EYE-GAZE PATTERNS DURING LIVE SOCIAL INTERACTIONS IN CHILDREN WITH AUTISM SPECTRUM DISORDERS

by

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A DISSERTATION

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Children with autism have been shown to demonstrate deficits in their facial processing skills and are known to make less eye contact than typically developing children. It has also been assumed that children with autism are more anxious during social interactions than typically developing children. It has been hypothesized that these deficits manifest themselves as the use of a localized facial processing style in which children with autism focus primarily on the mouth and miss much of the pertinent social information conveyed by the eyes.

More recent research, however, has found contradictory evidence. Specifically, some studies have shown that children with autism look at the eyes as often as their peers when viewing happy faces, and other studies have found that the eye-to-mouth gaze ratio is the same as that of typically developing children, but those with autism tend to focus more on non-social background stimuli. Some studies have found that children with autism are not more anxious during social situations than typical children, and there have been a variety of methodologies employed in all of these studies.

This study seeks to utilize eye tracking technology, real-time physiological measurements, and live social interactions to compare eye gaze patterns and
physiological reactions between children with autism and typically developing children.

The researchers found that children with autism tended to exhibit very similar total percentages of interaction time fixated on the eyes, mouth, and non-face areas when compared to their peers, and they did not exhibit different levels of anxiety during either familiar or unfamiliar interactions. However, children with autism exhibited significantly shorter look durations to the eyes when compared to their peers.

These results suggest that children with autism are having difficulty understanding social information because they are constantly switching their attention to and from the eyes, rather than focusing for longer on the eyes and processing the social information they convey. Future studies should replicate these findings with larger samples and various social scenarios.

Keywords: autism, eye-tracking, attention, anxiety, FaceLab™, VivoMetrics
DEDICATION

This dissertation is dedicated to my parents, Richard and Marilyn Gower, my brother, Daniel Gower, and my dog, Marley, for their love and continual support throughout the process of completing my doctorate. I truly would not have been able to do it without all of you. I love you all.
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INTRODUCTION

The first population-based study ever done of the prevalence of Autism Spectrum Disorders (ASD) cited their prevalence as being 4.5 per 10,000 individuals (in Yeargin-Allsopp, 2002). More recent reports cite the prevalence of Autism Spectrum Disorders (ASD) as being 1 per 88 children in America, and 1 in 54 boys and 1 in 252 girls (Centers for Disease Control and Prevention, 2012). Partly due to this drastic increase in estimated prevalence rates, there has been a marked rise in interest in these disorders, including ways to identify children with autism as early as possible, the effects of early intervention on these disorders, and different patterns of behavior observed in individuals with ASD. These studies have found that individuals with autism show a number of characteristic impairments, such as atypical facial processing abilities and deficits in social and communication skills (Boucher & Lewis, 1992; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Frith, 1989; Kanner, 1943). With advances in knowledge of these impairments in ASD came advances in the technology used to study them, giving rise to a body of literature that utilizes eye-tracking technology to assess facial scanning patterns and even anxiety levels in order to further the literature relating to these disorders and their associated areas of difficulty (Chawarska & Shic, 2009; Freeth, Chapman, Ropar, & Mitchell, 2009; Hernandez, Metzger, Magné, Bonnet-Brilhault, Roux, Barthelemy, & Martineau, 2008; Riby & Hancock, 2008).
In many ways, eye-tracking technology appears to hold a great deal of promise for the future of autism research. However, it has also posed a number of difficulties that must be overcome before its potential is maximized. Specifically, results of many eye-tracking studies have contradicted some of the long-standing beliefs regarding the disorder. It has long been thought that individuals with ASD, when presented with a picture of a face, will typically look more at the lower half of the face (e.g. mouth) (Freeth et al., 2009; Hernandez et al., 2008), compared to typically developing peers, who look at the upper half of the face (e.g. eyes) more (Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002). If true, this would mean the children with autism are not attending to the area of the face that provides the most useful social cues and emotional information – the eyes (Neumann et al., 2006). However, some more recent eye-tracking studies suggest that children with autism attend to the eyes as much as their typically developing peers (Speer, Cook, McMahon, & Clark, 2007; van der Geest, Kemner, Verbaten, & van Engeland, 2002). Another barrier to progress in eye-gaze research is the fact that there are very few standardized guidelines for conducting this type of research consistently. As a result, most studies vary greatly in their methodologies, and stimuli are often unrealistic or cannot be generalized to other situations. For example, most studies with eye-tracking have used static images of faces as stimuli out of necessity (e.g. difficulty of calibrating a moving target, etc.), but static images are not encountered in real-world social scenarios, and thus will not suffice if conclusions about live social interactions are to be drawn.
This study seeks to resolve some of these obstacles in eye-tracking research by tracking facial scanning patterns and physiological anxiety levels in children and adolescents with and without ASD during a live social interaction. Before describing the study in detail, however, it is necessary to review the relevant literature related to attention and cognition, facial scanning patterns, and social and communicative difficulties associated with individuals both with and without ASD, as well as summarize the eye-tracking literature, its limitations, and its methodological differences upon which the current study hopes to improve.

Attention and Cognition

For nearly the last half-century, developmental psychologists have become increasingly interested in learning how people’s cognitive abilities develop over time, with particular interest in development during infancy. Many of these studies have focused on specific areas of cognition, including memory, higher-order reasoning, and category acquisition, as well as sensation and perception (including multimodal and cross-modal perception) (Colombo, 2001). In the mid- to late-1990’s, many researchers began to note that knowledge of the development of visual attention is responsible for many advances in the aforementioned areas of research. The body of cognitive-developmental literature has since reflected an increased interest in the development of visual attention skills (Colombo, 2001).

This burgeoning field of cognitive neuroscience has shed a great deal of light on the development of visual attention by incorporating well-established information regarding the functions of specific areas of the brain with visual
attention research, including measures of both covert and overt attention (Csibra et. al, 1997; Mundy & Jarrold, 2010; Posner & Petersen, 1990; Richards, 2003; Richards, 2005). Covert attention refers to attentional behaviors or events that can be measured prior to any visible eye movements toward a stimulus. Overt attention includes directly observable attentional behaviors, including looking at or orienting towards a target stimulus.

What is Attention?

While attention may appear to be an easily defined concept, the great increase in visual attention research resulted in an increase in the number of theories, conceptualizations, and definitions of what constitutes and affects “attention.” For example, researchers have specified different kinds of attention based on a person’s motivation for attending to a stimulus. People can engage in voluntary attention, during which they willfully attend to a stimulus, or involuntary attention, during which they attend to a stimulus automatically, without putting forth a conscious effort to do so. Additionally, individuals can attend to a number of different stimuli, including visual, auditory, and tactile stimuli.

Processes of Attention

Because the study of attention can be approached in so many ways, researchers have attempted to define a number of skills that fall under the general category of visual attention processes. Not surprisingly, there now exists a variety of conceptualizations of attention processes, many of which are defined in distinct,
yet somewhat related, terms. Some of these processes include focused attention, sustained attention, selective attention, and joint attention. Traditionally, psychologists have measured these constructs by measuring overt behaviors, such as calculating the amount of time an individual spends attending to particular aspects of visual stimuli he or she is presented, a measure often referred to as “looking time.” Frequently, however, the participants of a study do not attend to the stimuli for the same amount of time. For this reason, looking time is typically converted into percentages to allow comparison among individuals of varying attention spans. In the area of cognitive neuroscience, visual attention is typically measured more covertly, often utilizing technology that allows researchers to measure events that are unobservable to the naked eye, such as concentrations of neurotransmitters in particular areas of the brain and what pathways, if any, these neurotransmitters follow (Csibra et al., 1997; Richards, 2003; Richards, 2005; Tang, Rothbart, & Posner, 2012).

**Models of Attention Development**

Given the wide variety in the definitions involved in and approaches to visual attention research, scientists have struggled to generate a single, unified conceptualization of the development of visual attention. However, there are a number of popular working models of the development of visual attention, two of which will now be presented. Both of these models, as well as the studies from which they were derived, support the idea that visual attention throughout the
lifespan is impacted by a number of independent factors, each of which is possibly mediated by a corresponding pathway in the brain.

Colombo's Triphasic Developmental Model

In a review of the visual attention literature, developmental psychologist John Colombo proposed a conceptual model for understanding how visual attention develops during infancy by utilizing concepts drawn from a number of current studies and models.

He identified four factors as being particularly relevant to the development of early visual attention skills. Research has shown each of these factors to develop at different rates over the first years of life and each factor interacts with the others to affect visual attention (Colombo, 2001).

The first factor Colombo identified was “alertness,” which refers to a state of arousal involving preparedness for some kind of sensory input and is sometimes referred to as “anticipatory readiness.” The second is “spatial orienting,” or a person’s ability to select a particular locus or stimulus on which to focus his or her attention. Third, he identified “object attention” as looking at a specific visual stimulus, a behavioral precursor to the identification and recognition of visual stimuli. Finally, “endogenous control” refers to aspects of attention related to volitional, or willful, direction of attention to a chosen locus or stimulus.

Based on previous research, Colombo concluded that visual attention follows a “triphasic” developmental trajectory over the first year of life (2001). That is to say that there are three distinct phases of visual attention development during the
first 12 months. The first period is from birth to two months of age, during which infants learn to attain an alert state. The second is from two or three months to six months of age, during which spatial orienting and object attention develop. Finally, from six months of age and beyond, infants begin to develop endogenous control (Colombo, 2001).

Therefore, at very young ages, visual attention is often controlled more by external, or exogenous, events than by internal motivation to attend to a stimulus, as well as the varying levels of maturity of each of the four previously discussed factors. Colombo (2001) hypothesized that because infants experience more exogenous than endogenous control, an ascending pathway (meaning a pathway in which lower-order functions performed by subcortical structures control higher-order functions in the cortex) in the brain controls their visual attention. In adults, who exert much more endogenous control on their attention, it stands to reason that these pathways would primarily be descending rather than ascending, meaning that higher-order structures, such as the frontal cortex, control lower-order functions such as shifting or sustaining attention. In other words, at some point in human development, a person’s state of arousal becomes modulated more by volitional, or endogenous, control. This supports Colombo’s Triphasic Model because endogenous control does not begin to develop until the second half of the first year of life and continues to develop over time (Colombo, 2001; Wainwright & Bryson, 2002; Wainwright & Bryson, 2005). When the relationship between the development of anticipatory readiness or “alertness” throughout the lifespan and the ascending noradrenergic pathway is considered, it becomes clear that
behavioral and neurological studies can be utilized in concert to better understand the development of visual attention.

