An Analysis of Emotion Recognition and Facial Processing Across Human and Cartoon Stimuli in Individuals with Autism Spectrum Disorders

by

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Abstract

The emotion recognition and eye tracking literature has yielded inconsistent findings with respect to the social perception and attentional abilities of children and adults with ASD. Previous research has suggested that both cartoon stimuli and circumscribed-interest (CI) stimuli may assist in elucidating variable results. The present study examined emotion recognition and gaze fixation patterns using computer-generated and naturalistic static human and cartoon scenes. Participants included 12 children with an Autism Spectrum Disorder and 13 typically developing children ages 4 to 11 years. Children with ASD (CWA) were found to demonstrate impairments in emotion recognition in only one stimulus subtype: naturalistic human stimuli. Significant differences in eye gaze were also identified across groups. Typically developing participants tended to gaze more at the face and mouth of computer-generated and naturalistic cartoon stimuli than CWA. Gaze fixation duration and count to static human scenes were not found to be abnormal in the ASD group. Emotion recognition and gaze differed across CWA with a CI in Thomas the Tank Engine and CWA without a CI in Thomas the Tank Engine. Limitations and clinical implications are discussed.

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Introduction

The term Autism Spectrum Disorder (ASD) was recently redefined in DSM-5 (American Psychiatric Association, 2013). Changes to the criteria were supported by strong evidence suggesting the need to collapse previously held subtypes of ASD into a larger diagnostic category in which individuals are instead distinguished by levels of severity (Lord et al., 2011; Kasari & Rotheram-Fuller, 2005; Macintosh & Dissanayake, 2004). A second, and perhaps equally significant revision, is the de-emphasis on communication impairments per se and a greater focus on social communicative behavior. The emphasis on social communicative behavior (i.e., difficulties in the *social* use of verbal and nonverbal communication), as opposed to pure language impairments (i.e., receptive and expressive language deficits), corresponds with an increased research focus on the social and emotional impairments exhibited by children with autism spectrum disorders (CWA) (Hobson, 1991; Matson & LoVullo, 2008). Our understanding of these impairments has also increased exponentially due to the technological advancements (e.g., eye tracking technology) that allow for fine-grained analyses of emotion recognition and processing. Yet, despite these advances, the emotion recognition literature and emotion/facial processing literature appear to comprise two distinct lines of research. As such, these two literatures and their corresponding limitations will be described separately in the following sections. A theoretical review of emotion recognition and facial processing deficits within the ASD population is also provided.

Emotion Recognition

Early descriptions of both Autism and Asperger's Disorder (AS)[1] include mention of emotional deficits. Leo Kanner, in his seminal paper *Autistic Disturbances of Affective Contact* (Kanner, 1943), focused significant attention on the difficulty his patients exhibited in relating to others affectively. More specifically, Hans Asperger, in writing about AS, referred to a "paucity of facial and gestural expression" (pg. 69, Asperger trans. 1991). These clinical observations are substantiated by decades of research investigating the ability of individuals with ASD to label both their own and others' emotions. This literature has focused on different behavioral indicators of emotion recognition including: 1) the labeling of emotions when presented with faces depicting emotional expressions (e.g., Hobson, Ousten, & Lee, 1988; Golan, Baron-Cohen, & Hill, 2006), 2) the ability to define emotions and select emotional states when provided with contextual clues (e.g., Tantem, Monaghan, Nicholson, & Stirling, 1989; Capps, Yirmiya, & Sigman, 1992), and 3) the regulation of emotional responses to others' affective states (i.e., the tendency to mimic the emotions of others under experimental and/or naturalistic conditions) (e.g., Scambler, Hepburn, Rutherford, Wehner, & Rogers, 2007).

