Emotion Recognition of Dynamic Faces in Children with Autism Spectrum Disorder

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Psychology

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Corrections to Emotion Recognition of Dynamic Faces in Children with Autism Spectrum Disorder

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Several mistakes in the reported statistics were discovered in the review of this thesis in preparation for requesting acceptance for continuation in the PhD Clinical Psychology program at Virginia Polytechnic Institute and State University. While these changes do not change the general interpretation of this study, the author wanted to report accurate statistical findings. This erratum lists corrections for these mistakes by page number.

Page 18: Percentage of parents in the TD group earning over $100,000 was reported to be 50%, but should be changed to 62.5%
Page 20: Range of stimuli time reported was 2.5-5 seconds when it should be 2-5 seconds
Page 23: Thesis states that the first 2.5 seconds of videos were used when only the first 2 seconds were used
Page 25: t-test matching values were changed
Page 26: F-test and t-test values changed, values for the between factor were added
Page 27: values for hierarchical regression were changed changed
Page 49: values in table 1 changed
Page 50: values in table 2 changed
Page 51: values in table 3 changed
Page 52: values in table 5 changed
Page 54: figure 1 changed

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ABSTRACT

Studies examining impaired emotion recognition and perceptual processing in autism spectrum disorders (ASD) show inconsistent results (Harms, Martin, & Wallace, 2010; Jemel, Mottron, & Dawson, 2006), and many of these studies include eye tracking data. The current study utilizes a novel task, emotion recognition of a dynamic talking face with sound, to compare children with ASD (n=8; aged 6-10, 7 male) with mental age (MA) and gender matched controls (n=8; aged 4-10, 7 male) on an emotion identification and eye tracking task. Children were asked to watch several short video clips (2.5-5 seconds) portraying the emotions of happy, sad, excited, scared, and angry and identify the emotion portrayed in the video. A mixed factorial ANOVA analysis was conducted to examine group differences in attention when viewing the stimuli. Differences in emotion identification ability were examined using a t-test and Fisher's exact tests of independence. Findings indicated that children with ASD spent less time looking at faces and the mouth region than controls. Additionally, the amount of time children with ASD spent looking at the mouth region predicted better performance on the emotion identification task. The study was underpowered; however, so these results were preliminary and require replication. Results are discussed in relation to natural processing of emotion and social stimuli.

Dedication

This thesis is dedicated to my wonderful, supportive family including my husband, Jim and little man, James. You make everything in life, even writing a thesis, better. This is also for and all the children with autism and their families I've worked with in the past and present who inspire me every day.

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Thanks to my family and friends who supported me when I was scrambling to finish my thesis by the end of the semester. Thanks for all the babysitting, taking care of the house, and ears lent for venting. I couldn't have done it without you!

Finally, thank you to all the families who donated their time to participate in the study. I know how busy life is when you have children, and taking an hour or more to participate in a study with no compensation is very greatly appreciated.

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Introduction

A diagnosis of autism spectrum disorder (ASD), including autism, pervasive developmental disorder – not otherwise specified (PDD-NOS), or Asperger's disorder, is given when an individual exhibits difficulties in the areas of repetitive or stereotypical behavior, communication, and social functioning (APA, 2000). Of these behaviors, one that is often detected the earliest is a social aloofness expressed through poor eye contact and an apparent lack of interest in social interaction and the social world (Baron-Cohen 1988; Senju & Johnson 2009). Not all individuals with ASD, however, are socially aloof (Downs & Smith, 2004). In fact, many individuals with ASD express a desire for social interaction, but lack the skills to interpret social information and to interact with others appropriately (APA, 2000). One social cue that has long been studied in the ASD literature is the ability to identify and process information about emotion, a skill that is integral to interacting in a social world.

Emotion Identification in ASD

Difficulties in emotion identification have long been observed in individuals with ASD (Hobson, Ouston, & Lee, 1989; Macdonald et al., 1989). In fact, current diagnostic criteria and diagnostic tools use this symptom to help inform the diagnosis of this disorder (APA 2000; Lord et al., 2000). The ability to identify how another is feeling is imperative to interacting with others as another person's emotional state will guide an impending or ongoing social interaction. Evidence of emotion recognition has been linked to the development of relationships and self-regulation. For example, young children who have better emotion understanding tend to have more adaptive social behaviors (Izard, Fine, Schultz, Mostow, Ackerman, & Youngstrom, 2001) and adults who have difficulties with emotion identification also are likely to have increased anxiety, depression, and poor emotion regulation (Taylor & Bagby, 2004).

Deficits in emotion identification may be a hallmark symptom of ASD; however, the literature is less conclusive as many studies have failed to find a difference in performance on emotion identification tasks when comparing individuals with ASD and controls (see Harms, Martin, & Wallace, 2010 for a review). This may be due to several factors including demographic characteristics such as IQ, ASD functioning level, age, task demands included in the paradigm, and the dependent variables measured. For example, studies using strictly behavioral data (i.e. did the person correctly identify the emotion or not) were more likely to utilize a sample with higher functioning individuals with ASD who used compensatory strategies to correctly name an emotion in facial emotion recognition tasks. However, nearly all eye-tracking, electrophysiological, and imaging studies of facial emotion recognition using both high and low-functioning individuals with ASD find differences in processing of stimuli. While nearly all of these studies find differences in how individuals with ASD process facial emotional stimuli, it is less clear exactly what these differences are (Harms et al., 2010).

Facial Processing

Lack of attention to the eye region.

There is evidence that a key feature in facial processing is the eyes. The eyes can help us decipher emotion (Baron-Cohen, Wheelwright, & Jolliffe, 1997; Dalton et al., 2005; Gross, 2004), determine trustworthiness (Boraston, Corden, Miles, Skuse, & Blakemore, 2008), and recognize individuals (Dalton et al., 2005; Sterling et al., 2008;

Trepagnier, Sebrechts, & Peterson, 2002) It has been demonstrated that children at risk for autism show diminished eye gaze with their mothers as early as six months of age (Merin et al., 2007) and diminished eye gaze is indicative of an autism diagnosis for two-year old children (Jones, Carr, & Klin, 2008). Many studies have shown that individuals with autism spend less time fixating on the eye region when viewing a person's face across the developmental trajectory as well (Baron-Cohen, Wheelwright, & Joliffe,1997; Gross, 2004; Merin et al., 2006)

In a three part study, Baron-Cohen, Wheelwright, and Joliffe (1997) found that typically developing (TD) adults show a high degree of agreement when inferring mental states from facial expressions and that the whole face is more informative than just a part of the face. When either the mouth or eye regions were shown in isolation, TD adults were more likely to correctly ascribe mental states based on the eyes than the mouth. On the other hand, adults with ASD showed impairment in determining mental states in all conditions, but were most markedly affected in the eyes only condition indicating a deficit in using the eyes to process mental states.

Similar tasks have been done with children. In a task where children were directed to ascribe emotional states for humans, orangutans, and dogs while viewing the entire face, children with ASD were more likely to make mistakes in emotion recognition across species when compared to TD and mentally retarded (MR) children (Gross, 2004). Post-hoc error analyses indicated that children with autism were more likely to make errors when they involved the processing of the eye region to make decisions about emotion.