_Porges's Polyvagal Theory_

While Colombo (2001) focused on the development of visual attention during infancy, Porges (1995, 2001) concentrated on the development of behaviors relating to social engagement. The development of appropriate social skills requires the ability to engage another person in a social interaction. In order to succeed at this, a specific type of attention, known as joint attention, must be attained. Joint attention is the ability to share attention (meaning engaging, disengaging, and switching focus of attention) between an object of interest and one or more other people. Not only this, but the initiation of social interactions also requires the ability to voluntarily focus on an object, inhibit the desire to attend to other objects, and direct the attention of another person to the object of interest. Given the knowledge related to the neurological pathways mentioned above, Porges set out to conceptualize how pathways related to attention might also relate to social development.

The result of his work is the Polyvagal Theory of social engagement, which states that behaviors that are positively associated with social development are fostered when an individual finds him- or herself in a safe environment and a calm visceral state (Porges, 1995; Porges, 2001). Further research led Porges to propose that these social behaviors are regulated through an integrated Social Engagement System (SES; 2003). The SES can be broken down into visceromotor and somatomotor components, according to Porges, with the visceromotor component
controlling involuntary physical reactions, such as heart rate, and the somatomotor component controlling observable behaviors, including looking time and eye contact (Porges, 2003). The sensory center of the visceromotor component is a subcortical structure in the medulla known as the Nucleus Tractus Salitarii (NTS), which is known to relay visceral information via ascending cholinergic pathways to upper brain cholinergic systems, including the septum and basal forebrain. Research has linked both the septum and basal forebrain in attentional, cognitive, and motivational processes (Bazhenova et al., 2007; McGaughy, Dalley, Morrison, Everitt, & Robbins, 2002; Sarter & Bruno, 1997; Sarter, Givens, & Bruno, 2001; Wenk, 1997). Based on the results of these studies, social engagement and social skills can be linked empirically to one’s ability to engage in particular behaviors related to visual attention.

Correlates of Visual Attention

Researchers hypothesized that measures of visual attention might serve as a predictor of development in other areas. Indeed, visual attention has been shown to be an accurate predictor of a number of indices of performance on a variety of psychological measures, including social competence, language skills, and current and future cognitive abilities (Colombo & Mitchell, 1990; Rose & Feldman, 1990; Ruddy & Bornstein, 1982).
Social and Communicative Correlates

In infant populations, vestibular or tactile stimulation typically induces a state of alertness (Becker et al., 1993; Korner & Grobstein, 1966). This could be related to the fact that the structures of the neurological pathways extending from the brainstem are involved in processing all kinds of sensory stimulation in addition to their specific roles in processing visual stimuli. Indeed, investigators have found that the visual responses of newborns and 1-month-old infants to visual stimuli of varying levels of complexity, motion, or novelty can be strongly influenced simply by manipulating the infant’s state of arousal or by stimulating non-visual sensory modalities, such as touch (Colombo, 2001).

Some studies have related activity in the frontal cortex to the modulation of how rewarding engaging in joint attention is for an individual (Mundy et al., 1992; Mundy, 1995; Mundy, Card, & Fox, 2000). In other words, the activation of the frontal cortex that occurs when an individual is engaged in a social interaction may also activate a system in which engaging in social interactive behavior becomes positively reinforced.

Other studies have relied on overt behaviors when relating attention to social development. Sheinkopf and colleagues (2004) conducted a study of joint attention in infants prenatally exposed to cocaine and their developmental outcomes at 3 years of age. They specifically looked at how initiating joint attention (IJA) and responding to joint attention (RJA) affect social development. Seibert, Hogan, & Mundy (1982) defined IJA as engaging in joint attention with another person specifically for the purpose of “social sharing” (e.g. showing a toy, pointing out
something they enjoy so you can enjoy it, as well), rather than initiating joint
attention for instructional or instrumental purposes (e.g. pointing at the bottle to
request a drink). RJA was defined as shifting attention to an object by following
another person’s gaze or point (Seibert et. al., 1982). These definitions are still used
and expanded on today (Mundy et. al., 2009). Sheinkopf and colleagues found that
IJA was a positive predictor of an infant’s social development (Sheinkopf et al.,
2004). Join attention has also repeatedly been shown to be a positively related to
language and communicative development beginning as early as three to four
months of age and continuing throughout childhood (Ulvund & Smith, 1996; Mundy
& Gomes, 1998; Kasari et. al., 2012; Baranek et. al., 2013; Oller et. al., 2013).

Other research involving joint attention and social competence has compared
children diagnosed with autism, a disorder characterized by deficits in social skills,
to those with disorders that are not characteristically social in nature. For example,
Sigman & Ruskin (1999) compared children with autism to those with Down
Syndrome and developmental delays. Their results indicated that the children with
autism showed significantly lower social competence than either the children with
Down Syndrome or those with developmental delays. This finding was due to the
relatively lower rates of both responding to and initiating bids for joint attention in
the children with autism.

Norbury and colleagues (2009) conducted a study of communicative and
social competence in teenagers with autism. Their results suggested that the
percent of time participants spent fixated on particular regions of the face was
associated with communicative, but not social, competence, as measured by the
Cognitive Correlates

The well-established connection between engaging in various forms of attention, particularly joint attention, and future cognitive status, dates back as far as the early 1980’s (Ruddy & Bornstein, 1982). Subsequent studies have focused on determining which specific features of attention are responsible for its ability to predict cognitive ability (Colombo & Janowsky, 1998; Colombo & Frick, 1999). Research on infant states of arousal has consistently shown that early state-organization is correlated with better cognitive performance both concurrently and in the future (Colombo & Mitchell, 1990; Rose & Feldman, 1990; Ruff, 1990). In other words, the ability to regulate one’s arousal, including alertness, positively predicts current and future cognitive functioning.

Ulvund & Smith (1996) found that initiation of communicative behaviors, particularly joint attention, was a significant predictor of cognitive ability at five years of age in low birth weight Norwegian babies. For this population, initiation of joint attention predicted cognitive status at five years of age better than the cognitive index on the Bayley Scales of Infant and Toddler Development. Other studies have consistently shown a relationship between joint attention and later language and cognitive abilities (Adamson et al., 2004; Carpenter et al., 1998; Delgado et al., 2002; Mundy & Gomes, 1998; Smith & Ulvund, 2003; Tomasello & Todd, 1983). In fact, initiation of joint attention is such a strong predictor of
cognitive ability that it has been used to assess the efficacy of early cognitive development interventions (Colombo, 1997).

Knowing how visual attention correlates to this wide range of functioning in other areas highlights the fact that individual differences in behaviors, including the regulation of alertness and initiating joint attention, may serve to explain the difficulties experienced in many clinical populations. As a result, some researchers have shifted focus from understanding what constitutes typically developing visual attention to investigating what, if any, clinical populations might exhibit atypical visual attention patterns. The result is a growing body of literature of studies investigating differences in visual attention in individuals with schizophrenia, prosopagnosia, and other psychological or developmental disorders (Gooding & Basso, 2008). In recent years, there has been a dramatic increase in the study of Autism Spectrum Disorders (ASDs) because of the characteristic social and communicative deficits observed in individuals on the spectrum.

**Autism Spectrum Disorders**

Compared to some psychological or developmental disorders, which have been documented since the 19th century, such as psychosis or schizophrenia, Autism Spectrum Disorders are relatively new concepts in the psychological literature. Early accounts of children with ASD often described them as appearing to have a form of childhood schizophrenia. “Autism” was first described in 1943 by Austrian psychiatrist and physician, Dr. Leo Kanner. In his seminal paper, Kanner described eleven cases of children he had treated beginning in 1938 who exhibited symptoms
that differed “markedly and uniquely from anything reported so far” in the psychological literature (Kanner, 1943). The hallmark features these cases shared were impaired social and communicative functioning. Often the individuals exhibited restricted and repetitive behaviors, in the form of hand flapping, spinning, or compulsive and ritualistic behaviors.

After Kanner presented these case studies, interest in children exhibiting this behavioral phenotype began to rise, and epidemiologists began to inquire about the prevalence of autism. Lotter (1996) performed one of the first population-based studies of the prevalence of autism and estimated that 4.5 in 10,000 children born would be diagnosed with autism, and other studies using the same diagnostic criteria found similar prevalence rates (see Fombonne, 2002 and Yeargin-Allsopp, 2002 for in-depth reviews). On the other hand, more current estimates state that as many as 1 in every 88 children born in America will have a diagnosis on the autism spectrum, however these prevalence rates varied significantly (between 4.8-21.2 per 1000 children) across research sites (CDC, 2012).

There are a number of reasons why this dramatic increase in ASD prevalence has been found over such short time. For example, current estimates have acknowledged that it is possible to have an ASD that co-occurs with another disorder, such as Down Syndrome or Fragile X, whereas earlier estimates considered it impossible for individuals with these genetic disorders to also have an ASD. Another possible explanation is that recent estimates have focused on Autism Spectrum Disorders, rather than the specific diagnosis of Autistic Disorder. In the past, autism was used as a broad, rather poorly defined term that was typically only
applied to the most severe of cases, such as those Kanner described, that exhibited a
great deal of delayed echolalia, verbal rituals, stereotyped behaviors, and hand and
finger mannerisms. With the increased attention to this population, researchers
have developed much better conceptualizations of these individuals, resulting in the
idea of the “autism spectrum.” The term spectrum was applied to these individuals
to acknowledge that there are a range of individual differences that make one
explicit diagnosis difficult.

Currently, the autism spectrum is described in the DSM-IV under the
Pervasive Developmental Disorder section (American Psychological Association,
2000). This section includes 5 developmental disorders: Autistic Disorder, Asperger
Syndrome, Pervasive Developmental Disorder - Not Otherwise Specified (PDD-NOS),
Childhood Disintegrative Disorder, and Rett’s Syndrome. The autism spectrum
contains only the first three of these disorders, because the latter two are
characterized by typical development until a certain point, followed by a severe
regression in all skills. Individuals with ASDs, on the other hand, typically exhibit
developmental delays very early in life. The DSM-IV specifies that an individual
must exhibit deficits in three areas of functioning to receive a diagnosis on the
spectrum: social skills, communication, and restricted and repetitive behaviors. A
child’s particular diagnosis within the spectrum depends on the combination of
specific deficits within these areas, as interpreted by the clinical evaluator
Association, 2013) was not used because it had not been published at the time this
study began.
Facial Processing Deficits and ASDs

Kanner (1943) noted that the children described in his paper appeared to make less eye contact and pay less attention to faces and other sources of social information than their typically developing counterparts. Research on people with ASDs has continually noted deficits in the ability of these individuals to process facial stimuli and to respond appropriately to social information (Dawson et al., 1998).