The primary mechanism by which researchers have investigated emotion recognition in individuals with ASD involves exposing the participant to an emotional stimulus (usually a facial expression) and then either asking the participant to name the emotional state or to select a photograph or other stimulus from a series of stimuli that corresponds with the emotion originally presented (i.e., a match to sample task). In one such study, Hobson et al. (1988)

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[1] Autism Spectrum Disorders (ASD) was a term introduced in DSM-IV to describe a spectrum of developmental disorders. The term included Autistic Disorder (AD), Asperger's Syndrome (AS), and Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS). These distinct diagnoses were recently collapsed under one all-encompassing term Autism Spectrum Disorder.

presented 21 individuals with ASD and 21 individuals with Intellectual Disability (ID) matched in verbal mental age (VMA) and chronological age (age range, 12 to 25 years) a series of emotional and non-emotional tasks. Participants listened to audio-recorded emotional sounds (e.g., sighing, gasping, humming) and non-emotional sounds (e.g., birds chirping, water running, traffic) and were asked to select the picture that best represented the sound. Participants with ASD had significantly more difficulty matching emotional sounds than non-emotional sounds. These results were one of the first to suggest emotion recognition difficulties are specific to individuals with ASD and not a function intellectual deficits alone.

In a more recent investigation, Golan et al. (2006) provided further evidence individuals with ASD have difficulty pairing emotional expressions with corresponding vocal stimuli. The authors developed a battery of 20 emotional states comprised of facial stimuli (i.e., actors portraying different facial expressions) and vocal stimuli (i.e., audio recording of actors reading non-emotional content in an emotionally expressive fashion). Participants were then asked to select the emotional state matching the previously presented facial expression or verbal stimulus from a series of four options. Twenty-one adults with AS (ranging in age from 17 to 49 years old) and 17 individuals without AS matched in age and verbal ability completed this study. The authors found that participants with AS scored significantly lower on both facial and vocal tasks compared to individuals without AS. Interestingly, the authors also found scores on the battery were not correlated with age, verbal, or non-verbal mental ability; rather, emotion recognition scores were significantly correlated with scores on a measure of Autism symptomatology (i.e., the Autism Spectrum Quotient; Baron Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). These findings again support the notion that deficits in emotion recognition are inherent to ASD.

Emotion recognition difficulties are also evident in young CWA. In a study designed to assess the developmental trajectory of emotion recognition difficulties in individuals with ASD, Rump, Giovannelli, Minshew, and Strauss (2009) administered a battery of emotion recognition tests to children ages 5-7, ages 8-12, 13-17, and adults (i.e., over the age of 17 years) with ASD. Participants were matched in chronological age and VMA with typically developing individuals who served as the control group. Participants viewed video images of a series of emotional expressions and were asked to label the emotion. CWA between the ages of 5 and 7 obtained significantly lower scores on this measure than their typical peers; demonstrating the most difficulty with the emotions angry and afraid. However, older CWA (children ages 8-12 and 13-17) showed no significant differences on this measure when compared to age and VMA-matched controls. Interestingly, adults with ASD tested with the same battery did demonstrate significant impairments on the measure and showed particular difficulty with the emotions angry, disgusted, and surprised. Thus, the results of Rump et al. (2009) suggest that in early childhood, CWA have difficulty with some simple emotions relative to peers. In late childhood, CWA "catch up" to their typical peers with respect to simple emotion recognition; however, typically developing individuals appear to continue to develop their emotion recognition skills such that by adulthood individuals with ASD demonstrate impairments in advanced emotion recognition ability. This study is one of the few studies in which multiple cohorts of CWA and children without ASD are tested on the same emotion recognition task. Thus, little to date is known on the course of emotion recognition difficulties. As this study illustrates however, emotion recognition abilities may fluctuate over the course of an individual's life.