Adults with autism are also impaired in determining whether a smile is fake or genuine (Boraston et al., 2008), when compared to their TD counterparts. According to the authors, the difference between a posed and genuine smile cannot be detected in the mouth as both incorporate an upturn of the mouth, but can be detected in the eye region as genuine smiles involve crinkling around the eyes while posed smiles do not. In addition, these authors found that individuals with autism spent significantly less time than the control group in looking at the eye region in this task. While the ASD group did spend more time focusing on the mouth than the eye region, there was not a significant difference between groups.

Eye gaze when looking at static photographs has also been linked to some neural correlates in both emotion recognition and facial discrimination tasks. Dalton et al., (2005) found that activation in the fusiform gyrus and amygdala were both positively correlated with eye gaze in adults with ASD. This research team proposed that previous findings that the fusiform gyrus is hypoactive when viewing faces in individuals with ASD (Grelotti et al., 2005; Shultz, 2005) may be actually because of diminished eye gaze. They also proposed that amygdala activation may be due to a heightened emotional response associated with gaze fixation.

Neural correlates of 3- to 7-year-old children with ASD were also found to be abnormal when compared to age-matched controls while processing direction of eye gaze (Grice et al., 2005). In this study, children engaged in a passive viewing task where they were shown several pictures of people with either direct eye gaze or averted gaze. Children with ASD showed a larger midline-N170 measured by EEG for direct gaze than for averted gaze, a phenomenon not seen in TD controls or adults. This pattern is similar to that seen in 4-month-old infants (Farroni et al., 2002) indicating a developmental delay in gaze processing for children with autism. The larger midline-N170 may indicate a deeper processing of faces with direct rather than averted gaze in infants and children with ASD, while TD children and adults process the face the same whether there is direct or averted gaze. However, another study found a different abnormality when using an active rather than a passive gaze detection task (Senju, Tojo, Yaguchi, & Hasegawa, 2005). This study found that both control and ASD children showed greater amplitude N170 for direct versus averted eye gaze, but children with ASD did not show lateralization, while controls showed right lateralization.

The lack of attention to the eye region in ASD is exhibited by children as young as 2 years old up through adulthood. In addition, some neurological evidence supports the hypothesis that the issue in facial processing is that individuals with ASD are ignoring the eye region leading to abnormal processing of the face (Dalton et al., 2005; Senju et al., 2005). Other neurological evidence, however, suggests that processing of the eyes may just be delayed in ASD (Farroni et al., 2002).

Overattention to the mouth region.

Atypical methods of looking at the face in ASD may not be due to inattention to the eye region, however, but rather to overattention to the mouth. As previously stated, children with ASD were found to use the mouth to identify a displayed emotion rather than the whole face in dogs, orangutans, and humans (Gross, 2004). Even when the mouth is not present in a picture, individuals with ASD may still try to reference this area. When using “bubbles” (revealing one facial feature while obscuring others) during an emotion recognition task, adults with high functioning autism (HFA) were more likely to saccade away from the eye being shown in the “bubble” and toward the mouth region which was obscured (Spezio, Adolphs, Hurley, & Piven, 2006).

This preference for the mouth over the eye area may be seen from a very early age. It was found that 6-month-old children at-risk for autism (i.e., had an older sibling with the disorder) were more likely to show diminished eye gaze to the eye region and heightened attention to the mouth when viewing a still face episode of his/her mother. However, no differences were found between the ASD group and typically-developing controls when comparing the amount of time they fixated on other specific facial features or the entire face (Merin et al., 2006). In addition, 2-year-olds with autism spent significantly more time looking at the mouth than TD controls when watching an engaging adult (Jones et al., 2008).

This preferential attention to the mouth may be different than TD counterparts, but may actually be indicative of better outcomes for adolescents with ASD. For example, when viewing naturalistic interactions between two people, adolescents with ASD who spent more time looking at the mouth showed less social impairment (Klin et al., 2002) and great communicative competence (Norbury et al.,2009). In addition, adolescents with ASD that spent similar amounts of time viewing the eyes actually scored lower on measures of verbal communication (Norbury et al., 2009), while adolescents that spent more time looking at objects scored lower on measures of social competence (Klin et al., 2002).

Much like the literature indicating that individuals with ASD spend less time looking at the eyes, the literature suggesting that they spend more time looking at the mouth spans from a very young age (6 months) to adulthood. As noted above, however, there are two issues with the hypothesis that preferential attention to the mouth leads to abnormal processing of the face. First of all, preferential attention to the mouth may be related to less time spent on the eyes (i.e. individuals with ASD spend less time on eyes; therefore, they look at other areas like the mouth more). Moreover, looking at the mouth may be adaptive for individuals with ASD by leading to increased social and communicative competence (Klin et al., 2002; Norbury et al., 2009).

Looking at irrelevant areas.

While a lack of attention to the eye region and preferential attention to the mouth in individuals with ASD may be an issue in facial processing, another issue may be that these individuals are not looking at salient facial features (i.e. mouth, nose, and eyes) enough. For example, Pelphrey et al., (2002) found that adult males with HFA spent significantly less time looking at salient features of the face when engaging in a passive viewing task and during an emotion recognition task. In addition, these researchers stated that the HFA men were generally "erratic, undirected, and disorganized" when compared to controls.

Looking at the same areas but processing differently.

The issue may not be where people with autism are looking, but rather *how* they are looking. Specifically, many theorists have proposed that the issue is not in the first or second order processing of the face, but rather the third order, or holistic, processing. Many individuals with ASD show heightened abilities in tasks that require the processing of individual pieces of information within an embedded figure (i.e., low spatial frequency), but this may be at the expense of more global processing (i.e., high spatial frequency) (Shah & Frith, 1983). This phenomena, referred to as "weak central coherence” (Frith, 1989) may be a contributing factor in perceptual abnormalities found in ASD. In line with this notion, research has shown that children with ASD are better at matching faces based on local facial features rather than global configuration of faces, while TD controls show the reverse (Deruelle, Rondan, Gepner, & Tardif, 2004). Similar findings were found not only for faces, but for objects as well (Behrmann et al., 2006).

Additional support for this theory has been found when presenting individuals with ASD with upright versus inverted faces. Typically-developing children and those with William’s Syndrome show a decreased ability to discriminate faces when they were inverted, while children with ASD showed no difference in performance (Rose et al., 2007). Van der Geest, Kemner, Verbaten, and van Engeland (2002) also found that TD children spent less time looking at an inverted face than an upright face while children with ASD spent the same amount of time on both inverted and upright faces. These results support the notion that children with ASD may rely more on local rather than global processing when looking at faces, and therefore global changes from inversion do not interfere with the ability to process the face. Another study found that children with ASD do spend less time fixating on inverted versus upright faces, but still spend more time fixating on inverted faces than TD peers (Falck-Ytter, 2008). Moreover, Pelphry et al.’s (2002) gaze path data further support the theory that individuals with ASD use more local processing. Erratic gaze patterns may be indicative of local processing, while a more controlled and planned gaze pattern may be consistent with global processing.

Yet, not all evidence suggests that individuals with ASD use local versus global information when examining faces. It has been found that children with ASD perform better on a discrimination task involving the mouth when information is presented holistically (in context of a face) rather than in a piecemeal fashion (not in a face). In this study, they also exhibited an inversion effect where they are slower to process information about the face when it is presented upside-down rather than right-side up (Joseph & Tanaka, 2003). This is a phenomenon that is seen in typically-developing individuals as well. In addition, adults with ASD have shown the ability to process faces holistically when identifying whether the top and bottom of a face were the same person (Nishimura, Rutherford, & Maurer, 2008). In this study, pictures of faces were presented to adults with ASD and a control group and they had to determine whether the top and the bottom of the face were from the same person. It was proposed that if adults with ASD were looking at the face using local processes, they would be superior to controls in determining whether the face was made from two different people, or one person; however, this effect was not found.