Before discussing the deficits related to facial processing in ASDs, however, it is necessary to define facial processing and briefly discuss its history. “Facial processing” refers to the sequence of events involved in perceiving and recognizing a face. Studies of facial processing skills have utilized behavioral as well as neurological measures to assess a variety of areas, including facial recognition skills and facial scanning and processing patterns. When the study of facial processing skills was in its infancy, many studies focused on behavioral measures, because they were overt and rather simple to assess. In infant populations, much of this research has dealt with the concepts of habituation, inhibition, look duration/latencies, etc. (Colombo, 2001; Dawson, Carver, Meltzoff, Panagiotides, McPartland & Webb, 2002, 2002; Dawson, Toth, Abbott, Osterling, Munson, Estes, et al., 2004). Older children, adolescents and adults, however, are often asked to perform a task in response to particular stimuli (e.g. match a face with a target face, answer questions based on stimulus, etc.), because they have the language skills to understand directions and respond verbally. As both knowledge of facial processing and technology have grown, more and more studies have begun to utilize more covert measures,
including neurological imaging and physiological measurement techniques. These experiments have taught us what constitutes the typical development of facial recognition skills, as well as what specific skills are lacking in a number of disabilities and disorders, including Autism Spectrum Disorders.

Behavioral data suggest that facial processing deficits are present in individuals with ASDs. For example, Boucher and Lewis (1992) discovered that children with autism did not match unfamiliar faces as well as an IQ-matched control group. Interestingly, though, the participants with autism did not show deficits in matching objects such as houses or buildings (Boucher & Lewis, 1992), suggesting that their visual processing difficulties are specific to facial stimuli. In 2008, Scherf et al. published a study that found that both children and adults with autism were not able to recognize faces and face-like stimuli (called “greebles”) as well as typically developing individuals. This study suggests that individuals with ASD exhibit a generalized deficit in visual processing throughout their lives. The authors also hypothesized that this deficit may specifically be related to the ability to undertake configural processing, which is a kind of processing that allows for discrimination between the subtle metric differences in the position of a face’s features (e.g. eyes, mouth, nose) (Scherf, Behrmann, Minshew, & Luna, 2008). This means that individuals with ASD may specifically have trouble discriminating two faces because they cannot distinguish the very slight differences in facial feature orientation, while they do not have difficulty distinguishing non-facial stimuli because of their relative heterogeneity. For example, a face is always structured the same way – two eyes that lie above a nose that lies above a mouth – making all faces
very similar in their shape and configuration. However, a non-face object, such as a house, can take numerous shapes and configurations and are thus more easily distinguished.

Other studies utilizing behavioral measures have presented images of inverted or scrambled faces to individuals with and without autism. For typically developing individuals, discriminating inverted and scrambled faces is much more difficult than discriminating upright, normal looking faces. However, research with populations of individuals with autism has found that they do not demonstrate the same decrement in discriminatory ability with inverted or scrambled faces (Teunisse & de Gelder, 2003; Maurer, le Grand, & Mondloch 2002; Tantam, Monaghan, Nicholson, & Stirling, 1989). These results were surprising, given that individuals with ASD typically show poorer performance than their typically developing counterparts on facial recognition task. To explain why individuals on the spectrum demonstrate better performance discriminating the more complex inverted and scrambled facial stimuli, researchers began investigating the visual scanning and processing patterns that occur in people with and without ASDs.

The results of these studies show that typically developing individuals tend to use what is known as a globalized, or “top-down,” processing style (Frith, 1989; Joseph & Tanaka, 2003; Klin et al., 2002; Pelphrey, Sasson, Reznick, Paul, Goldman, & Piven, 2002; Sekuler, Gaspar, Gold, & Bennett, 2004; van der Geest et al., 2002). The name “top-down processing” refers to the idea that the higher-order structures in the brain (e.g. frontal cortex) control the functioning of lower-order structures (e.g. subcortical areas such as the thalamus). In this style of processing, individuals
focus on the whole stimulus, such as a face, and voluntarily shift their attention between areas of interest (e.g. eyes, nose, mouth) to discriminate it from another face. Individuals with autism spectrum disorders, on the other hand, have been shown to use a localized, or “bottom-up,” processing style. In this type of processing, visual scanning is less endogenously driven and more exogenously driven. In other words, sensory input to subcortical structures controls higher-order functions in the brain (e.g. inhibition, sustained attention, etc.). Therefore, when using this type of processing, attention is often drawn to a small (local) area of high contrast (e.g. mouth). This phenomenon can explain the differences observed in the scrambled and inverted facial stimuli tasks because individuals with autism are able to discriminate local areas of the face better than their typically developing peers, who tend to focus on the entire face and are more distracted by the “noise” of the scrambled and inverted faces.

There has also been a great deal of neurological research on individuals with ASDs suggesting that deficits in facial processing are due to specific impairments in the areas of the brain involved in the processing of facial stimuli. In 2005, Dawson, Webb & McPartland found that individuals with ASDs demonstrate abnormal patterns of electroencephalographic (EEG) activity when viewing static images of faces. Before that, a few studies of people with autism found decreased activity compared to typically developing controls in an area in the right hemisphere of the brain known to be integral in the processing of facial stimuli, called the fusiform face area (FFA) (Pierce et al., 2001; Schultz et al., 2000). However, some more recent studies have refuted this research, citing that when the eye movements of children
with ASDs are controlled for, all differences disappear (Koldewyn et al., 2013a; Koldewyn et al., 2013b).

The superior temporal sulcus (STS) is a portion of the brain involved in detecting facial movements, such as eye gaze (Allison, Puce, & McCarthy, 2000; Puce et al., 1998; Winston et al., 2002). Studies using magnetic resonance imaging (MRI) have found the STS to be anatomically displaced to the anterior and superior areas of the brains of individuals with ASD compared to typically developing controls (Levitt et al., 2003). Additionally, studies using functional MRI technology (fMRI) have revealed greater activation of the STS in typically developing individuals compared to those on the spectrum (Pelphrey et al., 2005). Some researchers have noted increased gray matter, both overall and in specific areas of the brain, of individuals on the spectrum, including the right superior temporal gyrus (Waiter et al., 2004). It should be noted, however, that other studies have found contradictory results, including decreased gray matter in the STS of individuals with ASDs (Boddaert et al., 2004). Finally, a number of studies using event-related potentials (ERP) have noted differential activation patterns in a variety of areas of the scalp that may reflect unique processes in the brains of individuals with autism when interpreting social information (Golarai, Grill-Spector, & Reiss, 2006).

Reasons for Facial Processing Impairments in ASDs

As studies replicated the findings that individuals with ASDs tend to use localized, “bottom-up” processing styles, researchers began to ask why these people might be drawn to look at local areas of a stimulus, such as the mouth. A few
theories arose as possible explanations. One view maintains that these individuals are more attracted to the mouth (i.e. exogenous control) than the eyes because the mouth provides more salient input that involuntarily draws the person’s attention to it (e.g. vocal emission and movement) (Neumann et al., 2006). In a similar, yet distinct, vein, another assertion states that because the social information provided by the eyes is more difficult to interpret for someone with an ASD, people on the spectrum intentionally direct their attention (i.e. endogenous control) to the mouth as a compensatory mechanism for extracting the social information they could not glean from the eyes (Neumann et al., 2006). More recently, however, researchers have hypothesized that individuals with ASDs are not actually using bottom-up processing because they are more sensitive to it or prefer to use that style, but rather they experience specific deficits in their ability to use a top-down processing style, limiting them to the use of a bottom-up processing style (Neumann et al., 2006). In other words, children with autism may not be voluntarily choosing to focus on the mouth, but rather have no choice but to utilize a localized processing style due to an inability to utilize a top-down style.

The idea that deficits in neurological functioning result in the reliance on bottom-up processing in ASD is not a new concept. In 1989, cognitive developmental psychologist Uta Frith published a book titled *Autism: Explaining the Enigma*, in which she outlined the atypical cognitive development of individuals with ASD and the resulting manifestation of difficulties with communication and social interactions. In this book, she outlined two fundamental abilities that are impaired in individuals with autism. The first was Theory of Mind (ToM), or the
ability to take another person’s perspective or understand that their thoughts may be different from one’s own. The second ability she discussed was the ability to amalgamate various pieces of information into a coherent whole, referred to as Central Coherence (CC). Because individuals with ASD have difficulty with this, they are unable to engage in globalized, top-down processing, and as a result must rely on localized, bottom-up processing. This theory is known as the Weak Central Coherence Theory (Frith, 1989) and has remained a popular theory to help explain the facial processing deficits in ASD (Joseph & Tanaka, 2003; Klin et al., 2002; Pelphrey et al., 2002; Sekuler et al., 2004; van der Geest et al., 2002).

Some researchers have supported a third explanation for these impairments in facial processing that involves one’s level of arousal and the autonomic (involuntary) nervous system (ANS). Researchers in this camp postulate that individuals with ASDs experience significant anxiety and stress when engaging in eye contact or other social situations (Kylliainen & Hietanen, 2006; Dalton et al., 2005). According to Shields (1993), the level of involuntary activity in multiple organ systems is dependent upon the balance of inhibitory and excitatory input from both the parasympathetic and sympathetic divisions of the ANS. This balance prepares an individual to react appropriately according to the incoming information. The anxiety experienced by people with ASDs is thought by many to be the manifestation of atypical functioning of the ANS (Hirstein, Iversen, & Ramachandran, 2001).

Evidence supporting this hypothesis comes from studies that have shown atypical patterns of arousal in individuals with ASDs. People diagnosed with ASDs
have been found to experience reduced levels of both the quality and the amount of their sleep when compared to typically developing peers (Williams, Sears, & Allard, 2004). Additionally, many studies have demonstrated that individuals with ASDs exhibit heightened ANS responses compared to their peers while at rest, including increased skin conductance (Hirstein et al., 2001; Zahn, Rumsey, & Van Kemmen, 1987), heart rate (Hirstein et al., 2001; Ming et al., 2005), blood pressure (Ming et al., 2005), and respiration rate (Zahn et al., 1987).

However, other studies seem to offer contradictory results. For example, Goodwin and colleagues (2006) found that people on the spectrum do not show an increase in heart rate in response to potentially stressful stimuli. Hirstein and colleagues (2001) noted that individuals with ASDs also do not show an increase in skin conductance when in the presence of other humans. Another difficulty researchers have faced when attempting to investigate anxiety levels during social interactions is that most of the aforementioned measures are also dependent on one’s body mass index (BMI; Nagai & Moritani, 2004; Pitzalis et al., 2000). Individuals with ASDs have been found to have significantly higher BMIs than control groups or normative values in a number of studies (Mraz, Green, Dumont-Mathieu, Makin, & Fein, 2007; Torrey et al., 2004; Webb, Nalty, Munson, Brock, Abbott, & Dawson, 2007), which might confound the previously reported findings.