The inconsistent nature of emotion recognition across the lifespan of individuals with ASD may serve to explain studies in the literature that fail to find emotion recognition difficulties in this population (Harms, Martin, & Wallace, 2010). For example, Gepner, Deruelle, and Grynfeltt (2001) used a method similar to Golan et al. (2006) to assess emotion recognition and failed to substantiate the notion that CWA demonstrate difficulty in identifying emotions. Children were asked to match an emotional expression presented on a video screen with a photograph depicting the same emotional expression from a series of four photographs. The authors also explicitly assessed the effect of motion on emotion recognition ability. An examination of motion within the context of emotion recognition is important as human interaction requires the process of emotions in "real-time" by moving individuals. Motion was manipulated to yield the following four stimulus presentations: 1) a still condition in which the actress maintained a facial expression for 2 seconds, 2) a dynamic[2] condition in which the actress was filmed transitioning from a neutral facial expression to the expression of interest, and 3) a strobe condition in which the footage from the dynamic condition was transformed such that the video display occurred at 4 frames per second (referred to as the Strobe 4 condition) or 4) a strobe condition in which the footage from the dynamic condition occurred at 2 frames per second (i.e., Strobe 2). The strobe condition was included by the authors due to clinical reports from individuals with AS suggesting they perceive the world is "moving too fast" (Gepner et al., 2001, pg. 39). Thirteen CWA (M_{age} = 69 months, age range = 52 to 84 months) and thirteen typically developing children matched in developmental age participated in the study. Interestingly, the authors found no differences in emotion recognition across the ASD group and typical controls. Furthermore, the authors found no differences in stimulus conditions for CWA. Importantly, however, groups were not matched in age; thus, CWA were found to perform at the

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[2] Unfortunately, the term dynamic is used to refer to both stimuli that are socially complex in nature (i.e., a picture of two or more individual's) and/or stimuli comprised of video clips. In this case, the authors used the term dynamic to described video images of an arguably "uncomplicated" social scene (a change in facial expression).

level of typical children who on average were over 2 years younger. Given this limitation, these results may in fact indicate the existence of emotion recognition delays in CWA.

Rather than assessing correct identification of emotion through match to sample tasks, some investigators have assessed the ability of individuals with ASD to define or describe emotional states (i.e., “affect labeling”) and to identify emotions congruent with contextual information (e.g., to note that a person who tripped is likely to feel embarrassed). In an early such study of emotion recognition, Tantam et al. (1989) administered a series of labeling tasks to CWA and children without ASD (M_{age} = 12 years). The authors developed two experimental tasks designed to assess labeling of emotions. In one task participants were presented with a series of pictures depicting 6 basic emotions and a series of emotional words corresponding to the pictures. Instructions were to match the word that best described each picture. In a control task participants completed the same procedure with common objects. Despite use of a relatively small sample size (8 CWA and 9 children without ASD), the authors found significant differences on the emotional labeling task but not the object labeling task. Limitations of this study included participants were characterized as low-functioning (average Full Scale IQ for both groups was approximately 60) and groups were not matched in verbal ability, thus verbal differences (rather than ASD characteristics) may explain difficulty individuals with ASD experienced in completing this task. Nevertheless, this study was one of the first to document emotion-specific labeling difficulties in individuals with ASD. Furthermore, in a study of high-functioning children with PDD-NOS, Braverman, Fein, Lucci, and Waterhouse (1989) also found participants with PDD-NOS performed significantly worse on an affect labeling task than an object labeling task, suggesting this discrepancy in performance across emotional and non-emotional tasks cannot be fully described by cognitive ability alone.

Capps et al. (1992) conducted an affect labeling study in which they assessed the understanding of two simple (happiness and sadness) and two complex emotions (pride and embarrassment) in CWA and children without ASD. Eighteen high-functioning participants with ASD and 14 typically developing participants matched in Full Scale IQ (FSIQ), verbal ability, non-verbal ability, and age completed this study. In a fairly simple procedure, participants were asked to describe a time that they felt each emotion. Responses were coded by blind raters for appropriateness, the number of prompts required by the experimenter for a response, and latency to respond. A second task required participants to label the emotion depicted in a series of dynamic pictures[3] (children in a social situation, e.g., a boy exiting the girl's restroom). Unlike in the Tantam et al. (1989) study, participants were not provided with a list of words to complete this task. The authors coded these responses for response latency in order to measure difficulty and also conducted a qualitative analysis of responses. Results indicated CWA were more likely to recount the same type of experience for both simple and complex emotions (e.g., reporting feeling both pride and happiness upon completing homework), whereas typically developing children were more likely to provide distinct responses for these two emotional categories. Further, CWA often provided inappropriate scenarios (e.g., feeling pride when "somebody gave me gold and silver"). Expectedly, CWA also required significantly more prompts and exhibited longer latencies before responding in this task. The authors did not code for accuracy on the labeling task thus they did not report on differences between groups in emotional labeling. Nevertheless, the authors found that CWA required longer response latencies and more prompts to respond relative to controls. Interestingly, qualitative analysis indicated further deviations in the responding of CWA on the picture labeling task. Participants with ASD were often found to