Finally, another study found that scanning responses were similar between a TD, ASD, and developmental delay (DD) when examining different look zones on the face (eyes, nose, and mouth). Since looking was similar between groups, analyses were carried out on whether children looked on the face (internal) or off the face but still on the head (external). They found that when children with ASD examined internal features, pupil size decreased while TD pupil size increased. This suggests that TD children were better at engaging with and processing social stimuli than children with ASD (Anderson, Colombo, & Shaddy, 2006).

Emotion Identification and Dynamic Stimuli

A majority of the literature examining deficits or abnormalities in facial processing by individuals with ASD has been done using static images of faces. Recently, there has been an increase in the number of studies using dynamic stimuli. One study examined emotion recognition in children with ASD in the absence of an eye tracking component (Golan, Baron-Cohen, & Golan, 2008). In this study, they found that children with ASD performed worse in a task geared towards recognizing complex emotional states in dynamic video clips taken from child-friendly feature films with 1- to 4 characters. This is more ecologically valid than previous studies that use static photographs, since humans interact with moving stimuli that includes auditory input and context.

In another study, children with ASD were impaired in detecting anger and took longer to recognize emotions than TD controls when viewing silent videos where a face with a neutral expression transitioned to an emotional expression (Bal, Harden, Lamb, Van Hecke, Denber, & Porges, 2010). In this study, greater attention to the eyes was correlated with better emotion recognition and less severe ASD symptomology. Another study used a similar paradigm to examine emotion identification of dynamic faces in young children and across the developmental trajectory (Rump, Giovannelli, Minshew, & Strauss, 2009). They found that young children with ASD (ages 5-7 years) were impaired in recognizing negative emotions, especially afraid and angry. They also saw that TD individuals improved at emotion recognition as they aged, while individuals with ASD did not.

A similar task that has been used is the Emotional MultiMorph Task, a task where a picture of a neutral expression is slowly morphed into an expressive face. This is done by presenting 21 pictures that increase expression by 5% for each picture for 3 seconds at a time (Blair, Colledge, Murray, & Mitchell, 2001; Wallace et al., 2011). When using this paradigm, Wallace et al. (2011) found that adolescents with ASD were impaired in identifying sadness and required more intense expressions in order to identify any of the tested emotions. Furthermore, being impaired in recognizing sadness was correlated with ASD symptomology and adaptive functioning. Difficulties with emotion recognition were observed in another study that used the same paradigm, but only used 9 pictures with changes from neutral to full expression of 10% (Smith, Montagne, Perrett, Gill, & Gallaghera, 2010). In this study, they found that male adolescents with ASD were impaired at identifying anger, disgust, and surprise at lower intensity levels, anger and disgust at medium intensity, and disgust at full intensity. These studies show that children with ASD have difficulty recognizing emotions at lower intensity levels, but this is not the same as identifying emotions in naturalistic, dynamic stimuli. When in the natural environment, the face will not just morph into a more intense emotion, but will involve speaking, movement up and down and from side to side, and will involve speaking.

Multi-Modal Processing

Auditory processing.

Emotion processing is not a purely visual event. When interacting with others, we also obtain auditory information that can be used to make judgments about the social interaction, including emotion. When looking at auditory information in isolation, individuals with ASD may show difficulties in identifying emotion. For example, adults with ASD are less proficient than TD controls when identifying complex emotional states from a speaker's voice alone when there are no visual cues or contextual cues such as linguistic content (Golan, Baron-Cohen, Hill, & Rutherford, 2007).

Another study looking at adolescents with Asperger's Disorder (AS), HFA, and a TD control group found that children with AS were as proficient as TD peers at identifying emotions based on tone of voice, while children with HFA were impaired even when controlling for IQ by including it as a covariate in all analyses (Mazefsky & Oswald, 2007). This study is one of the first to compare emotion recognition across AS and HFA. In fact, another study that examined 10-14 year old children with different high functioning autism diagnoses (including classic autism, AS, and PDD-NOS) found no differences in the ability to recognize emotion from prosody alone when comparing the ASD group with a TD control group (Baker, Montgomery, & Abramsom, 2010). However, it is noteworthy that both of the studies including children and adolescents used basic emotions and allowed participants to choose the emotion from a list (Baker et al., 2010; Mazefsky & Oswald, 2007), while the study using adults looked at complex emotions and did not have a menu to choose from (Golan et al., 2007).

Multi-modal processing and language.

Language deficits are a core feature of ASD (APA, 2000), and speech, like emotion recognition, is not a unimodal process (Bristow et al., 2008). Both auditory and visual stimuli help guide speech perception and understanding from infancy to adulthood (Bristow et al., 2008; McGurk & MacDonald, 1976). One of the primary paradigms used to examine how auditory and visual information is combined to guide speech perception is the McGurk effect. In this task, an audiovisual mismatch is presented and the observer perceives a third, different sound. For example, an auditory /ba/ is presented with a visual /ga/ and a "fusion" response occurs where the observer hears /da/ (McGurk & MacDonald, 1976). This effect can be seen in infants as young as four months old

(Burnham & Dodd, 2004) and continues through adulthood (McGurk & MacDonald, 1976).

Several studies have examined the McGurk effect in an ASD sample. One study found that children (ages 6-13) with ASD were less sensitive to the McGurk effect than a TD control group. However, after a portion of the ASD sample underwent a speech-reading program training where they were taught to “read lips”; there was no longer a difference on performance (Williams, Massarob, Peela, Bosselerb, & Suddendorf, 2004). Furthermore, when they controlled for a lip-reading deficit in the ASD and TD samples, they found no differences. This led the authors to postulate that children with ASD do not have difficulty with integrating multi-modal information, but that a uni-modal deficit in visual “lip-reading” may be responsible for the difference in McGurk sensitivity. In fact, difficulties with lip-reading in autism have been shown in another study with adolescents (Smith & Bennetto, 2007).

Difficulties with the McGurk and other social audio and visual integration tasks were seen in another study comparing adolescents with ASD and TD controls. In this study, researchers attempted to compare difficulties with audio-visual integration between social and non-social stimuli. Adolescents with ASD were found to be less likely to integrate audio-visual stimuli for social tasks, such as the McGurk, while they performed at the same level as TD controls when exposed to non-social stimuli (Mongillo et al., 2008).

Finally, another study found that there was a difference between children with ASD and TD controls on the McGurk effect when children were younger, similar to the results found in the previous studies. However, this study examined how maturation affected performance on the McGurk paradigm. They found that while young children with ASD showed less of an effect, they tended to "catch-up" as they aged and showed no difference on the task by adolescence. This led the authors to believe that young children with ASD may have difficulties integrating auditory and visual information, but by adolescence, they would catch up to their TD peers (Taylor, Isaac, & Milne, 2010).

Multi-modal processing and emotion.

Emotion identification and processing in the natural environment is often a multi-modal process. In fact, infants as young as seven months are able to recognize when the emotion on a face and the prosody of the voice are congruent or incongruent as evidenced by ERP data (Grossmann, Striano, & Friederici, 2006). The ability to recognize congruence in emotional expression may be a deficit in individuals with ASD as evidenced by difficulties with sarcasm (Adachi et al., 2004). In fact, research has shown that many individuals with ASD are less proficient at recognizing emotional incongruence when presented with competing verbal prosody and visual information. For example, adults with AS were able to identify emotions portrayed in faces and prosody presented in isolation at the same level as a TD sample, but were not as proficient at identifying incongruence between a face and voice (O'Conner, 2007).