There are some measures known to be correlated with ANS functioning, such as tonic pupil size, that are not as susceptible to being affected by one’s BMI. Some researchers have found significant differences between individuals on the autism spectrum and their typically developing peers on these measures, supporting the
theory of dysfunction within the ANS in ASDs (Anderson & Colombo, 2008).

Interestingly, however, few studies to date have assessed anxiety levels during actual social interactions, preferring instead to assess anxiety and physiological responses to static images of faces.

Eye-Tracking Technology and ASDs

Researchers have yet to find an agreed-upon model to explain the deficits in facial processing and social skills that individuals on the autism spectrum experience. Recently, there has been a growing trend emphasizing the use of eye-tracking technology in the investigation of patterns of attention, gaze shifting, and facial processing in individuals with autism. Many studies have begun to use eye-tracking technology to investigate the qualitative differences in the way typically developing individuals and those with autism attend to both social and non-social stimuli (Chawarska & Shic, 2009; Freeth et al., 2009; Hernandez et al., 2008; Riby & Hancock, 2008).

Boraston & Blakemore (2007) published a paper outlining some of the past research with eye-tracking technology, specifically in the study of autism spectrum disorders. In this paper, they explain two methods of tracking gaze behavior, including the illumination of the eye with infrared light and following the pupil and corneal reflection. Typically, these kinds of eye trackers operate at a frequency between 50 Hz-2 kHz and a spatial resolution between .005-.5 degrees of visual angle, although some can operate at frequencies up to 200 Hz (Boraston & Blakemore, 2007; Gramatikov et al., 2007).
Results of eye-tracking studies in populations with ASD have been mixed and have sometimes contradicted long-standing previous research findings. For example, recent studies utilizing sophisticated eye-tracking technologies have shown that individuals with ASD and typically developing individuals both spend relatively more time looking at the upper part of the face than the lower face (Freeth et al., 2009; Hernandez et al., 2008), except when viewing a happy face (Hernandez et al., 2008). These results are in direct contrast with previous studies of gaze behavior in individuals with autism, which maintain that people with autism prefer to look at the lower half of the face (particularly the mouth region), rather than the upper face (e.g. the eyes) which contains pertinent and informative social cues (Hobson et al., 1988; Joseph & Tanaka, 2003; Klin et al., 1999; Klin et al., 2002). Differences in methodology and population between these studies may underlie many of these effects. However, the lack of explanations for observed differences highlights the fact that the investigation of patterns of attention, particularly in children with autism engaged in live social interactions, has yet to be seriously assessed.

There are numerous limitations to the current body of literature in the area of eye-tracking and autism spectrum disorders. Most notably, only one study to date has investigated visual attention patterns during live interactions (Merin et al., 2006). This study found that visual fixation patterns in 6-month-old infants distinguished those at-risk for an ASD diagnosis from a comparison group during a modified, live Still Face Paradigm conducted via closed-circuit television (Merin et al., 2006). While this is a great improvement on the static and video stimuli typically
used, this method's ecological validity would be enhanced by conducting such interactions in person, rather than via closed-circuit television. Also, the fact that everyday social interactions are constantly changing may present a particularly difficult challenge for individuals with ASD in terms of the location and processing of social information. Freeth et al. (2009) noted that the more rapidly stimuli are presented (2 seconds per stimulus vs. 5 seconds per stimulus) to high-functioning adolescents with ASD, the more difficulty they have in locating and processing pertinent social information.

In 2002, Klin et al. used moving stimuli in the form of film clips depicting “intense social interactions.” These clips were presented to adolescents with and without ASD, and their gazes were recorded using an eye-tracking program. The results indicated that the teens with ASD looked at the eye-region of the faces far less than their typically developing peers. However, the results of the Freeth et al. (2009) study suggest that the act of processing the stimulus was made more difficult as a result of the presence of factors not present in real social situations (e.g. scene cuts and other editing techniques; social situations not directly involving the research participant). It is likely that these factors account for the differences in visual attention that were found, rather than an aversion to facial stimuli.

Another limitation of these studies is that very few of those utilizing eye-tracking technology have been conducted on child populations. Often, due to physical or technological limitations of the eye-tracking equipment, the researchers must recruit older, higher-functioning participants to overcome these problems. For example, some systems utilize a head-mounted camera system; others may
require a participant to remain fairly still while capturing data. Lower-functioning individuals with autism are more likely to have sensory, cognitive, and/or attention difficulties that would prevent them from tolerating head-mounted cameras or remaining still during testing. In such a case, higher-functioning adults with ASD would be able to wear a head-mounted unit, understand the instructions, and be able to remain still. Of the few studies involving eye-tracking in children with ASD (Riby & Hancock, 2008; Chawarska & Shic, 2009), the sole reliance on variations of static images as stimuli emerges as a limitation to the generalization of their results to real-world scenarios.

Research on individuals with ASD has found mental age to be a powerful predictor of overall social ability (Leekam et al., 1998). Because of this research, studies of eye-tracking in individuals with ASD has generally taken the precaution of matching participants with ASD to their typically developing peers based on a variety of factors, such as mental age, full-scale IQ, age and gender. These controls, while important, can become limitations in terms of the generalizability of the study’s findings to the population of people with ASDs.

The Current Study

This study attempted to explore the differences, if any, in gaze patterns between 8- to 14-year old children with and without ASD diagnoses. The researchers also investigated changes in measures of physiological anxiety levels in each of these populations. Children and adolescents were the population of interest because of the developmental focus of this research and because of the relative
dearth of information regarding these age groups compared to adults. Younger children were not included because of technological limitations.

Although the vast majority of research in this area to date has focused on the presentation of static images as social stimuli, the researchers regard these stimuli as unnatural and as limitations to the studies previously discussed. Also, given the research supporting differential patterns of gaze depending on the familiarity of the stimulus, the researchers utilized live, in-person conversations between the participants and both familiar and unfamiliar people as stimuli. This alteration to the methodology of previous studies served to make any findings more generalizable to real-world situations and to provide vital information regarding gaze behavior of individuals with ASDs during live social interactions. After all, live social interactions are far more common (compared to encountering static faces) and likely present greater difficulty in responding appropriately for those on the spectrum.

OBJECTIVES

Given that previous studies involving populations of individuals with Autism Spectrum Disorders have been inconsistent in their results with respect to eye-gaze patterns and attention to social stimuli, particularly human faces, the researchers sought to explore these behaviors in a population of 8- to 14-year-old individuals with and without ASD. Additionally, because many people who study autism have adopted the hypothesis that social interactions are intrinsically anxiety-provoking situations for children with ASD, despite a minimal body of literature, the objective
of this study was to investigate what differences in gaze patterns, attention, and anxiety levels, if any, exist between children and adolescents with Autism Spectrum Disorders and their typically developing peers while they are engaged in live social interactions. The researcher’s a priori hypotheses were as follows:

I. For eye-gaze patterns:

a. During live social interactions, children with autism will look less at the eyes and more at the mouth and non-face regions when compared to their typically-developing peers.

b. During live social interactions, all participants will look more at the eyes and less at the mouth and non-face regions during familiar interactions versus unfamiliar interactions.

c. During live social interactions, the effect of diagnosis on all three areas of interest (eyes, mouth, and non-face) will depend on the level of familiarity. Specifically, children with autism will perform more like typically developing peers when looking at all areas of interest during familiar interactions than unfamiliar actions. These hypotheses are based on previous research showing these results (Freeth et al., 2009; Hernandez et al., 2008, Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002).
II. For measures of physiology:

a. During live social interactions, children with autism will show higher levels of anxiety as measured by heart rate and respiration rate than typically-developing children.

b. During live social interactions, all participants will exhibit higher levels of anxiety during the unfamiliar interaction versus the familiar interaction.

c. During live social interactions, the effect of diagnosis on heart rate and respiration rate will depend on level of familiarity. Specifically, children with autism will exhibit similar levels of anxiety as the typically-developing children during the familiar, but not unfamiliar interactions. These hypotheses are based on previous research showing increased levels of anxiety and atypical nervous system functioning in children with autism (Dalton et al., 2005; Hirstein, Iversen, & Ramachandran, 2001; Kylliainen & Hietanen, 2006).

METHODS

Design

The investigators utilized seven 2x2 mixed subjects ANOVAs to investigate the previously discussed hypotheses. The between-subjects factor in each analysis were diagnosis (ASD vs. Non-ASD), and the within-subjects factor in each analysis was level of familiarity (familiar v. unfamiliar).
Three of these ANOVAs focused on the eye-gaze areas of interest, with the dependent variable in each of these analyses being percentage of time spent looking at the eyes, mouth, and non-face regions, respectively.

Two ANOVAs focused on measures of average heart rate. The first ANOVA was conducted with average heart rate while speaking as the dependent variable, and the second ANOVA was conducted with average heart rate while not talking as the dependent variable.

The final two ANOVAs focused on measures of average respiration rate. The first ANOVA was conducted with average respiration rate when speaking as the dependent variable, and the second ANOVA was conducted with average heart rate while not talking as the dependent variable.

Due to the small sample size, the investigators then conducted non-parametric tests to increase power and verify the results of the repeated-measures ANOVAs. Eight Wilcoxon Rank-Sum tests were performed to test the differences between diagnoses – four tests for each level of familiarity. The dependent variable in each of these four sub-tests was the percentage of time spent looking at the eyes, mouth, non-face, and whole face (eyes and mouth together) areas, respectively. Another eight Mann-Whitney tests were performed to test the differences between levels of familiarity – four for each level of diagnosis. The dependent variable in each of these four sub-tests was the percentage of time spent looking at the eyes, mouth, face, non-face, and whole face areas, respectively.

Finally, to analyze the pattern of looking, the investigators calculated average look durations to the eyes and mouth, and performed the non-parametric tests.
discussed above, but used average look duration for the eyes and mouth, respectively, during both familiar and unfamiliar interactions as the dependent variables.