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[3] In this case "dynamic" was used to refer to still pictures of socially complex information.

provide “correct” but socially irrelevant emotional labels for many of the photographs. As an example, when depicting a picture of a boy exiting the girl’s restroom, approximately 80% typically developing participants responded with the emotional label “embarrassed”; CWA provided the label “confused”—indicating understanding of the situation but a failure to recognize the social significance of the event.

More recent studies appear to corroborate difficulties in labeling of emotions in CWA and adults with ASD in social situations. Dennis, Lockyer, and Lazenby (2000) found that CWA failed to apply the social context of emotion when completing affect labeling tasks. In this study, the authors assessed the ability of high-functioning CWA to identify “real” and “deceptive” emotions when presented with short vignettes. Deceptive emotions describe situations in which the character may feel a certain way “one the inside” but hides that emotion for socially prescribed reasons (e.g., “Terry wants to go outside but he has a tummy ache, he knows if he tells his mom that he has a tummy ache, his Mom will say that he can’t go out. Terry tries to hide the way he feels.”). Eight participants with ASD (M_{age} = 9.6 years) and 8 typically developing participants matched in age, gender, and verbal ability completed the study. Participants with ASD had significant difficulty with this type of affect labeling task. They were less able to describe how the participant felt “on the inside”, identify the emotional expression on the participant’s face, and describe the reasons the participant may attempt to hide their emotion (e.g., deceive another person).

Adults with both high-functioning and low-functioning ASD also appear to demonstrate difficulty with affect labeling tasks. Garcia-Villamisar, Rojahn, Zaja, and Jodra (2010) found low-functioning adults with ASD were significantly more impaired in labeling relatively simple emotional expressions (i.e., happy and sad) than their low-functioning peers without ASD.

Furthermore, although adults with high-functioning ASD appear able to recognize basic emotions (e.g., happy, sad, angry, afraid) when provided with a picture of a whole face, they demonstrate significant difficulty labeling complex emotions (e.g., reflective, arrogant, scheming, planning, etc.) when presented with only the eye-region of the face (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997) or emotionally-relevant vocal stimuli (Golan, Baron-Cohen, Hill, & Rutherford, 2006).

The experimental tasks described above have provided a broad base of information regarding emotion deficits in individuals with ASD. Nevertheless, these tasks are often contrived and generally exist outside a natural context. Thus, an extension of this literature has aimed to assess the emotional response of children and adults with ASD in more naturalistic interactions. Additionally, these tasks have focused less on the verbal behavior of individuals with ASD as they relate to emotion (e.g., tell me the name of this emotion) and more on the behavioral response of individuals with ASD in emotionally salient situations.

In one such study, Scambler et al. (2007) developed six emotional “presses.” During these presses, children were exposed to a series of situations designed to elicit emotional responses from children. As an example, within the context of play, the examiner would open a “surprise box” and make an obvious expression of either joy or fear. The child’s tendency to mirror the experimenter’s emotion and latency to change was coded by independent observers. Twenty-six CWA, 24 children with other developmental disorders and 15 typically developing children completed the study (importantly, CWA and developmental delays were significantly younger than typically developing children and had significantly lower VMA). The authors found, CWA responded to emotional presses half the number of times as the other two groups (despite the fact that the authors controlled for attention to the experimenter).

