicted that individuals with ASD would have a significantly higher percentage of looking time when viewing nonsocial over social situation videos. Within the social situation videos; it was predicted that participants with ASD would show a significantly greater percentage of looking time for the inverted and blurred face videos when compared to the social situation videos. It was also predicted that the children with ASD would produce a higher number of saccades than the TD children.

The participants did not significantly differ by age across the conditions and their adaptive behavior skills were within what was expected of TD children and children diagnosed with ASD. Bobby's scores on the VABS-3 were above what a TD child would obtain, and it would be expected he would obtain scores more similar to Jack's (Sparrow et al., 2016). Considering Bobby was only three months of age at the time of testing, we were most interested in whether he showed early signs of gaze preference based on familial history, despite having above average adaptive behavior scores at this time.

Yirmiya and Charman (2009) stated that early signs of ASD and the exact age of onset of these signs have not yet been determined. They concluded that there is a need for a measure that enables the identification of the ASD phenotype prior to the age of onset of symptoms. Both groups of participants did not significantly differ in the overall number of saccades and percentages of looking time. Overall, the participants looked at each video for a similar amount of time and produced a similar number of saccades.

The previous research has found a preference for geometric, nonsocial over social videos in children with ASD, and an opposite preference for TD children. Contrary to the previous research, there was not a significant difference between looking time percentage or saccade number within the TD children when viewing the social and geometric, nonsocial videos. However, the current study contained a small number of participants and violated some assumptions of the analysis. To control for the possible confounding variables of the previous literature, the inverted and blurred videos were also included. TD children and the children with ASD did not show a difference in looking time and saccade number between all four types of videos (social, inverted, blurred, and geometric); they attended to all videos equally. Analyses of the twins was also calculated for overall looking percentages and number of saccades as well as differences in percent looking and number of saccades between the social and nonsocial videos. There were no differences in looking time percentage or number of saccades between the TD child in the blurred condition and the child with ASD in the inverted condition.

Preferences were not shown across video condition within the TD or ASD groups, but there were differences identified within different age groups of the TD children. The participants were arbitrarily split into younger and older groups based on having an even number of participants in each group for comparison. The younger (three months to three years, five months) group viewed the videos for a smaller percentage of time and produced fewer saccades than the older (three years, six months to five years, nine months) group. This difference did not extend to the different conditions.

Gaze Patterns in Children with ASD When Viewing the Different Videos

In the previous literature, the children with ASD did not change their looking patterns when viewing blurred face and inverted stimuli (Deruelle et al., 2004; Deruelle et al., 2008; George et al., 2000; Kikuchi et al., 2012; White & Li, 2006). A difference in looking times and number of saccades was not found within the children with ASD when they were observing the social, inverted, and blurred videos. With the current data and number of participants, this study supports the previous literature because the children with ASD did not change their looking time or saccade number based on the different types of videos presented. This finding calls into question what the children with ASD really preferred in previous research that compared just kids playing as social versus geometric, nonsocial videos because, in our study, they did not change their looking based on viewing inverted and blurred videos. Children with ASD do not only look at nonsocial, geometric videos, they also view different versions of the social situation video when the certain aspects are changed.

The percentage of looking time to all videos could have had an effect on the overall results. The possibility of a ceiling effect within the percentage of looking time is supported by the level of skewness and Kurtosis within the social video data. With the exception of the child with ASD in the blurred condition, all participants viewed the videos for at least 85% of the time. The decision to make a string of eight, ten-second videos was supported by the previous research (Nakano et al., 2010; Pierce et al., 2011;

Pierce et al., 2016; Sekigawa-Hosozawa et al., 2017; Shaffer et al., 2017). In the current study, there seemed not be enough viewing time for the children to form a preference to any of the stimuli because they were interested in whatever they saw. Longer videos may have had an impact on the current findings because the children would have the opportunity to show a persistence in interest or lose interest.

Collective Data Comparison of TD Children and Children with ASD

Another interesting finding was that the children with ASD produced an overall smaller number of saccades than the TD children. The difference aligns with the featural and configural processing strategies that were explained earlier. Bombari et al. (2009) found that when individuals display a small number of saccades then they are utilizing featural processing and when more saccades are present, then a configural processing method has been used. The children with ASD displayed a smaller number of saccades overall when compared to the TD children. In other words, this could mean that the children with ASD were using the featural processing method and the TD children were using the configural processing method, which aligns with the previous literature (Bombari et al., 2009; Pierce et al., 2011; Pierce et al., 2016; Rice et al., 2012).