Participants

The participants in this study comprised typically-developing children and adolescents and those diagnosed with an ASD. The typically developing children had no diagnoses of any kind, including developmental delays, such as language delays. The participants recruited for the ASD group had been previously diagnosed with ASD by a professional, and they had no comorbid diagnoses, such as chromosomal, genetic, or psychological disorders. Participants were recruited from a variety of schools and programs around the Birmingham, Alabama area, such as Mitchell’s Place, Glenwood, Shelby County Schools, and parent groups for families with children with autism. Participants ranged in age from 8- to 14-years-old and were primarily Caucasian, middle- to upper-middle class. It should be noted that the participants with ASD who completed the study likely functioned slightly better than the average child with ASD, given that the ability to follow brief directions, remain relatively still during the interactions, and respond verbally were crucial for accurate data collection. All individuals who interacted with the children (i.e. unfamiliar individuals and familiar caregivers) were females, to control for any unforeseen effects of gender of the adult confederates.
Materials

Autism Diagnostic Observation Schedule (ADOS)

The Autism Diagnostic Observation Schedule (ADOS) is a standardized semi-structured play assessment used to help diagnose Autism Spectrum Disorders (ASD) by evaluating the core deficits in these disorders – social interaction, communication, play skills, and restricted and repetitive behaviors. It was developed to diagnose ASD across a wide range of chronological and mental ages ranging from 18 months of life to adolescence and adulthood. The ADOS consists of four different modules, each of which was developed for use with children at particular developmental stages and language levels.

For participation in this study, a reasonable level of expressive language was required so the participants could answer the questions posed to them without causing undue stress. For this reason, nonverbal children and children who only have phrase speech were not included in this study and ADOS Modules 1 and 2 were not used. Also, ADOS Module 4 was not used, because it is only developmentally appropriate for older adolescents and young adults. Therefore, all participants were administered Module 3.

Each ADOS module assesses the areas of Communication, Socialization, and Restricted and Repetitive Behaviors by noting the presence or absence of particular behaviors during interactions with a clinician. Each module has its own scoring algorithm that utilizes select items from each area to produce a Social Skills Total Score, Communication Total Score, and Restricted and Repetitive Behaviors Total Score. These three total scores are then added together, and classifications of either
Autism or Autism Spectrum are determined based on this overall score relative to specific cutoffs. Recently, revised scoring algorithms derived from research by Gotham, Risi, Pickles, and Lord (2007) were released. These revised algorithms suggest better validity of diagnostic classification than previous algorithms focusing only on social and communication impairments (Gotham et al., 2007). Additionally, the new algorithms are consistent with DSM-IV criteria for impaired social interactions and communication skills and the presence of restricted and/or repetitive behaviors. Therefore, these new algorithms were used when scoring the ADOS.

Social Responsiveness Scale (SRS)

The Social Responsiveness Scale (SRS) is a brief parent questionnaire used as a quick, cost-effective screening tool for assessing the presence of ASD in children. It takes about 10 minutes to complete and was designed for use with children between four and eighteen years of age. While this measure is not meant to be used as a solitary clinical diagnostic tool, research has demonstrated that the SRS scores agree highly with those of the Autism Diagnostic Interview, Revised (ADI-R), a clinical tool that is typically paired with the ADOS during a full ASD evaluation (Constantino, LaVesser, Zhang, Abbacchi, Gray, & Todd, 2007; Rutter, LeCourteur, & Lord, 2003; Murray, Mayes, & Smith, 2011). The SRS requires substantially less time to administer and score. Therefore, researchers have paired the SRS with the ADOS in previous research as a means of confirming pre-existing ASD diagnoses (van Daalen, Kemner, Verbeek, van der Zwaag, Dijkstra, Rump, et al., 2011).
The SRS Parent-Report comprises 65 questions on a 4-point Likert scale (1=Not True, 2=Sometimes True, 3=Often True, and 4=Almost Always True). It yields a total T-Score as well as five subtest T-Scores (Social Awareness, Social Cognition, Social Communication, Social Motivation, and Autistic Mannerisms). T-Scores of 76 or higher are descriptively classified as falling in the “severe” range and are strongly associated with a clinical diagnosis on the spectrum. T-Scores of 60-75 are descriptively classified as falling in the “mild to moderate” range and are indicative of clinically significant social impairments that result in mild to moderate interference in social interactions. T-Scores below 60 are descriptively classified as falling in the “normal” range of functioning.

Vineland Adaptive Behavior Scales, Second Edition (Vineland-II)

The Vineland Adaptive Behavior Scales, Second Edition (Vineland-II) is an interview measure that assesses performance on the day-to-day activities necessary to take care of oneself and get along with others. It was designed for use with nearly any age group and many specific diagnostic groups, including individuals with ASD. It yields standard scores in the core domains of Communication, Socialization, and Daily Living Skills, as well as an overall standard score known as the Adaptive Behavior Composite (ABC). The Vineland-II also contains optional scales, including the Motor Skills scale and an index known as the Maladaptive Behavior Index (MBI) that measures difficult behaviors such as internalizing and externalizing symptoms. Scores on the Vineland-II are age-based and indicative of the behaviors in which an
individual regularly engages, rather than the behaviors of which an individual is capable.

The Vineland-II comes in 4 forms – the Survey Interview Form, Parent/Caregiver Rating Form, Expanded Interview Form, and Teacher Rating Form. For this study, the Parent/Caregiver Rating Form will be utilized for a number of reasons. Because the respondents in this study are primary caregivers, the Teacher Rating Form was clearly inappropriate, and the Expanded Interview Form were not be used, as it would have taken too long to administer and score. The Parent/Caregiver Rating Form and Survey Interview Form cover the same content; however, the Parent/Caregiver Rating Form requires much less time to complete because it utilizes a rating scale format. By contrast, the Survey Interview Form utilizes a semi-structured interview format that provides more in-depth information but takes far more time and resources (i.e. more examiners to administer this interview) to complete. Because the Vineland-II was administered while the examiners are occupied with evaluating participants using the ADOS, and the caregivers had a number of forms to fill out, the Parent/Caregiver Rating form was the best choice for this study.

faceLAB™ 5 Eye-Tracking by Seeing Machines (faceLAB™)

To assess scanning and fixation patterns, the researchers used a non-invasive eye-tracker known as faceLAB™ 5 (Seeing Machines, 2009). This system functions by illuminating the eye with infrared light and following the reflections of the participant’s pupil and cornea, a method mentioned previously (Boraston &
Blakemore, 2007). This technology allows not only a greater range of movement than many eye-trackers available, but is also more comfortable for the participants. As discussed in Boraston & Blakemore (2007), most eye-tracking technologies operate at frequencies between 50 Hz-2 kHz and spatial resolutions between .005-.5 degrees of visual angle. FaceLAB™ 5 operates at a sampling rate of 60 Hz. It can track and recover head rotations of up to 90 degrees in either direction around the $y$-axis and up to 45 degrees in either direction around the $x$-axis. Additionally, faceLAB™ 5 can track and recover eye rotations of up to 45 degrees in either direction around the $y$-axis and up to 22 degrees in either direction around the $x$-axis (Seeing Machines, 2009). FaceLab™ 5 also records the scene at which the participant is looking and superimposes their eye-gaze onto that video, to provide a file that shows where the child is looking in real-time.

These videos were hand-coded by the researchers in order to ascertain the percentage of time each child spent looking at each area of interest. Hand coding was accomplished by watching videos produced by the faceLAB™5 system and noting the portions of time that the participant is focused on each area of interest. A participant must have looked for at least a second at an area of interest in order to have that overture considered as a “fixation” to that particular region. Then, percentage values were calculated to determine the total percentage of time during the interaction that each child spent fixating on each area of interest by dividing the number of seconds spent fixated on each area of the face by the total number of seconds in that particular interaction. Reliability analyses were run between observers for both familiar and unfamiliar interactions. Correlations between
observers were all above .85 and statistically significant. See Tables 1 and 2 for summaries of these correlations.

Table 1. Inter-Observer Reliability Correlations for Unfamiliar Interactions

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<th>p-value</th>
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<td>.004</td>
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<tr>
<td>Mouth</td>
<td>4</td>
<td>.896</td>
<td>.016</td>
</tr>
<tr>
<td>Non-Face</td>
<td>4</td>
<td>.877</td>
<td>.022</td>
</tr>
</tbody>
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Table 2. Inter-Observer Reliability Correlations for Familiar Interactions

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<th>df</th>
<th>r</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>Eyes</td>
<td>4</td>
<td>.857</td>
<td>.029</td>
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<tr>
<td>Mouth</td>
<td>4</td>
<td>.985</td>
<td>.000</td>
</tr>
<tr>
<td>Non-Face</td>
<td>4</td>
<td>.899</td>
<td>.015</td>
</tr>
</tbody>
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*LifeShirt® by VivoMetrics (LifeShirt®)*

In order to assess each participant's physiological activity and anxiety level, the researchers used the LifeShirt® Model 200 system (VivoMetrics Inc., Ventura, CA). This system is made up of a mesh shirt worn underneath a participant's clothing. This technology allows the individual being monitored to move about while sensors inside the LifeShirt® simultaneously record a number of physiological measures, including heart rate and respiration rate (Grossman, 2004; Heilman & Porges, 2007). Recording multiple measures is one of the greatest advantages of the LifeShirt® system (Grossman, 2004). The LifeShirt® system has
been extensively tested with approximately 1750 subjects across at least 90 studies in many leading research institutes, and it has received all necessary regulatory approvals in a number of countries, including the United States (Grossman, 2004). According to the user manual, the LifeShirt® Model 200 can detect heart rates between 30 to 250 beats per minute (BPM) and respiration rates between 0 to 150 breaths per minute (VivoMetrics Inc., 2004). The sampling rate for measuring heart and respiration rate functions at 50 Hz (VivoMetrics Inc., 2004).

Procedure

All participants, typically developing and those diagnosed with an ASD, were recruited from various schools and programs around the Birmingham, Alabama area, including Mitchell’s Place, Glenwood, Shelby County Schools, and parent groups for families of children with autism. Parents were informed of all inclusion and exclusion criteria, procedures, benefits, possible risks, and all responsibilities associated with participating in the study.

After consenting to participation, the parents or legal guardians of the children and adolescents involved completed a demographic questionnaire, the Social Responsiveness Scale (SRS), and the Vineland-II. The SRS and Vineland-II were used as measures of symptom severity and to help confirm the participants’ ASD diagnoses or lack thereof, for typically developing participants. Actual testing took place over the course of two separate data collection sessions. Caregivers and participants signed their consent and assent forms on the day of their first session with the researchers. The scheduling of the next appointment took place on that
day, as well. If scheduling of the second session could not be completed on the day of the first session, it was accomplished via telephone or e-mail. While it was possible to complete children in one long session, the demands (cognitive, physical, and time-related) of completing all tasks on one day would have resulted in less-than-optimal conditions to accurately collect data. Both sessions took place in a research room that had white walls, a table and two chairs, and behind a black curtain one researcher would operate the FaceLab™ equipment out of view of the participants.

The first session of testing served to obtain clinical measures of the participants’ functioning in a variety of areas. Upon arriving for their first session of testing, the participants were evaluated using the Autism Diagnostic Observation Schedule (ADOS) as a measure of symptom severity and to confirm their diagnostic status. They also participated in the KBIT-2 to measure their level of cognitive functioning. During this time, the child’s primary caregiver served as the respondent for the Vineland Adaptive Behavior Scales, Second Edition (Vineland-II). The second session of data collection was scheduled after all clinical measures are completed.