In a similar study, Bacon, Fein, Morris, Waterhouse, and Allen (1998) also showed CWA are less likely to respond to signals of distress from the examiner within a naturalistic play context. Two contrived presses were developed: in one scenario the experimenter pretended to lose his/her pen and in another the experimenter pretended to bang his/her hand, elbow, or knee while exclaiming "ouch!". Even when prompted, both low-functioning and high-functioning CWA failed to respond to examiner's distress. Charman, Sweetenham, Baron-Cohen, Cox, Baird, and Drew (1997) also identified poor emotional response in CWA. Three groups of participants (CWA, children with Developmental Delay, and typically developing children) were assessed in this study (M_{age} = 20 months). CWA and children with Developmental Delay were matched in cognitive ability; however, typically developing children had significantly higher Verbal IQ (VIQ) and Non-verbal IQ (NVIQ) scores. While playing with the participant, the examiner pretended to hurt his/her finger with a toy hammer. The child's response to this situation was coded by observers who assessed the child's tendency to attend to the examiner (e.g.,, look at the examiner's hand, stop playing with the hammer, and exhibit a positive, negative, or neutral emotion). The performance of CWA significantly deviated from the performance of typically developing children. Only 40% of CWA attended to the examiner's face following the press compared to 100% in both control groups. Additionally, none of the CWA showed facial concern, 80% continued to play with the toy, and only 20% attended to the examiner's hand. As a comparison, approximately 40% of participants with developmental delay and typical development continued to play with the toy and a much larger proportion of these participants showed facial concern (44% and 68%, respectively). The significant differences across groups on these naturalistic "presses" highlights the importance of assessing emotion recognition and response within a socially relevant and naturalistic context.

CWA also appear less likely to produce recognizable facial expressions in a naturalistic play-like setting. In a study by Loveland, Tunali-Kotoski, Pearson, Brelsford, Ortegon, and Chen (1994) CWA were asked to generate different emotional expressions (e.g.., “show me how you look when you are happy”). CWA produced less recognizable emotions (as determined by blind coders) compared to children with Down’s syndrome. Unfortunately, typical children were not assessed in this study. Furthermore, it is unclear if these findings are indicative of emotion recognition difficulties or motor difficulties, which are also commonly present in CWA (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Minshew, Sweeney, Bauman, & Webb, 2005).

Summary. Overall, the emotion recognition literature suggests both children and adults with ASD demonstrate difficulty matching emotional states, labeling emotions, interpreting contextual cues related to emotions, and responding to emotional salient stimuli in a typical manner. Unfortunately, some mixed findings exist in this literature (e.g., Jones et al., 2011, Ozonoff, Pennington, & Rogers, 1990; Sasson et al., 2007; Tracy, Robins, Schriber, & Solomon, 2011). As noted, methodological limitations may serve to explain null findings. Small samples sizes (e.g., fewer than 10 participants) are often utilized in these studies along with disparate tasks and instructions. Furthermore, as suggested by several authors, ceiling effects, especially in the case of adults and high-functioning CWA may be responsible for the lack of differences on some emotion recognition tasks (Baron-Cohen et al., 1997; Golan et al., 2006). A second issue relates to matching practices within this literature, which have yet to be empirically established. Some researchers have documented differences in emotion recognition only when matching on non-verbal ability (e.g, Braverman et al., 1989; Ozonoff et al. 1990). Moreover, current recommendations for this literature suggest the need to assess for differences based on both verbal and non-verbal ability and propose the practice of enlisting two control groups (one matched on verbal ability and the other matched in nonverbal ability when assessing emotion recognition (Harms et al. 2010). Finally, it is possible that CWA use compensatory strategies to “solve” emotion recognition tasks, which may mask difficulty this population experiences in emotion recognition. This suggestion is supported by strong evidence of abnormal facial processing strategies (discussed next) and abnormal neurological activation during facial processing tasks in individuals with ASD (Bookheimer, Wang, Scott, Sigman, & Dapretto, 2008; Corbett, Carmean, Henry, Carter, & Rivera, 2009; Grelotti et al., 2005). Despite mixed findings, however, emotion recognition difficulties appear to differentiate individuals with ASD from typically developing peers and appear to be highly correlated with symptoms of ASD (Bal, Harden, Lamb, Van Hecke, Denver, & Porges, 2010; Riby & Hancock, 2008; Riby & Hancock, 2009; Wallace, Case, Harms, Silvers, Kenworthy, & Martin, 2011).