Young children with ASD may also have difficulties processing verbal prosody and visual information. In a study by Kahana-Kalman and Goldman (2008), children with ASD were able to detect emotion mismatch, based on looking time, between silent videos and vocal expressions when watching their mothers but not for novel women while a TD control group were able to detect the emotion mismatch in both novel women and their mothers. Children with ASD also showed a preference for sound and visual match for inanimate objects (like dropping marbles in a jar or xylophone) like TD controls.

Many studies that have noted difficulties with emotion identification in individuals with ASD, so it is not surprising that Lindner and Rosén (2006) saw that children and adolescents with ASD performed more poorly than TD controls on emotion identification tasks involving static facial expression, dynamic facial expression, and prosody. However, they found that both the ASD and TD groups performed similarly on an emotion identification task when verbal content gave hints as to the emotion portrayed in a neutral voice and when presented with dynamic facial expressions with matching prosody and verbal content. These results suggest that individuals with ASD may rely more on verbal content than other affective clues when presented with multi-modal stimuli.

These results are inconsistent with findings from another study that examined how well individuals with ASD and a TD control group were able to identify emotion from dynamic stimuli of a person saying a phrase where the emotion was identified in the content, implied by content, or was neutral in content and the face either expressed the emotion or was neutral (Loveland et al., 1997). In this study, they found that individuals with ASD performed at the same level as TD controls when matched by functioning level. However, differences in performance were seen based on whether individuals were high or low functioning based on IQ scores, with individuals in the low-functioning group impaired at emotion recognition when compared to the high-functioning group. This effect was seen in both ASD and TD samples.

Collectively, these studies suggest that individuals with ASD may have difficulties integrating information from prosody and facial affect when interacting with unfamiliar people, but are able to use verbal content to help augment information about emotion expression. This effect is not likely due to an inability to integrate multi-modal information as evidenced by the ability to recognize incongruences in non-social stimuli and in facial affect and prosody in highly familiar people, but rather difficulty in generalizing these skills to social information with unfamiliar people. This could lead to differences in viewing patterns between children with ASD and TD peers when faced with dynamic stimuli with multi-modal information since both groups may be using different information to make social judgments including emotion recognition.

The Proposed Study

The current study will examine the differences between children with autism and controls matched on mental age and gender during an emotion recognition task using a dynamic face with voice. Using a dynamic face with voice allows us to examine how children with autism may process a face that is more naturalistic than a static face. If children with ASD show atypicalities in viewing a dynamic face, we can hypothesize that this may be a contributing factor for difficulties in emotion recognition and social interaction. If the children with ASD are not looking at the entire face, they may be missing important social cues. On the other hand, if the hypotheses are not supported using a dynamic face, then previous results suggesting children with ASD view the face in an atypical way may be due to the stimuli rather than a true deficit.

Hypotheses

1. Children with ASD will spend less time foveating on the eye region and more time foveating on the mouth region than mental age (MA) and gender matched controls when viewing a dynamic face with sound.
2. Children with ASD will spend less time looking at the face than MA and gender matched controls when viewing a dynamic face with sound.
3. Children with ASD will be less accurate in an emotion recognition task than their MA and gender matched counterparts when viewing a dynamic face with sound.
4. The amount of time spent foveating on the eye region will be related to accuracy of emotion recognition.

Methods

Participants

Participants in the ASD group were 8 children with a community diagnosis of autism (n=3) or Asperger's Disorder (n=5) and 8 children in a TD control group matched for mental age and gender (7 male, 1 female) with guardian consent to participate in the study. The guardians who gave consent and completed parent-report questionnaires were all mothers of the children in this sample. The children in the ASD group were all Caucasian and the children in the TD group were 87% Caucasian and 13% African American. Parents of children in the TD group generally earned more than parents in the ASD group with income being over $100,000 in 65% of the TD group and between $20,000 and $39,999 for 50% of the ASD group. Additionally, parents of children in the TD group tended to have more education with 50% of them earning a graduate degree and 50% of the parents in the ASD group had a college degree. To be included, ASD diagnosis was confirmed by the Social Responsiveness Scale (see below). Additionally, children had to be able to remain seated relatively independently for at least thirty minutes and be able to provide one-word answers to "what" questions. Three children with ASD were not included in the study as their IQ scores fell below the cut-off of 70. See Table 1 for demographic characteristics for both groups.

Matching.

Children in the ASD and TD groups were matched on mental age (MA) and gender at the group level. Mental age was calculated by multiplying the child's chronological age by their full scale IQ and dividing the product by 100. MA is not a perfect measure of developmental level (Thurston, 1926); however, it provides a simple, brief measure of functioning level that has significance in this population.

Apriori Power Analysis

An apriori power analysis was performed to determine the sample size needed to find a medium effect size with $\alpha=.05$ and power of $\beta=.8$. According to Stevens (2009), a small, medium, and large effect size coincides with a Mahalanobis distance of .25, .5, and 1.0 respectively. With $\alpha=.05$ and power of $\beta=.8$, a total of 50 participants per group were needed to detect a medium effect size, and a total of 26 participants per group were needed to detect a large effect size. A majority of prior studies include fewer than 15 participants per group. This study aimed for a sample size of 30 participants per group, which would be sufficient to detect a large effect. However, due to difficulties with recruitment, only 8 participants were included in each group. As such, this study is underpowered, and results must be viewed as preliminary until additional participants are tested.

Apparatus

A Tobii T60 eye tracker was used to measure children's eye gaze fixations. The Tobii T60 uses infrared technology to measure corneal reflection in the children without the use of a head-mounted device. This is done by measuring the X and Y coordinates of the children's pupils at 60 Hz while viewing a 17" monitor.

Stimuli

Stimuli were ten 2-5 second videos that were part of a larger set of stimuli depicting four different women saying various phrases and exhibiting the emotions of happy, sad, scared, excited, and angry. There were two different videos for each emotion, counter-balanced so the same woman or emotion was never presented twice in a row. These videos were pre-judged by faculty and students in the department of psychology at Virginia Tech to determine validity of emotional expression. The videos with the highest ratings of emotion accuracy and strength were chosen as stimuli for the study. All videos were rated as portraying the selected emotion at least 80% of the time and with a strength rating of 3 or higher on a 5 point Likert scale with 1 being weak to 5 being strong. Data were collected on whether children identified emotions correctly, incorrectly, or failed to respond to stimuli. The number of correct responses was used in the analyses.

Measures

Demographic form.

A guardian of the child completed a demographic form (Appendix A), with the following information about the guardian: relation to child, highest level of education, and household annual income. Information about the child included the child's age in years and months, gender, race/ethnicity, amount of education completed, any medications the child was taking, and the type of ASD diagnosis (for the ASD group).

Social Responsiveness Scale (SRS).

The Social Responsiveness Scale (SRS) is a parent-report questionnaire including 65 questions scored from 0 (not true) to 3 (always true) that takes approximately 15-20 minutes to complete. The clinical cut-off for autism is >70 for males and >65 for females. The SRS measures the severity of autism spectrum traits in children between the ages of

4 and 18. The SRS provides information on the child's social behavior in social settings with subscales measuring social awareness, social cognition, social communication, social motivation, and autistic mannerisms (Constantino & Gruber, 2005).