The second session of testing served as the interaction session, during which the participants interacted separately with their caregiver and an unfamiliar examiner. The presentation of familiar and unfamiliar interactions was counterbalanced to account for any order effects these interactions might create. Before the interactions began, however, the participants were instructed to put on the LifeShirt® in a private designated changing area. If a participant required
assistance in donning the vest, his or her caregiver would assist them. If further assistance was needed, an experimenter of the same sex as the participant would guide the process, with permission of the participant and his or her caregiver. After this, the faceLAB™ eye-tracker was calibrated to the participant using a 4-point calibration system. Once faceLAB™ was calibrated, the participants remained seated while either the familiar caregiver or unfamiliar researcher sat opposite them. The participants were given a short break between the familiar and unfamiliar interactions to prevent any discomfort or anxiety due to prolonged sitting or boredom, rather than the social interaction itself. The durations of the interactions ranged from four to seven minutes, with most interactions lasting about five minutes.

The order of presentation for the familiar and unfamiliar interactions was counterbalanced for each participant to prevent order effects. During the familiar interaction, the caregiver attempted to elicit a social interaction representative of their child by asking him or her some scripted questions (e.g. “Tell me about [a recent activity],” or “How was your day at school?”), as well as allowing the participant to discuss something of particular interest to them. During the unfamiliar interaction, the examiner attempted to engage the participants in interactions that reflect their typical reactions to social overtures from strangers. This was accomplished using a script of questions similar to that used in the familiar interaction. The script used during the unfamiliar interaction contained different questions than the familiar interaction script, but these questions were related to the same topics of discussion (e.g. school, friends, activities, etc.) as the familiar
script to ensure that the topic of conversation does not impact the results. See Appendix A for a copy of the scripts used. Because the interactions were semi-structured and different questions may have been asked to different participants, it was not possible to counterbalance the order of questions.

While each of these interactions took place, faceLAB™ eye-tracking technology was used to monitor the eye-gaze of the participants. Concurrently, the LifeShirt® technology measured physiological changes in the participants that are indicative of anxiety. All faceLAB™ and LifeShirt® equipment was kept in the locked testing room when they were not in use. All physiological and video recording data was saved to an external hard drive that remained in the locked testing area at all times. After the interactions were complete and the data had been recorded and saved, the participants and guardians had completed all of their responsibilities. At this time, the participants and guardians were given the opportunity to request a copy of the results of the experiment, including both overall analyses and their individual scores on clinical measures, and any remaining questions related to the study will be answered.

RESULTS
Descriptive Statistics

Sixteen children ranging from 8- to 14-years-old were enrolled in this study. Half of these children were diagnosed with an autism spectrum disorder, while the other half were typically developing. The sample comprised seven females and nine males. Nearly 81.25% of the participants were Caucasian, and 18.75% were of
unknown or mixed racial backgrounds. Three children were not included in the analyses because of technical difficulties that compromised their data collection. See Tables 3-7 for a graphical breakdown of the final sample.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ASD Group (n=6)</th>
<th>Control Group (n=7)</th>
<th>Total (n=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>Age</td>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6 (100)</td>
<td>2 (28.6)</td>
<td>8 (61.5)</td>
</tr>
<tr>
<td>Female</td>
<td>0 (0)</td>
<td>5 (71.4)</td>
<td>5 (38.5)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>6 (100)</td>
<td>6 (85.7)</td>
<td>12 (92.3)</td>
</tr>
<tr>
<td>Unknown/Mixed</td>
<td>0</td>
<td>1 (14.3)</td>
<td>1 (7.7)</td>
</tr>
</tbody>
</table>

Table 4. Means (Standard Deviations) for IQ Scores as Measured by the KBIT-2 by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>VIQ (SD)</th>
<th>PIQ (SD)</th>
<th>FSIQ (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>103.7 (14.2)</td>
<td>109.5 (8.73)</td>
<td>108.0 (12.0)</td>
</tr>
<tr>
<td>TD</td>
<td>102.3 (11.9)</td>
<td>99.3 (17.3)</td>
<td>101.0 (16.1)</td>
</tr>
</tbody>
</table>

Table 5. Means (Standard Deviations) for Vineland-II Domain Scores by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Communication</th>
<th>Daily Living Skills</th>
<th>Socialization</th>
<th>Adaptive Behavior Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>88.0 (10.5)</td>
<td>86.33 (19.9)</td>
<td>79.5 (15.0)</td>
<td>82.8 (11.1)</td>
</tr>
<tr>
<td>TD</td>
<td>109.0 (17.0)</td>
<td>110.0 (18.4)</td>
<td>108.9 (10.9)</td>
<td>110.1 (16.4)</td>
</tr>
</tbody>
</table>
Table 6. Means (Standard Deviations) for SRS Domain T-Scores by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Social Awareness</th>
<th>Social Cognition</th>
<th>Social Communication</th>
<th>Social Motivation</th>
<th>Autistic Mannerisms</th>
<th>SRS Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>ASD</em></td>
<td>75.0 (11.1)</td>
<td>65.8 (7.7)</td>
<td>69.5 (7.71)</td>
<td>73.2 (12.1)</td>
<td>68.3 (19.1)</td>
<td>68.2</td>
</tr>
<tr>
<td><em>TD</em></td>
<td>43.1 (7.82)</td>
<td>40.1 (6.20)</td>
<td>43.7 (7.06)</td>
<td>40.0 (4.69)</td>
<td>46.0 (9.83)</td>
<td>43.1</td>
</tr>
</tbody>
</table>

Table 7. Means (Standard Deviations) for ADOS Domain Scores by Diagnosis

<table>
<thead>
<tr>
<th>Gender</th>
<th>Social Affect Score</th>
<th>Restricted/Repetitive Behaviors Score</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>ASD</em></td>
<td>8.83 (3.25)</td>
<td>1.5 (1.05)</td>
<td>10.3 (2.73)</td>
</tr>
<tr>
<td><em>TD</em></td>
<td>1.57 (1.27)</td>
<td>0.00 (0.00)</td>
<td>1.57 (1.27)</td>
</tr>
</tbody>
</table>

Descriptive statistics were also calculated to determine the shapes of the distributions and to test all assumptions of the analyses to be run. The results of those tests showed that all assumptions of normality and homoscedasticity were not violated. One additional child with autism was excluded from the analyses of the eye-gaze ANOVAs because he spent 70% of the time (far more than any other participant) looking at the mouth in each interaction, making him an outlier.

Eye-Gaze ANOVAs at Non-Face

The dependent variables for this analysis were calculated by dividing the number of seconds each participant spent looking at the non-face area by the total interaction length in seconds. A repeated measures ANOVA analyzing the effects of diagnosis and familiarity when looking at the non-face area revealed no significant
main effects of diagnosis, $F(1,10)=0.58$, $p=0.464$, or familiarity, $F(1,10)=0.06$, $p=0.814$. The diagnosis-by-familiarity interaction was also non-significant, $F(1,10)=0.76$, $p=0.404$. See Tables 8 and 9 for the statistical results of this test.

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>0.58</td>
<td>0.464</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.06</td>
<td>0.814</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>0.76</td>
<td>0.404</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>45.5 (22.5)</td>
<td>37.8 (16.9)</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>Familiar</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td></td>
<td>39.9 (16.5)</td>
<td>42.0 (21.8)</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>ASD/Fam.</td>
<td>ASD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>47.2 (20.2)</td>
<td>43.7 (24.7)</td>
</tr>
<tr>
<td></td>
<td>TD/Fam.</td>
<td>TD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>34.7 (12.3)</td>
<td>40.8 (21.5)</td>
</tr>
</tbody>
</table>

Due to the small sample size, a set of Wilcoxon Rank-Sum tests were performed to analyze the effects of diagnosis and familiarity. The Wilcoxon tests revealed no significant differences between children with and without autism for the familiar ($z=0.974$, $p=0.172$) or unfamiliar interactions ($z=0.487$, $p = 0.319$). See Table 10 for the statistical results of these tests.
Table 10. Wilcoxon Rank-Sum Tests for Independent Samples for Non-Face Interaction

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Wilcoxon Z</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>0.487</td>
<td>0.319</td>
</tr>
<tr>
<td>Familiar</td>
<td>0.974</td>
<td>0.172</td>
</tr>
</tbody>
</table>

There were no significant differences in percentage of time spent looking at the non-face regions on the basis of familiarity for children with autism (mean difference = -3.49), t(4)=0.39, p=0.714, or their typically developing peers (mean difference = -6.164), t(6)=0.89, p=0.406. See Table 11 for the statistical results of these tests.

Table 11. Wilcoxon Matched-Samples Rank-Sum Tests for Non-Face Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>df</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>4</td>
<td>-0.39</td>
<td>0.714</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>0.89</td>
<td>0.406</td>
</tr>
</tbody>
</table>

Eye-Gaze ANOVAs at Mouth

The dependent variables for this analysis were calculated by dividing the number of seconds each participant spent looking at the mouth by the total interaction length in seconds. A repeated measures ANOVA analyzing the effects of diagnosis and familiarity when looking at the mouth revealed no significant main effects of diagnosis, $F(1,10)=2.48$, $p=0.147$, or familiarity, $F(1,10)=0.31$, $p=0.592$. The diagnosis-by-familiarity interaction was also non-significant, $F(1,10)=0.17$, $p=0.687$. See Tables 12 and 13 for the statistical results of this test.
Due to the small sample size, a set of Wilcoxon Rank-Sum tests were performed to analyze the effects of diagnosis and familiarity. The Wilcoxon tests revealed no significant differences between children with and without autism for the familiar \((z=0.812, p=0.216)\) or unfamiliar interactions \((z=1.137, p=0.134)\). See Table 14 for the statistical results of these tests.
Table 14. Wilcoxon Rank-Sum Tests for Independent Samples for Mouth

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Wilcoxon Z</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>1.137</td>
<td>0.134</td>
</tr>
<tr>
<td>Familiar</td>
<td>0.812</td>
<td>0.216</td>
</tr>
</tbody>
</table>

There were also no significant differences in percentage of time spent looking at the mouth on the basis of familiarity for children with autism (mean difference = -0.381), $t(4)=0.09, p=0.934$, or their typically developing peers (mean difference = -2.674), $t(6)=0.77, p=0.472$. See Table 15 for the statistical results of these tests.