Facial Processing

As noted above, investigators rarely assess emotion recognition and facial processing in conjunction. Nevertheless, several researchers have suggested emotion recognition deficits may stem from generalized impairments in facial processing (Harms et al., 2010; Senju & Johnson, 2009). That is, a faulty facial processing system in individuals with ASD is thought to lead to poor performance in emotion recognition tasks (e.g., labeling emotions accurately). The development and availability of eye tracking software has extensively affected the quality of research in this field and has allowed experimenters to carefully assess early observations by Kanner and Asperger, both of whom suggested individuals with ASD pay extraordinary low levels of attention to faces (Asperger, 1991; Kanner, 1943).

In one of the first studies to use eye tracking technology to examine the gaze pattern of individuals with ASD, Klin, Jones, Schultz, Volkmar, and Cohen (2002) presented adolescents and adults with ASD a series of dynamic images of social scenes (i.e., short video clips from the movie *Who's Afraid of Virginia Wolf)*. The authors assessed the visual fixation patterns in a group of high-functioning individuals with ASD (*N* = 15) and age-, sex-, and VIQ-matched control subjects. Fixation to mouth, eyes, body, and objects were assessed. The authors found significant differences in the gaze fixation time for all areas of interest (AOIs) measured. Individuals with ASD focused twice as long on the mouth and objects in the background than control participants and half the amount of time on the eyes. Additionally, participants with ASD gazed at the body for a longer period of time than the face compared to typical controls. In support of work indicating individuals with ASD show gaze aversion to the eyes (Dalton et al., 2005; Dalton, Holsen, Abbeduto, & Davidson, 2008), Klin et al. found length of gaze fixation to the eyes to be the best predictor of group membership.

Despite striking differences in gaze fixation found by Klin et al., a study conducted by van der Geest, Kemner, Verbaten, and van Engeland (2002a) failed to document impairments in facial processing. The authors included static scenes to assess gaze fixation patterns in CWA (M_{age}= 10 years) and typical children matched in age, VIQ, and PIQ. Stimuli included photographs of emotionally expressive human faces (e.g., surprised, happy, angry) and neutral faces. The authors assessed the following AOIs: eyes, mouth, face. Results suggested similar rates of gaze to each AOI and a similar pattern of fixations (both groups tended to fixate towards the eye region first, and then fixate towards the mouth or away from the face). These authors also conducted a second experiment in which they attempted to assess the hypothesis that individuals with ASD fail to process faces using a "holistic" or gestalt processing approach and instead process faces in a “piece-meal fashion.” This theory was previously suggested by Hobson et al. (1988) and Tantam et al. (1989) who found CWA perform similarly well on facial recognition tasks when faces are presented upright or upside down. In contrast, typically-developing children (presumably because they rely on holistic facial information processing strategies) tend to show decreased performance when recognizing rotated as opposed to right-side up faces. Thus, in order to assess gaze fixation patterns under these conditions, van der Geest et al. exposed participants to a series of right-side up and upside-down neutral faces. Unexpectedly, the authors found no differences in mean fixation time or number of fixation to the face, mouth, or eyes. The authors did find some evidence however for the inversion effect. Although typically developing children spent less time looking at inverted faces, CWA spent equal amounts of time looking at both inverted and right-side up faces.