The featural processing displayed by the children with ASD did not change the number of saccades that they produced when the different videos types were compared. The "inversion effect" (Yin, 1969) occurs when a face is inverted and the configural processing methods are disrupted. Configural processing has also shown to be disrupted when children view blurred faces (Deruelle et al., 2008; George et al., 2000; White & Li, 2006). Children with ASD had difficulty with configural processing and displayed featural processing characteristics in the current study, which could explain why the children with ASD did not change their gaze when viewing the different videos.

The difference in number of saccades between TD children and children with ASD suggests that the TD children utilized the configural processing method. As previously stated, the literature has found that the configural process is disrupted when viewing inverted and blurred videos; this impact has been particularly evident in TD children who use configural processing methods. Based on previous findings, it was suspected that TD children would change their saccade number and looking percentages when viewing the different types of videos, but the TD children did not change their gaze. This could possibly be due to the high amount of variance within the standard deviations of saccade numbers. The high amount of variance could have impacted the ability to find a significant difference in the statistics. There could also be other reasons as to why a difference was not found. Maybe the TD children found that the different types of videos were interesting and wanted to investigate more with a higher number of saccades. Maybe the videos were not long enough for the change to be observed. Regardless of the reason behind it, the TD children within the current study did not change their gaze patterns when viewing the different types of videos.

Differences by Age Groups

The difference in percentages of looking time and number of saccades between the two age groups is also an interesting result. Previous research has not fully examined the discrepancies across age. Some studies did not examine age differences within their work (Franchini et al., 2016; Rice et al., 2012). Two studies found no difference by age, but there was either an older population of children tested (Shaffer et al., 2017) or a very small range of age in participants assessed (Pierce et al., 2011). One study found differences by age but attributed the difference to a high dropout rate at follow-up examination (Sekigawa-Hosozawa et al., 2017). The current study assessed differences in children as young as three-months-old to as old as five-years and nine-months-old. For age, the typically developing participants were separated into two classifications of younger and older. The younger group (N=7) consisted of participants who were eight months to three years and five months old. The older group (N=8) consisted of participants who were three years and six months old to five years and nine months old. The younger children produced a lower number of saccades and had a lower percentage of looking time than the older children, but this difference was not observed within each condition.

This lack of difference within conditions could be due to the high amount of variance within the standard deviations of each condition for saccade number and percentage of looking time, but further investigation in future research would be necessary to know for sure. Another possible factor that could have affected the results is the span of ages within each condition. The current study had a large age range within each condition and all of the conditions contained younger and older children. We found that these two groups had different overall percentages of looking time and number of saccades. Because of this, it is possible that the differences between the conditions were altered because the younger and older child differences cancelled each other out. Differences between the ages could be attributed to attention span changes over time or different life experiences that the children have had that causes them to assess the situation more thoroughly. Further investigation into the causes of the differences and differences in percentage looking time and saccade number should be investigated in future research. To create an implementable screening measure, the differences by age need to be examined to ensure accurate identification of ASD.

Limitations

Within the children with ASD condition, there are a couple of findings that may also have an impact on individuals who would like to conduct future research in this area. Five children were actually recruited for the current study; two did not attend the eye tracking session, one child did not obtain a reliable calibration, and only Jack and Bobby participated in the study to completion. Two of the TD children also had trouble gaining interest in the videos without sound and had to make a second appointment.

Another limitation of the current research is the possibility of a ceiling effect in percentage of looking time. All of the children, with the exception of Bobby, observed the videos for at least 85% of the time. The ceiling effect may have had an impact on the findings within this study because the children may not have had enough observation time to show preferences for the videos. Within the current study, we were not able to identify a preference within the participants this could possibly be due to the ceiling effect.

Differences by age could have also affected the results of the current study. There were wide ranges of ages within each condition. Since differences in both saccade number and percentage of looking time were found, this could have impacted the findings. When the younger and older children data were combined, the extremes in looking percentage and number of saccades could have cancelled each other out and differences in these areas may not have been found. The decision of which group the participant would go in by age was arbitrarily chosen and not based on previous research, which could have also impacted these findings.

The data analysis is also a limitation to the current study. An ANOVA fits well with the research design that was used, but with the small number of participants the results are not as reliable. The assumptions of ANOVA were violated within this study, so interpretation of results should be done with caution.

Future Directions

There are several possible considerations for future researchers. One is to extend the length of the videos that are presented to the participants. Some of the previous research has included videos that are three to five minutes long instead of one and a half minutes used in the current study (Chawarska et al., 2013; Murias et al., 2017; Rice et al., 2012). The current study did not include videos that were long enough to gain a difference in gaze between the groups of participants across the conditions. The current study may have had too short of videos and the children may not have had time to show a preference for type of video because they were still interested in being shown any type of stimuli. Using longer videos and challenging the attention span of the young children and impact the preferences that the child displays. Further research should consider finding a good length of videos for eye tracking to be used as a screening measure; videos that are not too long and not too short.