The SRS is shown to have good reliability when used with parents: split-half reliability=.93-.97, construct temporal stability=.77-.85 (time between administrations=17 months), and interrater reliability=.75-.91 (Constantino & Gruber, 2005). The SRS has also been shown to have good validity as it is highly correlated with the Autism Diagnostic Interview-Revised (ADI-R, r=.7) (Constantino et al., 2003).

The SRS was included in this study because it is a brief yet valid and reliable measure of autistic symptomology. All children with ASD were required to score above the clinical cutoff and all children in the control group were required to score below the cutoff. Refer to Table 1 for descriptives.

Kaufmann Brief Intelligence Test, Second Edition (KBIT-2).

The Kaufmann Brief Intelligence Test, Second Edition (KBIT-2) is an intelligence test that provides a measure of verbal intelligence, nonverbal intelligence, and a composite IQ score with a mean of 100 and standard deviation of 15. The KBIT-2 is appropriate for use with individuals between the ages of 4 and 90 and takes about 15-30 minutes to administer. Verbal scales include a verbal knowledge test to measure receptive language and general knowledge and a riddles test to measure comprehension, reasoning, and vocabulary knowledge. The non-verbal scale utilizes a Matrices subtest to measure the ability to complete visual knowledge and relationships (Kaufmann & Kaufmann, 2004).

The KBIT-2 was standardized on a group of 2,120 individuals of different gender, race/ethnicity, geographic region of the United States, and educational level. The KBIT-2 is shown to have acceptable reliability: internal consistency=.93, test-retest stability=.90 over (22.5-30.8 days between testing). It has shown good construct validity with no gender differences and a general increasing trend in raw scores across age groups (Kaufmann & Kaufmann, 2004).

The KBIT-2 is a brief yet valid and reliable measure of IQ. In addition, it can be used with a wide range of ages so all children can be tested using the same measure. The KBIT-2 can be administered relatively quickly (15-30 minutes) which will help reduce the possibility of fatigue before the eye-tracking task. A brief measure of IQ is best used when working with young children and children with ASD who may have shorter attention spans. All children who scored below 70 on the KBIT-2 were excluded from the study as previous research has shown that low cognitive ability may confound emotion recognition studies.

Procedure

Calibration.

Children were seated on a chair 24 inches from the monitor that was mounted on an extension arm. A bouncing ball was presented on the screen in five different places with a beeping sound to determine where the individual was looking to calibrate the tracker. When a location shows poor tracking, it can be selected and recalibrated. We repeated this procedure until 4/5 points showed good tracking for each eye. It should be noted that we sat children 24 inches from the monitor, but many of the participants moved around frequently, so this may have affected tracking after calibrating the eye tracker.

Stimulus presentation.

Prior to calibration, children were told that they were going to watch some movies and look at some pictures. Before any trials were administered, a manipulation check was performed. Children were presented with a picture of a cat and asked, "What color was the cat?" Children were then presented with a picture of a horse and asked, "What color was the horse?" This manipulation check assured that children were able to answer "what" questions. Only one child failed the manipulation check and she was removed from the analyses for this reason in addition to an IQ score below 70. Prior to each stimulus presentation, an X with a circle in the center was presented on the screen and the child was instructed to look at the middle of the X. After each movie clip, a screen with the question "What was she feeling?" was presented on the screen and a recording of a woman's voice asking the same question was presented. If the child did not answer within 10 seconds, the audio recording played again and the child was given another 10 seconds to respond. If the child did not answer after the second prompt, then the X was represented on the screen and the next trial was started.

Eye tracking data.

The amount of time that each child spent in the following regions was measured: eye area, mouth area, and on face viewing. In order to standardize the length of each video, only the first 2 seconds of each video were included in the analyses. After the amount of time each child spent on specific areas was determined based on the trials with data, average looking time per video for each area of interest (eye, mouth, face and off-face) was determined by dividing the sum looking time by the number of trials with data and the emotion was correctly identified by the child.

Analytic Plan

The relationships between demographic variables (i.e. age, race, and gender) and face viewing time and emotion recognition were examined to look for intercorrelations that needed to be controlled for and examine the relationship between the amount of time spent on the eye region and emotion recognition accuracy (hypothesis 4). The amount of time that each child spent in the following regions was measured: eye area, mouth area, and face. After the amount of time each child spent on specific areas was found, they were averaged to provide the average amount of time spent on each area for each group. Only trials when the child identified the emotion correctly and had tracking data were included in the analyses. A Group (2) X Area of Interest (3) mixed factorial ANOVA was conducted to determine whether there was a significant difference between viewing times of specific areas between groups and examine interactions. If significant results were found with the ANOVA, a series of t-tests was performed to determine which areas of interest led to the significant ANOVA result (hypotheses 1 and 2). The accuracy of emotion recognition in each child was also measured and a total emotion identification score was determined for each child by summing the number of trials where they correctly identified the emotion. An independent samples t-test was conducted to compare groups on emotion recognition. A series of Fisher's exact tests of independence were conducted for each emotion to determine if children differed on emotion recognition performance for each emotion (hypothesis 3). This is a preliminary, exploratory study; therefore, significance was set at $\underline{p} \leq .1$.

Results

A series of t-tests were performed to ensure that groups were matched on MA and Verbal MA. Age, IQ, verbal IQ, and % of data collected in the eye tracking task were also examined (See Table 2). There were significant differences between the groups on verbal IQ; $\underline{t}(14)=-2.32$, $\underline{p}\leq.05$, and percent of data collected; $\underline{t}(14)=-2.56$, $\underline{p}\leq.01$) with children with ASD being lower on both variables. A series of chi square analyses were carried out to explore whether there were differences between groups on categorical variables including income, parental education, and child education. No significant group differences were found for family income, $\underline{X}^2$ (4, N=16)=7.47, $\underline{p}=.11$, or child education $\underline{X}^2$ (4, N=16)=1.67, $\underline{p}=.80$; although there was a significant relationship for parental education, $\underline{X}^2$ (3, N=16)=6.80, $\underline{p}\leq.1$. A series of correlations were conducted to examine relationships among variables in the total sample as well as in each group (See Table 3). When examining correlations, some key relationships were observed. These included relationships between amount of time spent on the mouth and face and emotion identification, especially for the ASD group and a relationship between verbal MA and emotion identification, especially for the ASD group.

Hypotheses 1 & 2

A 2 x 3 mixed factorial ANOVA was conducted with group (ASD,MA control) as the between subjects factor and AOI (eye area, mouth area, face) as the within subject factor. All variables were tested for normality prior to analysis by examining the Shapiro-Wilks statistic, standardized skewness (skewness statistic/standard error of skewness value), and visual inspection of Q-Q plots (Stevens, 2009; Tabachnick & Fidell, 2007) by group for each AOI (see Table 4). The Shapiro-Wilks statistic was significant for the eye area for the ASD group; however, standardized skewness was between ± 3.29 and the Q-Q plot looked normal, so normality was assumed for this variable. Mauchley's Test for Sphericity was significant so the Greenhouse-Geisser corrected F-values were used to examine differences for within-subject factors (AOI and the interaction). There was a main effect of AOI $\underline{F}(2,28) = 2.97$, $\underline{p} \leq .1$. There was an interaction between group x AOI $\underline{F}(2,28) = 5.00$, $\underline{p} \leq .05$. There was a main effect for group $\underline{F}(1,14) = 15.33$, $\underline{p} \leq .01$ with children with ASD looking at the face less than controls. Independent samples t-tests indicated that children with ASD spent significantly less time looking at the mouth than TD controls; $\underline{t}(14) = -3.94$, $\underline{p} \leq .01$.