Table 15. Wilcoxon Matched-Samples Rank-Sum Tests for Mouth

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>df</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>4</td>
<td>-0.09</td>
<td>0.934</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>-0.77</td>
<td>0.472</td>
</tr>
</tbody>
</table>

Eye-Gaze ANOVAs at Eyes

The dependent variables for this analysis were calculated by dividing the number of seconds each participant spent looking at the eyes by the total interaction length in seconds. A repeated measures ANOVA analyzing the effects of diagnosis and familiarity when looking at the eyes revealed no significant main effects of diagnosis, $F(1,10)=2.61, p=0.137$, or familiarity, $F(1,10)=0.00, p=0.970$. The diagnosis-by-familiarity interaction was also non-significant, $F(1,10)=0.54, p=0.479$. See Tables 16 and 17 for the statistical results of this test.
Table 16. Repeated Measures ANOVA for Eyes

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>2.61</td>
<td>0.137</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.00</td>
<td>0.970</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>0.54</td>
<td>0.479</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 17. Means (Standard Deviations) for Each Hypothesis Test Related to the Eyes

<table>
<thead>
<tr>
<th>M.E. of Diagnosis</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37.8 (17.5)</td>
<td>51.2 (15.6)</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>Familiar</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td></td>
<td>45.8 (15.9)</td>
<td>45.4 (18.7)</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>ASD/Fam.</td>
<td>ASD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>35.9 (16.1)</td>
<td>39.7 (18.9)</td>
</tr>
</tbody>
</table>

Due to the small sample size, a set of Wilcoxon Rank-Sum tests were performed to analyze the effects of diagnosis and familiarity. The Wilcoxon tests revealed no significant differences between children with and without autism for the unfamiliar interaction ($z=-0.974$, $p=0.172$). The difference between the two groups approached statistical significance for the familiar interaction, however ($z=-1.624$, $p=0.053$). See Table 18 for the statistical results of these tests.
Table 18. Wilcoxon Rank-Sum Tests for Independent Samples for Eyes

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Wilcoxon Z</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>-0.974</td>
<td>0.172</td>
</tr>
<tr>
<td>Familiar</td>
<td>-1.624</td>
<td>0.053*</td>
</tr>
</tbody>
</table>

*Approaches statistical significance

There were no significant differences in percentage of time spent looking at the eyes on the basis of familiarity for children with autism (mean difference = 3.87), t(4)=0.39, p=0.714, or their typically developing peers (mean difference = 3.49), t(6)=-0.72, p=0.499. See Table 19 for the statistical results of these tests.

Table 19. Wilcoxon Matched-Samples Rank-Sum Tests for Eyes

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>df</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>4</td>
<td>0.39</td>
<td>0.714</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>-0.72</td>
<td>0.499</td>
</tr>
</tbody>
</table>

Measures of Physiology

Four repeated measures ANOVAs analyzing the effects of diagnosis and familiarity on heart rate (while talking and while not talking) and respiration rate (again while talking and while not talking) were conducted.

The ANOVAs using heart rate as the dependent variable found no significant main effects of diagnosis while talking, F(1,10)=0.00, p=0.988, or while not talking, F(1,10)=0.00, p=0.988. Additionally, no main effects of familiarity were found while talking, F(1,10)=0.49, p=0.499, or while not talking, F(1,10)=0.70, p=0.423. No interaction effects were found while talking, F(1,10)=2.86, p=0.122, or while not
talking, F(1,10)=1.51, p = 0.247. See Tables 20-23 for the statistical results of these tests.

Table 20. Repeated Measures ANOVAs for Heart Rate While Talking

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>0.00</td>
<td>0.998</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.49</td>
<td>0.499</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>2.86</td>
<td>0.1216</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 21. Means (Standard Deviations) for Each Hypothesis Test Related to Heart Rate While Talking

<table>
<thead>
<tr>
<th>M.E. of Diagnosis</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>93.7 (10.8)</td>
<td>93.6 (10.4)</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>Familiar</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td></td>
<td>94.1 (10.1)</td>
<td>93.3 (10.3)</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>ASD/Fam.</td>
<td>ASD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>95.9 (9.72)</td>
<td>91.6 (11.9)</td>
</tr>
</tbody>
</table>
Table 22. Repeated Measures ANOVA for Heart Rate While Not Talking

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>0.00</td>
<td>0.998</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.70</td>
<td>0.423</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>1.51</td>
<td>0.247</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 23. Means (Standard Deviations) for Each Hypothesis Test Related to Heart Rate While Not Talking

<table>
<thead>
<tr>
<th>M.E. of Diagnosis</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>93.1 (11.0)</td>
<td>93.1 (10.6)</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>Familiar</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td></td>
<td>93.8 (10.2)</td>
<td>92.5 (10.5)</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>ASD/Fam.</td>
<td>ASD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>95.3 (10.3)</td>
<td>91.0 (11.8)</td>
</tr>
</tbody>
</table>

The ANOVAs using respiration rate as the dependent variable found no significant main effects of diagnosis while talking, $F(1,10)=0.52$, $p=0.486$, or while not talking, $F(1,10)=0.81$, $p=0.388$. Additionally, no main effects of familiarity were found while talking, $F(1,10)=0.08$, $p=0.781$, or while not talking, $F(1,10)=0.10$, $p=0.757$. No interaction effects were found while talking, $F(1,10)=0.12$, $p=0.738$, or while not talking, $F(1,10)=0.48$, $p = 0.503$. See Tables 24-27 for the statistical results of these tests.
Table 24. Repeated Measures ANOVA for Respiration Rate While Talking

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>0.52</td>
<td>0.486</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.08</td>
<td>0.781</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>0.12</td>
<td>0.738</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 25. Means (Standard Deviations) for Each Hypothesis Test Related to Respiration Rate While Talking

<table>
<thead>
<tr>
<th>M.E. of Diagnosis</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26.6 (4.85)</td>
<td>24.9 (4.83)</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>Familiar</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td></td>
<td>25.4 (5.55)</td>
<td>25.8 (3.94)</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>ASD/Fam.</td>
<td>ASD/Unfam.</td>
</tr>
<tr>
<td></td>
<td>26.1 (5.13)</td>
<td>27.1 (4.56)</td>
</tr>
</tbody>
</table>

Table 26. Repeated Measures ANOVA for Respiration Rate While Not Talking

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E. of Diagnosis</td>
<td>1</td>
<td>0.81</td>
<td>0.388</td>
</tr>
<tr>
<td>M.E. of Familiarity</td>
<td>1</td>
<td>0.10</td>
<td>0.757</td>
</tr>
<tr>
<td>Diagnosis*Familiarity</td>
<td>1</td>
<td>0.48</td>
<td>0.503</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 27. Means (Standard Deviations) for Each Hypothesis Test Related to Respiration Rate While Not Talking

<table>
<thead>
<tr>
<th>M.E. of Diagnosis</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26.9 (4.69)</td>
<td>24.1 (6.25)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M.E. of Familiarity</th>
<th>Familiar</th>
<th>Unfamiliar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25.0 (4.93)</td>
<td>25.6 (6.35)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diagnosis*Familiarity</th>
<th>ASD/Fam.</th>
<th>ASD/Unfam.</th>
<th>TD/Fam.</th>
<th>TD/Unfam.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27.1 (3.99)</td>
<td>26.6 (5.39)</td>
<td>23.4 (5.21)</td>
<td>24.9 (7.29)</td>
</tr>
</tbody>
</table>

Post-Hoc Analyses of Look Duration

While collecting the data for this research, the investigators noticed that the children with autism appeared to have much shorter look durations at the face than did the typically developing children. Therefore, post-hoc non-parametric analyses were conducted to test this hypothesis. Wilcoxon Rank-Sum tests were performed to test the difference in look durations between diagnoses when looking at each area of the interest (mouth, eyes, and total face) for each type of interaction (familiar and unfamiliar) for a total of six tests.

For unfamiliar interactions, children with autism had slightly longer look durations than typically developing children when looking at the mouth, but this difference only approached statistical significance ($z=1.385$, $p=.081$). Additionally, children with autism did not appear to have significantly different look durations than the typically developing children when looking at the eyes ($z=-0.162$, $p=0.438$).
or total face ($z=0.325, p=0.361$). See Tables 28 and 29 for the statistical results of these tests. Figure 1 shows the distributions for each diagnosis while looking at the mouth during unfamiliar interaction.

| Table 28. Means (Standard Deviations) for Unfamiliar Look Durations in Seconds for Each Area of the Face by Diagnosis |
|-------------|-------------|-------------|-------------|
| Diagnosis   | Mouth       | Eyes        | Total Face  |
| ASK         | 2.03 (0.52) | 3.91 (1.36) | 2.67 (0.84) |
| TD          | 1.76 (0.67) | 5.16 (4.01) | 3.46 (2.21) |

| Table 29. Wilcoxon Rank-Sum Tests for Independent Samples for the Unfamiliar Interaction |
|----------------------------------|-----|-----|
| Area of Face                    | Wilcoxon Z | p-value |
| Mouth                           | 1.385      | .081*   |
| Eyes                            | -0.162     | 0.438   |
| Total Face                      | 0.325      | 0.361   |

*Approaching statistical significance
For familiar interactions, children with autism again showed similar look durations to typically developing children when looking at the mouth ($z=0.895$, $p=0.183$). When looking at the eyes, however, children with autism showed significantly shorter look durations than their typically developing counterparts ($z=-1.786$, $p=0.037$). Of the 13 participants, one participant in the autism group had a look duration to the eyes that was longer than that of the longest gaze duration of the typically developing children, and was considered an outlier. Therefore, tests for the familiar interactions were also conducted with this participant removed. The difference in look durations to the eyes became even more significant with the outlier removed ($z=-2.551$, $p=0.003$). Finally, children with autism exhibited similar look durations to typically developing children when looking at the whole face ($z=-1.299$, $p=0.101$) when all participants are included. When the outlier was removed,
however, children with autism again exhibited significantly shorter look durations than their typically developing peers ($z=-1.984, p=0.021$). See Tables 30 and 31 for the statistical results of these tests. Figures 2-4 show the distributions of each diagnosis.