Continuation of investigating what the children with ASD and TD children specifically prefer within the videos should be considered in future research. The current study found that children with ASD did not change their gaze pattern based on the video being inverted and blurred, which means that there is something within the "social" videos of previous research that attributed to their preference for geometric videos. Specific Areas of Interest (AOI's) could be investigated to identify the specific interests of the children. The calculation of AOI's can be used in eye tracking research because it is automatically calculated by the eye tracker. The AOI calculation displays which areas of the video that the child attended to for the longest amount of time. Areas of Interest investigation was beyond the scope of this study but could contribute to identifying exactly what the children with ASD prefer within the videos. Continuing to use other variations of the social video could also contribute to the narrowing down of what the children specifically preferred within the videos. Future research should further investigate the differences in children when viewing inverted and blurred stimuli.

Another area of interest for future research would be within the percentage of looking time and number of saccade differences between the ages. In the current study, the participants were arbitrarily split into younger and older groups based on having a similar amount of data in each group. Future research should expand on this finding by looking at when changes in looking time occur. In addition, for eye tracking to be an effective screening measure, there needs to be a normative set of data for each age like a standardized test. In order to create normative data, infants at different ages need to be assessed to find the different patterns of gaze within each age category. Future research should strongly consider variations in looking percentages and saccade number within each age group and form potential conclusions as to why there is a difference.

From observation of testing the participants it was apparent that there were barriers for the parents of children with ASD in coming to the eye tracking session. Two of the five children with ASD that were recruited did not attend the appointment for the eye tracking session, all of the TD children were in attendance. Research on the barriers to research participation should be expanded on in future research. As previously stated, children with ASD typically prefer "sameness" in their daily lives. Coming to an appointment at an unfamiliar building, which violates "sameness", may have been stressful for the child leading to difficulties in attention. Another possible barrier could be that there was too much stimuli occurring around them. Taking in all of the new sights and sounds may have been tough for a young child with ASD to process. Research in this area would benefit any future studies conducted on children with ASD because investigators could attempt to reduce such barriers and have a larger sample size.

For practical reasons, if eye tracking were to be used as a screening measure then the addition of sound would be useful. Sound was excluded from the videos to control for extraneous variables, but if eye tracking were to be used as a future screening measure, the practicality of having no sound in the videos should be considered. Young infants have shorter attention spans than their older counterparts, as noted by this study. Multiple participants that we had also had a difficult time attending to the videos because of an absence of sound. If this measure were to ever be used as a screening measure, the lack of sound may impact the accuracy of identification. A more accurate method of identifying ASD is the main focus of this study and previous research, but the lack of sound may impede on the accuracy.

Summary

Previous research has simply defined social stimuli as children moving around on a screen and nonsocial as geometric shapes floating around a screen (Franchini et al., 2016; Nakano et al., 2017; Pierce et al., 2011; Pierce et al., 2016; Shaffer et al., 2017). There may have been confounding variables within the previous studies that attributed to the preferences found within the children with ASD such as color, contrast, and number of objects on the screen. Instead of solely relying on the adult hypotheses of what social is for a young child with ASD, future research should attempt to narrow down what the children with ASD really prefer within the videos.

It was hypothesized that the children with ASD would prefer the inverted and blurred videos over the geometric. This finding would have aligned with previous research on blurred face preference and the inversion effect. However, this prediction was not supported by the current study. The children with ASD did not display higher looking percentages or number of saccades for any of the videos. This means that for the current study, there was nothing within the videos that the children with ASD found to be more interesting. This finding calls into question what the children with ASD could really be preferring in the previous literature. In spite of this, is does seem that eye tracker has the potential to be an effective future screening measure for Autism Spectrum Disorder.

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APPENDIX A

CONSENT FORM

Informed Consent Form

Title of the Study: Gaze patterns of social and non-social stimuli: A possible early marker for autism spectrum disorder

Purpose of the Study: You and your child are invited to participate in a study being conducted by Dr. Elizabeth Nawrot, Professor of Psychology, Rachel Stotts, Assistant Professor and Clinical Supervisor in the Speech, Language Hearing Sciences, and Ashley Doll, Graduate Student in School Psychology. We are investigating the developmental patterns of visual attention to social and non-social stimuli in typically-developing children and those with a previous clinical diagnosis of autism spectrum disorder (ASD) by parental report. Children with ASD, as well as typically developing children have been invited to participate. We will not be assessing you child's risk for any developmental disorder or making any clinical diagnosis of ASD.