No significant differences between groups were observed between the amount of time spent on the eyes; $\underline{t}(14) = -1.01$, $\underline{p}=.30$. See Table 5 for complete t-test statistics. Average duration for each AOI by group are presented in Figure 1.

Hypothesis 3

A t-test was performed to determine whether children with ASD differed in their ability to recognize emotions when compared to controls. There was no difference in emotion recognition ability between groups; $\underline{t}(14) = -.548$, $\underline{p}=.59$. Since other studies have found differences in emotion recognition only for specific emotions (Rump et al., 2009; Smith et al., 2010; Wallace et al., 2011) between children with ASD and TD controls, a series of Fisher's exact tests of independence were conducted for each emotion. Since there are only three possible scores for each emotion (recognized 0, 1, or 2 examples of each emotion), data need to be treated nominally. Fisher's exact test of independence allows for fewer than 5 observations per cell and was used instead of chi square analysis for this reason. None of the probabilities from Fisher's exact test of independence were statistically significant (see Table 6). Individual performances on the emotion identification task are presented in Table 7.

Hypothesis 4

There was not a significant relationship between amount of time spent on the eye region and emotion identification (see Table 3); however, the relationship between amount of time spent on the mouth region and emotion identification was explored further. Since verbal MA and time spent on the mouth region were significantly correlated with emotion identification in the ASD group, a hierarchical regression analysis was conducted to determine whether the time spent on the mouth region predicted emotion identification while controlling for verbal MA. Time spent on the mouth region continued to account for a significant amount of variance in emotion identification while controlling for verbal MA in the ASD group ($\underline{R}^2_{change}$=.16, $\underline{p}\leq.05$).

Discussion

As predicted, children with ASD spent less time foveating on the face than gender and MA-matched controls during an emotion identification task. Contrary to the prediction, however, children with ASD did not spend less time foveating on the eye region or more time foveating on the mouth region than controls. In fact, controls tended to foveate on the mouth region longer than children with ASD. Furthermore, the amount of time spent foveating on the mouth region was correlated with ability to identify the emotions portrayed in the videos in both groups, with a significant correlation ($p \leq .05$) for children with ASD. This is contrary to the predicted relationship that more time foveating on the eye region would be related to better emotion identification. Finally, there were no significant group differences on the ability to accurately identify different emotions. This may have been due in part to using an MA-matched control group where children tended to be younger than in the ASD group. Emotion identification was positively correlated with age in the MA-matched control group while it was not for children with ASD.

The findings that children with ASD spent less time foveating on the face than MA-matched controls is consistent with the current conceptualizations of ASD in that they spend less time looking at social stimuli (APA, 2000); however, children with ASD did not spend less time foveating on the eyes, as is often found when viewing static pictures (Pelphrey et al., 2002; Boraston et al., 2008). Interestingly, children with ASD spent less time foveating on the mouth region. Many studies have found that individuals with ASD spend the same amount of time on the mouth region than a TD control (Bal et al., 2010; Hernandez et al., 2009), while others have found that individuals with ASD are more likely to utilize the mouth region (Neumann et al., 2006; Spezio et al., 2007). Only trials where the child correctly identified the emotion were used indicating that, even when children with ASD are able to identify emotions correctly, they look at the mouth less than TD children. Even though the difference in the amount of time spent foveating on the mouth region was nonsignificant between groups, the novel direction of the effect and the relationship with emotion identification in this study warrants further investigation.

As previously stated, the time spent foveating on the mouth region was correlated with emotion identification ability. This correlation was significant for both the ASD and TD group but was stronger for children with ASD. This effect was observed in children with ASD even when controlling for verbal MA and despite a tendency to foveate on the mouth region less than controls. The relationship between amount of time foveating on the mouth region and better emotion identification is consistent with prior results indicating that attention to the mouth was indicative of social competence and improved communication in children with ASD (Klin et al.,, 2002; Norbury et al., 2009). Communication, social competence, and emotion recognition are all constructs that are needed to navigate in a social world, and it appears that, for children with ASD, attention to the mouth may aide in these skills.

One question that remains is why foveation on the eyes is associated with better performance on emotion identification with static pictures as found in prior research and why foveation on the mouth may be more important when viewing dynamic stimuli with sound. The answer may lie in multi-modal processing. When viewing dynamic stimuli with sound, a person receives visual input including what they are looking at and movement and auditory input including both prosody and semantic content. It has been shown that children with ASD may have difficulty identifying emotions when given only prosody, the face alone, or a combination of the two (Lindner & Rosén, 2006). However, when children with ASD are given semantic information either alone or in conjunction with other stimuli, they can identify emotion on the same level as TD controls (Lindner & Rosén, 2006). Attention to the mouth allows a person to use both visual (lip reading) and audio (spoken words) information to determine what a person is saying. Children who are able to integrate both the auditory and visual information may be better at recognizing the semantic content of what was said and use this information to help guide emotion identification. Since the stimuli in the current study included semantic content, it is unclear whether attention to the mouth would have provided as much information about emotion if semantic information was not available, as previous studies have shown that semantic content supplements emotion understanding in children with ASD (Lindner & Rosén, 2006).

It should be noted that foveation only indicates that a person is looking directly at an object. It does not take into account a person's a person's entire visual field. A child may be foveating on the mouth, but they can also see the rest of the person's face and environment. Foveation is important for examining detail while movement (like that seen with a talking mouth) is actually processed in the periphery. However, foveating on the mouth may allow children to better identify the placement of the tongue, teeth, and lips; therefore, improving lip-reading ability and understanding the semantic content.

There were several limitations to this study. A MA-matched control group was used rather than an age and IQ matched control. MA was calculated based on age and IQ, which may not be the most accurate measure of ability; however, MA is a more accurate measure in children than adults (Thurston, 1926). While samples were matched on MA, there was a significant difference between verbal IQ at the $p=.05$ level between groups. Additionally, there was significantly less tracking information in the ASD group when compared to the MA-matched control group. We controlled for this as much as possible by eliminating trials where no data were collected for all participants, but this may have affected results.

Several factors may have led to the lack of eye-tracking information in children with and without ASD. Children often had difficulty sitting still and would lean from side to side and back and forth. When doing this, we frequently lost tracking information as children would be too close or too far away from the sensors to accurately track the pupils. Hyperactivity is a symptom that many children with ASD exhibit (Mayes, Calhoun, Mayes, & Molitoris 2012), and this may have caused there to be less tracking information in this group. Furthermore, we observed difficulties in the ability of the equipment to track the eyes when children wore eyeglasses; 25% of the children with ASD and none of the control children wore eyeglasses. Finally, it must be noted that eye-tracking technology only measures foveation, or where pupils fixate. Children with ASD may be less likely to foveate, or fixate directly, at social stimuli and may rather look at the face indirectly or "out of the corner of their eyes," so they may be getting the needed information to inform emotion identification, but may not look directly at social information. Further analyses using behavioral data from video of children being tracked need to be examined to explore these hypotheses further and determine whether time spent off screen was due to less foveation on screen or difficulty in tracking children with glasses and active children.