Table 30. Means (Standard Deviations) for Familiar Look Durations in Seconds for Each Area of the Face by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Mouth</th>
<th>Eyes</th>
<th>Total Face</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>2.20 (0.16)</td>
<td>2.43 (0.56)</td>
<td>2.31 (0.31)</td>
</tr>
<tr>
<td>TD</td>
<td>1.91 (0.80)</td>
<td>4.22 (1.26)</td>
<td>3.06 (0.85)</td>
</tr>
</tbody>
</table>

Table 31. Wilcoxon Rank-Sum Tests for Independent Samples for the Familiar Interaction

<table>
<thead>
<tr>
<th>Area of Face</th>
<th>Wilcoxon Z</th>
<th>p-value</th>
<th>Area of Face</th>
<th>Wilcoxon Z</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>0.895</td>
<td>0.183</td>
<td>Mouth</td>
<td>1.137</td>
<td>0.124</td>
</tr>
<tr>
<td>Eyes</td>
<td>1.786</td>
<td>0.037**</td>
<td>Eyes</td>
<td>-2.551</td>
<td>0.003**</td>
</tr>
<tr>
<td>Total Face</td>
<td>-1.299</td>
<td>0.101</td>
<td>Total Face</td>
<td>-1.984</td>
<td>0.021**</td>
</tr>
</tbody>
</table>

**Statistically significant
Figure 2. Distribution of Wilcoxon ranks when looking at the eyes during the familiar interaction with all participants included

Figure 3. Distribution of Wilcoxon ranks when looking at the eyes during the familiar interaction with outliers removed
Figure 4. Distributions of Wilcoxon ranks when looking at the face during the familiar interaction with outliers removed

DISCUSSION

The purpose of this research was to determine differences in looking patterns and physiological reactions between children and young adolescents with autism and their typically developing counterparts. It was designed to be the first study of children with autism to use a live social interaction in its design. It was also meant to be the first study to monitor multiple measures of physiological anxiety in children with autism during these interactions. The results suggest that high-functioning children with autism tend to look at the eyes, mouth, and non-face regions for similar total amounts of time as typically developing children during both familiar and unfamiliar interactions, but they exhibit significantly shorter look durations to the eyes than their peers when speaking to a familiar individual. The
children with autism did not appear to exhibit any greater anxiety than typically developing children during any interactions.

Looking at Different Areas of the Face

This study shows that children with autism look at the eyes, mouth, and non-face regions for about the same total percentage of time as their typically developing peers during both familiar and unfamiliar live social interactions. However, it should be noted that the children with autism (mean percentage = 35.86) looked less at the eyes than their typically developing peers (mean percentage = 52.97) in the familiar interaction only. Due to the small sample size, this result should be interpreted with caution and needs to be replicated with a larger sample size in a live interaction. With the exception of this potential difference, these patterns of looking are contradictory to what has been previously assumed to be happening (Freeth et al., 2009; Hernandez et al., 2008, Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002).

When these results are viewed from the viewpoint of Colombo’s Triphasic Theory, they suggest that children with autism are able to attain an alert state, orient to a particular locus in space, and engage in object attention similarly to typically developing children. However, it should be noted that there was a substantial amount of variability across children, particularly in the autism group, which supports his idea that alertness, spatial orienting, object attention, and endogenous control all interact with each other at varying levels of maturity to impact visual attention. It is highly likely that some children exhibit more
difficulties with certain areas than others, which likely will result in different presentations of visual attention skills (i.e. different look durations, different areas of focus, etc.).

Measures of Physiology

Additionally, children with autism do not appear to exhibit different levels of anxiety (while speaking or not talking) than their typically developing peers in either type of interaction. These results, while not statistically significant, are quite theoretically significant, given that researchers have assumed for many years that children on the autism spectrum are more anxious during social situations than other children. They also suggest that working on anxiety reduction in children with autism might not result in improved social understanding, per se, and instead may serve to lessen the restricted and repetitive behaviors often seen in autism, which are also thought to be related to anxiety.

With regard to Porges’s Polyvagal Theory, these results suggest that children with autism are able to attain a calm visceral state, which fosters social development, but the observable behaviors (i.e. look times and durations) of these children are being impacted because of the aforementioned difficulties with direction and inhibition of attention.

Measures of Look Duration

The truly interesting results, however, come from the analyses of look duration, which showed that children with autism have significantly shorter look
durations than their typically developing peers when looking at the eyes and total face, which means that they spend a great deal of time switching attention from one area to another. The results also showed that children with autism may have longer look durations to the mouth during unfamiliar interactions than their typically developing peers. This likely prevents these children from appropriately collecting and processing the social information provided by the eyes, resulting in their atypical social behaviors during both familiar and unfamiliar interactions. It also could explain why higher-functioning children are more difficult for professionals to identify, particularly when they spend a short amount of time with the child, since the children with autism are making eye contact for similar total percentages of time with unfamiliar people (e.g. psychologists, psychiatrists, pediatricians, etc.) when compared to typically developing children. However, due to the small sample size this result only approached significance and should be interpreted with caution until they are replicated.

In terms of Colombo’s Triphasic Theory, the results of this study suggest that children with autism are having difficulty with their spatial orientation skills, which develop in the second phase he defined (between the second and sixth month of life). In terms of Porges’s Polyvagal Theory, these results suggest that children with autism are having more difficulty than typically developing children when it comes to direction and inhibition of attention. While the typically developing children are able to orient to a specific locus in space and sustain their attention there, the children with autism are frequently switching their spatial orientation and do not sustain their attention for as long. This results in greater processing difficulties
because they are only sustaining attention to the eyes, which contain the most useful social information, for short periods of time. As Freeth et al. (2009) showed, the speed of stimulus presentation can greatly impact how well children with autism are able to process social information.

Implications

This study helps to resolve some of the conflicting information in the literature regarding eye-gaze patterns in children with autism. The initial analyses indicated that children with autism are, for the most part, looking the same total percentage of time at each area of interest as their typically developing counterparts in both familiar and unfamiliar interactions. However, this is in direct contrast to previous studies showing that children with autism tend to look more at the mouth and less at the eyes than their peers without autism (Freeth et al., 2009; Hernandez et al., 2008, Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002). These results lend credence to the idea that children with autism are not necessarily “choosing” to act in a way different from their peers (e.g. choosing to look away from the face because it is less anxiety-provoking to do so, or choosing to look at the mouth because it is more interesting than the eyes), but rather are making efforts to behave like neurotypical children (e.g. looking proportionately more at the eyes than the mouth, etc.) and are finding it difficult to understand and process the social information they encounter (Koldewyn et al., 2013a; Scherf et al., 2008). This is not surprising given the look duration analyses performed, which illustrated that the children on the spectrum
had significantly shorter look durations at the eyes. The constant switching of
attention that takes place as a result of these short look durations in turn might
prohibit these children from fully processing facial stimuli.

Taking all of these results together, it appears that high-functioning children
with autism spend similar percentages of time looking at each area of the face when
compared to typically developing children, and they exhibit no significant
differences in physiological anxiety. Instead, where they appear to be different is in
the duration of each overture to the eyes when interacting with familiar individuals.
Despite the confusing nature of these results, they appear to make logical sense.
Children with autism and typically developing children will both spend less time
making direct eye contact with unfamiliar individuals, but when interacting with
familiar individuals, where longer bids of eye contact are expected, the children with
autism are not exhibiting these longer gazes. This study provides support for
interventions such as the PEERS Program, which focuses on creating groups of
children for long-term group therapy sessions, and in these groups they are able to
practice social interaction skills with familiar rather than unfamiliar individuals.
The PEERS Program has already been shown to be highly effective, particularly with
high functioning children and adolescents with ASD (Laugeson, Fankel, Gantman,
Dillon, & Mogil, 2012), and, based on the results of this study, more similar
programs should be seriously considered, implemented, and researched in the
future.

It should also be noted that all children, but particularly those with autism,
appeared to look away from both the adults when the child was responding to a
question and would then return their gaze to the face of the adults when they were finished. It is not unusual for children to look away from people when they are speaking, particularly when they are thinking of what to say, but it would be interesting to see if there is any significant difference in the frequency or duration of these occurrences between children with and without autism.

Limitations and Future Studies

The most important limitation to this study is clearly the limited sample size. When studying limited populations such as children with ASD, and with all funding coming out-of-pocket from the researchers, obtaining a large sample of participants was difficult for this study. Therefore, future studies will need to focus on procuring funding in order to attain an appropriate sample size. Also, because this sample is restricted to higher-functioning, older individuals, it is crucial for future studies to investigate these patterns of behavior in younger children and children who are lower-functioning, in order to form a true understanding of eye-gaze patterns in children with autism. Additionally, future studies should take advantage of any technological advances that make the collection and analysis of data more simplistic, as one of the primary obstacles to furthering this research is the difficulty associated with using eye-tracking equipment with younger and/or lower-functioning children. Future studies should also utilize varied social scenarios (i.e. having children interact with other children or in more naturalistic settings) in their design. Finally, this study was unable to account for any early intervention services that the participants had engaged in prior in life. Because these were older children, it is
very likely that they have had years of intervention to improve their social skills that may have impacted the findings. In order for these results to be generalizable to a greater population, replications of this study with larger samples and more diverse populations must be completed.
REFERENCES


Doty, R.W. (1995). Brainstem influences on forebrain processes, including memory. In NE Spear, LP Spear, ML Woodruff (Eds.), *Neurobehavioral Plasticity:


competence in individuals with autism. *Archives of General Psychiatry, 59*(9), 809-16


the UCLA PEERS program. *Journal of Autism and Developmental Disorders, 42*(6), 1025-36


APPENDIX A: SCRIPTS FOR SOCIAL INTERACTIONS

Unfamiliar Interaction:

Investigator (I): Tell me about your regular school day. What do you do when you first get to school?
Participant (P):
I: How many kids are in your class(es)?
P:
I: What is your favorite part of school? Why?
P:
I: What is your least favorite part of school? Why?
P:
I: Who are your friends at school?
P:
I: Are there kids who give you a hard time or are “not nice” to you?
P:
I: Do you hang out with anyone from school on the weekends or after school? Who?
P:
I: OK, this question doesn’t have anything to do with school. If you had 3 wishes for anything in the world, what would you wish for?
P:

Familiar Interaction:

Caregiver (C): Tell me about [a regular activity engaged in by participant]. What happens/do you do?
Participant (P):
C: How many other kids [do aforementioned activity] with you? OR (if activity is a team sport such as baseball, football, etc.) How many kids are on your team?
P:
C: What is your favorite part of it? Why?
P:
C: What is your least favorite part of it? Why?
P:
C: Who do you like to [do this activity] with the most? OR (if activity is a team sport) Who are your friends on your team?
P:
C: Is there anyone (on your team – if applicable) who gives you a hard time or is “not nice” to you?
P:
C: If you were stranded on a deserted island and could have any 3 things in the world with you, what would they be?
P:
APPENDIX B: IRB APPROVAL FORM

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on January 24, 2017. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

Principal Investigator: GOWER, MICHAEL W.
Co-Investigator(s):
Protocol Number: X100820019
Protocol Title: Eye Gaze Patterns During Live Social Interactions in Children with Autism Spectrum Disorders

The IRB reviewed and approved the above named project on 6-4-13. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.
IRB Approval Date: 6-4-13
Date IRB Approval Issued: 6-4-13

Marilyn Doss, M.A.
Vice Chair of the Institutional Review Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.