What you and your child will do in this study: Parents will be asked to do a brief questionnaire relating to their child's developmental stages and report whether their child has previously received a clinical diagnosis of ASD. Children will watch a series of short video clips while their visual attention is tracked using remote infra-red eye tracking. The eye tracker uses light reflect from the child's cornea and pupil to track their gaze as they watch the video. Your child will be with you the entire time and either sit on your lap or a small chair during the video presentations. A debriefing session in which the particulars of the study are explained will be held immediately following the experiment. The study will be carried out in the MSUM Child Development Lab in Bridges Hall 358.

Time required: This study takes place in one session and is expected to last about 30 minutes.

Risks and benefits of participation: We do not expect you or your child to experience any undesirable consequences as a result of participation in this study. However, you are free to end your participation at any time. We hope that you and your child will find this an enjoyable and educational experience and that it will help you to better understand your child's development. We will offer you a token for you child (a small toy or book) as compensation for your time.

Confidentiality: The responses in this study are being collected for research purposes only. Results from this study are not intended for diagnosis or treatment of any kind. You will not be able to see you and your child's individual results, data will only be made available in summary form. Records of you and your child's responses will be stored in the offices or laboratories of the investigator, and will be made available only to researchers directly involved in the study. Response sheets are coded anonymously, and you and your child will not be personally identified in any report or publication resulting from this study.

Participation and Withdrawal: You and your child's participation is voluntary. Your decision whether or not to participate in this study will not affect you or your child's future relationships with MSUM. If you decide to participate, you and your child are free to discontinue participation at any time without prejudice.

Contact: Please feel free to ask questions now or at any time during the study. If you have additional questions about the experiment, you can contact Dr. Elizabeth Nawrot in the Psychology Department, office: Br 360 K, phone: (218) 477-4079, and email: nawrot@mnstate.edu.

Whom to contact about your rights in this experiment: You may contact Dr. Lisa Karch, Chair of MSUM Institutional Review Board at lisa.karch@mnstate.edu or (218) 477-2699.

If you feel that you are experiencing adverse consequences from this study: Adverse consequences are not expected, but if concerns arise as a result of participating in this experiment, please contact the Principal Investigator for referral.

Agreement: Your signature below indicates that you agree to participate in the study. Your signature also indicates that you give permission for your child (under the age of five years old) to participate. Your child's active participation in the study implies their assent, however you may withdraw permission and end their participation at any time. You also agree to give us permission to show any recording made of you and your child to students and faculty collaborators, and for education audiences including conference presentations (no identifying information accompanies the recordings). You understand that you and your child are free to withdraw at any time without incurring any penalty.

Parent Name (print) Parent Signature Date

Child Name Child DOB

APPENDIX B

DEMOGRAPHIC FORM

Demographic Information Form

Title of Study: Gaze patterns to social and non-social stimuli: A possible early marker for autism spectrum disorder (ASD)

Instruction: This form is to be filled out by the parent or legal guardian of the child participating in this study. Please do not write your name or your child's name anywhere on this form. Your answers will remain confidential and anonymous. For each item, please read the question carefully and select *one* answer that best describes you and your participating child.

*This first section is about **you:**

1. **What is your relationship to the child in this study?**
 ☐ Mother ☐ Father ☐ Other

2. **Please select the category that includes your age.**
 ☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65 or above

3. **What is your gender?**
 ☐ Female ☐ Male ☐ Other ☐ Prefer not to answer

4. **What is your marital status?**
 ☐ Single ☐ Married ☐ Separated ☐ Divorced ☐ Widowed

5. **With which racial or ethnic category do you identify?**

 ☐ African American ☐ Asian/Pacific Islander ☐ Caucasian ☐ Latino

 ☐ Native American ☐ Other ☐ Prefer not to answer

*Please answer the following questions about **your child.** According to Parent/Guardian Report:

6. **Is your child typically developing and meeting appropriate milestones?** ☐ Yes ☐ No

 If NO, please explain:
 ____

7. **Does your child have any known physical or cognitive impairments?** ☐ Yes ☐ No

 If YES, please explain:
 ____

8. **Were there any complications during labor or delivery?** ☐ Yes ☐ No

 If YES, please explain:
 ____

9. Does your child have a diagnosis of Autism Spectrum Disorder? □ Yes □ No

If YES, please explain: ____

10. Does your child participating in this study have an immediate family member (parent sibling, grandparent) with a medical diagnosis of Autism Spectrum Disorder (ASD): □ Yes □ No

If Yes, please indicate that family member's relationship to the child participating in this study: ____