There were several other limitations in this study. First and foremost was the small sample size. Given the size of the sample, all results must be interpreted with caution. Furthermore, to the author's knowledge, there are no standardized dynamic videos portraying emotion. Videos were rated by independent coders for the name of emotion portrayed and strength. Videos exhibited good validity as they were all reliably identified by coders but were not consistent in length or strength. Additionally, an open-ended emotion identification task was used rather than an emotion selection task. This was used in an attempt to avoid ceiling effects for emotion identification; however, this may have led to the high level of variability in the emotion identification task. Finally, ratings on the amount of semantic information available in the videos were not conducted, so there is no way to determine whether semantic information improved emotion recognition ability for children with ASD.

Further parameters for eye tracking data should also be explored with this sample. Duration was used as a measure of foveation and attention to a specific area. This is commonly done in the eye tracking literature, but looking at the data in a different way may lead to differences in results and interpretation. Other units of analysis include fixation counts, duration to first fixation, and pupilometry data. Looking at these measures may lead to different results, interpretations, or augmentations. For example, children with ASD may be less likely to look directly at a person for a long period of time (as measured by duration), but may instead glance at the person frequently to gain that information (as measured by fixation count).

Overall, this study provided some preliminary, albeit limited, evidence that children with ASD are less likely to foveate on faces than their TD counterparts when encountering dynamic stimuli; additionally, they appear to spend a similar amount of time on the eyes but may spend less time on the mouth. Despite a tendency for less viewing of the mouth, amount of time viewing the mouth region was significantly related to emotion accuracy in the ASD group, suggesting that children with ASD may benefit from information in the mouth region. Given the small sample size and relative lack of statistically significant results, these results need to be expanded with a larger sample size and replicated. Further studies should also parse out whether understanding semantic information is a key contributor to emotion understanding with dynamic stimuli and further examine the relationship between attention to the mouth and emotion recognition in children with ASD and TD controls.

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Appendix A

Demographic Survey

Subject #: _________________

You may choose <u>not</u> to answer one or more of the questions.

<u>GENERAL INFORMATION ABOUT THE PARENT</u>

What relation are you to the child?

____Mother
____Father
____Stepmother
____Stepfather
____Adoptive Mother
____Adoptive Father
____Legal Guardian
____Other Relative (please specify): _________________________

What is your race/ethnicity?

____African American
____Asian
____Caucasian/European American
____Native American
____Latino, Hispanic, or Chicano
____Other (please specify): _________________________

What is your highest level of completed education?

____Some High School
____High School Graduate
____Some College
____College Degree
____Some Graduate Studies
____Graduate Degree

Which of the following is closest to your annual household income?

____Under $20,000
____$20,000 - $39,999
____$40,000 - $59,999
____$60,000 - $79,999
____$80,000 - $99,999
____$100,000 and above

<u>GENERAL INFORMATION ABOUT THE CHILD</u>

When is your child's birthday?
____Month ____ Day ____ Year

How old is your child?
____Years ____Months

What is your child's gender?
____Male
____Female

What is your child's race/ethnicity?
____African American
____Asian
____Caucasian/European American
____Native American
____Latino, Hispanic, or Chicano
____Other (please specify): ______________________________

What level of education has your child completed?
____None
____Preschool
____Kindergarten
____Elementary School

Specify highest grade completed: ______________________________

Does your child take any medications?
____Yes ____No

If yes, please specify what medications:
____

____

GENERAL INFORMATION ON DIAGNOSIS AND PROFESSIONAL SERVICES

What is your child's current Autism Spectrum Disorder diagnosis?
____Autism or Autistic Disorder
____Asperger's Disorder
____Childhood Disintegrative Disorder
____Rett's Syndrome
____Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS)
____Other (please specify):______________________________

How old was your child when he/she got this diagnosis?
____Years ____ Months

Have any of the child's siblings been diagnosed with Autism Spectrum Disorder?

____Yes
____No

If Yes, please specify which disorder: ________________________

Does your child have any other symptoms or diagnoses? (check all that apply)
____Anxiety Disorder
____Attention Deficit Hyperactive Disorder
____Obsessive Compulsive Disorder
____Central Auditory Processing Disorder
____Depression
____Schizophrenia
____Hearing Impairment
____Vision Impairment
____'Tunnel Vision Syndrome' (peripheral vision, vision perception impairment)
____Mental Retardation
____Seizures
____Dietary Allergies
____Digestive Problems (constipation, diarrhea, bloating, or abdominal pain)
____None
____Other (please specify): __________________________

If answered yes to dietary allergies, please specify: __________________________

What type of professional diagnosed your child with Autism Spectrum Disorder?
____Developmental Pediatrician
____Psychologist
____Neurologist
____Primary Care Physician
____Psychiatrist
____Other (please specify): __________________________

CURRENT SYMPTOMS DISPLAYED BY CHILD

Please check the symptoms currently exhibited by your child:
____Doesn't respond when called
____Self-injurious behaviors
____Destructive behaviors
____Receptive language delay
____Expressive language delay
____No verbal language
____Apraxia (oral motor, articulation problems)
____Absent or limited gestures
____Cognitive delay
____Strong visual learner
____Strong auditory learner
____Gross motor delay
____Fine motor delay
____Undersensitive to pain
____Oversensitive to pain

____Undersensitive to sound
____Oversensitive to sound
____Aggressive to others
____Has trouble joining a group
____Happier left alone
____Frustrated
____Gets angry easily
____Cries excessively
____Hums frequently
____Insists on sameness
____Agitated when routine is disrupted
____Insists on precision
____Poor eye contact
____Stomach Pain
____Constipation
____Diarrhea
____Eczema
____Thrush (white tongue yeast infection)
____Itchy penis/perineum/all
____Losing weight
____Gaining weight
____Fixation on objects or topics
____Unusual cravings for certain foods
____Has known food sensitivity
____Sustained odd play
____Echolalia (repeats the same phrase over and over)
____Does not require long sleep
____Requires longer than average sleep
____Does not stay asleep
____Wakes up at night and does not go back to sleep
____Takes a long nap daily
____Tantrums
____Anxiety
____Depression
____Hand flapping
____Toe walking
____Spinning self
____Likes to watch objects spin
____Rhythmic or rocking behaviors
____Other types of self-stimulatory behavior (please specify):
____

If answered yes to unusual cravings for certain foods, please specify:
____

If answered yes to known food sensitivity, please specify:
____

Appendix B

Tables & Figures

Table 1
Demographic Characteristics

	ASD n=8			TD n=8		
	Range	Mean	SD	Range	Mean	SD
Age (months)	78-122	104.88	16.84	54-128	96.13	25.09
Mental Age (MA)	64.74-135.66	110.72	24.24	55.62-186.69	115.25	49.71
Verbal MA	69.00-142.74	104.61	26.15	55.08-185.22	114.13	45.91
SRS score	69-90	80.63	8.18	36-58	43.88	7.68
Emotion Recognition	2-8	5.87	2.03	5-9	6.88	1.64
Highest child grade completed	0 (pre-k)-4	2.29	1.38	0 (pre-k)-6	2	2.14

	ASD		TD	
	Frequency	Percent	Frequency	Percent
Income				
$20,000-39,999	3	37.5%	1	12.5%
$40,000-59,999	2	25.0%	1	12.5%
$60,000-79,999	2	25.0%	0	0.0%
$80,000-99,999	0	0.0%	1	12.5%
Over $100,000	1	12.5%	5	62.5%
Parental Education				
Some College	4	50.0%	1	12.5%
College Degree	3	37.5%	3	37.5%
Some Graduate School	0	0.0%	0	0.0%
Graduate Degree	1	12.5%	4	50.0%

Note: ASD=Autism Spectrum Disorder, TD=Typically Developing

Table 2

ASD and TD matching: t-test results

	Group			
	ASD	TD	t	df
Mental Age	110.72 (24.24)	115.25 (49.71)	-.232	14
Verbal Mental Age	104.61 (26.15)	114.13 (45.91)	-.509	14
Age (months)	104.88 (16.84)	96.13 31.53	.692	14
IQ	104.88 (11.80)	117 18.69	-1.551	14
Verbal IQ	99.38 (16.71)	116.13 11.73	-2.321*	14
% data collected	45.88% (17.28)	72% (17.28)	-2.56*	14

Note. ASD=Autism Spectrum Disorder, TD=Typically Developing. Standard deviations appear in parentheses below means. **$p \leq .01$, *$p \leq .05$

Table 3

Correlations Between Measures

	Group	Verbal MA	MA	Time on Face	Time on Eyes	Time on Mouth	Emotion Identification	SRS	Verbal IQ
MA	TD	.982**							
	ASD	.869**							
	Total	.953**							
Time on Face	TD	-.268	-.197						
	ASD	.250	.091						
	Total	-.025	-.057						
Time on Eyes	TD	.467	.392	-.500					
	ASD	-.031	-.213	-.463					
	Total	.331	.227	-.466+					
Time on Mouth	TD	.065	.090	.640+	-.512				
	ASD	.260	.295	.826*	-.674+				
	Total	.176	.139	.247	-.183				
Emotion Identification	TD	.627+	.512	-.618+	.615+	-.166			
	ASD	.859*	.682+	.578	-.335	.606+			
	Total	.681**	.521*	.153	.201	.279			
SRS	TD	.062	.030	-.295	-.025	.138	.588		
	ASD	.338	.376	-.159	-.151	-.183	.280		
	Total	-.066	-.006	.148	-.271	-.669**	-.080		
Verbal IQ	TD	.854**	.895**	-.010	.186	.057	.409	.086	
	ASD	.746*	.427	.621+	-.216	.537	.859*	.044+	
	Total	.684**	.554*	.249	.116	.531*	.701**	-.470	
Age	TD	.989**	.951**	-.329	.553	.037	.679+	.069	.773*
	ASD	.771*	.915**	-.163	.053	-.041	.484	.495	.159
	Total	.889**	.914**	-.146	.331	-.120	.485+	.247	.283

Note. ASD=Autism Spectrum Disorder, TD=Typically Developing, Total=combined groups. ** $p \leq .01$, * $p \leq .05$, + $p \leq .1$.

Table 4

Tests for Normality for AOI by group

	ASD n=8		TD n=8	
	Shapiro-Wilks	Standardized Skew	Shapiro-Wilks	Standardized Skew
Eye	.80*	1.42	.92	1.09
Mouth	.91	1.46	.93	.16
Face	.86	-1.08	.91	-.47

Note. ** = $p \leq .01$, *= $p \leq .05$., + $p \leq .1$

Table 5

T-test results for each AOI

	Group			
	ASD	TD	t	df
Time spent on face	.34 (.19)	.26 (.09)	.91	14
Time spent on eyes	.44 (.28)	.61 (.36)	-1.01	14
Time spent on mouth	.24 (.22)	.83 (.36)	-3.94**	14

Note. ASD=Autism Spectrum Disorder, TD=Typically Developing. All times are reported in seconds. Standard deviations are reported in parenthesis below means.
**$p \leq .01$, *$p \leq .05$, +$p \leq .10$.

Table 6

P values for Fisher's Exact Test of Independence by Emotion

	P values
Sad	1.00
Happy	0.20
Angry	0.80
Scared	1.00
Excited	0.61

Note: ASD=Autism Spectrum Disorder, TD=Typically Developing
***$p \leq .01$, *$p \leq .05$, +$p \leq .10$.*

Table 7
Individual Results for Emotion Identification Task

ASD						
Child Age in months	Sad	Happy	Angry	Scared	Excited	Total
78	2	2	0	0	0	4
81	2	1	1	1	2	7
100	2	0	0	0	0	2
113	2	1	1	1	0	5
114	2	2	2	1	0	7
115	2	1	1	2	1	7
116	2	2	2	2	0	8
122	1	2	2	1	1	7

TD						
Child Age in months	Sad	Happy	Angry	Scared	Excited	Total
54	2	2	1	0	0	5
58	1	0	0	0	0	1
88	2	2	0	2	1	7
96	2	2	2	2	1	9
102	2	2	2	1	0	7
103	2	2	2	1	0	7
108	2	2	2	1	1	8
103	2	2	2	1	0	7
128	2	2	2	1	1	8

Note: ASD=Autism Spectrum Disorder, TD=Typically Developing. Number of emotions identified by each participant out of 2 possible per emotion.

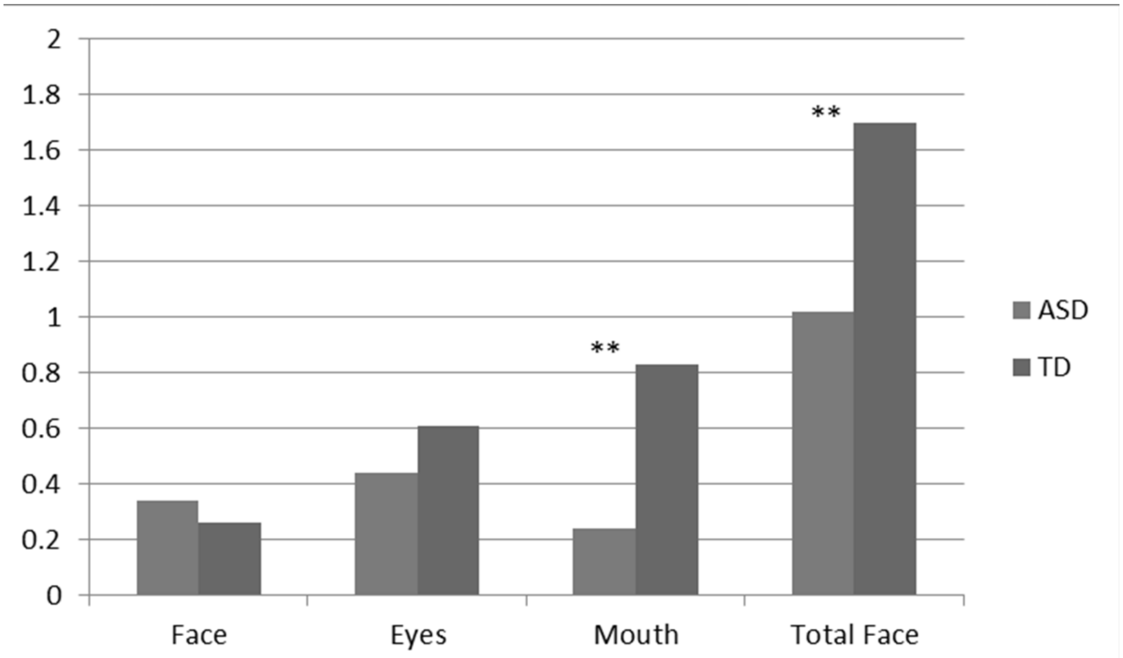

Figure 1. Duration of gaze foveation for each area of interest by group. ASD=Autism Spectrum Disorder, TD=Typically Developing. All times are reported in seconds. **p≤.01, *p≤.05, +p≤.1.