In a follow-up study, van der Geest, Kemner, Camfferman, Verbaten, and van Engeland (2002b) also assessed the gaze patterns of 16 CWA (M_{age} = 10.6 years) and 14 typically developing children matched in age and FSIQ using static cartoon images that included a human figure (e.g., a drawing of a house with a person inside). Substantiating their previous null results (i.e., van der Geest et al., 2002) regarding gaze patterns in CWA, the authors again found no differences between groups in the number of fixations at the human figure, mean fixation time on the human figure, or latency to the first fixation towards the human figure.

The discrepant results across Klin et al. (2002) and van der Geest et al. (2002a) was addressed in a study conducted by Speer, Cook, McMahon, and Clark (2007). These authors noted that differences in stimuli (i.e., dynamic social scenes by Klin et al and static images of only one individual) might have contributed to the lack of significant findings by van der Geest and colleagues. The authors developed four types of stimuli using clips from *Who’s Afraid of*

Virginia Wolf: social dynamic (video clips of more than one person engaged in a social interaction), social static (photographs of social interactions), isolated dynamic (video clips of one person), and isolated static (images of only one person). Twelve high-functioning males with ASD (ranging in age from 9 to 18 years) and age-, VIQ-, and PIQ-matched typical participants completed the study. As predicted, the authors found individuals with ASD spent significantly less time looking at the eyes in the social-dynamic condition only. Additionally, in the social dynamic condition only, individuals with ASD spent an inordinate amount of time looking at the body compared to typical participants. Thus, the results of Speer et al. suggest facial processing difficulties in individuals with ASD may depend on the social relevance of the stimuli. Interestingly, these results conflict with the null results of Gepner et al. (2001) who found emotion recognition did not differ across three stimulus conditions in which motion was manipulated (i.e., still, dynamic, strobe). This discrepancy may be explained in the different type of dynamic stimuli used (faces only in the Gepner et al. study and a social scene in the study by Speer et al.) and the fact that participants were not matched in chronological age in the study by Gepner et al.

Although these findings imply individuals with ASD process static images in a typical fashion, several investigators have found significant difference in eye gaze patterns using static images. For example, Pelphrey, Sasson, Reznick, Paul, Goldman, and Piven (2002) found adults with ASD attended more often to non-core facial features and less often to the eyes, nose, and mouth of static emotionally expressive images. Similarly, Riby and Hancock (2008) found individuals with ASD (M_{age} = 13) spent less time gazing at the face and eye region of an actor's face in a photograph depicting a social scene (i.e., static social images) compared to both a verbal and non-verbal matched control group. Furthermore, Spezio et al. (2007) found abnormal fixation to the eyes and mouth in addition to abnormal directionality of saccades from the eyes and mouth when presented with static images of two facial expressions (happy and afraid). By using a paradigm that only revealed certain features of the face, the authors further determined that individuals with ASD appeared to gaze away from the eyes when emotionally relevant information was present in the eyes, and to gaze at the mouth even if emotionally relevant information was not present in the mouth (i.e., showed reduced gaze specificity to the mouth region). Sasson et al. (2007) also found high-functioning adults with ASD attended to faces in photographs of social scenes less often than participants matched in FSIQ. This study is one of the few studies to assess a variety of emotional conditions (happy, surprise, angry, afraid, and sad) within an eye-tracking paradigm and to concurrently assess for emotion recognition (no difference in emotion recognition was found, although latency to respond was not assessed and participants were not restricted in their response time). Given these mixed findings, it is unclear if static images are abnormally processed by individuals with ASD. Overall, however, dynamic and socially-relevant images appear to pose significantly more difficulty for individuals with ASD than static and less socially-relevant images.

Despite the noted importance of using naturalistic and socially relevant stimuli in eye-tracking studies (Klin et al., 2002), attempts to replicate previous findings has led to the use of a fairly narrow range of dynamic stimuli. As noted by Riby and Hancock (2009), a relatively low number of studies have attempted to use movie images and of those two have used movie clips from the film *Who's Afraid of Virginia Wolf*. In an attempt to disconfirm the notion that facial processing impairments in ASD are stimuli specific, Riby and Hancock (2009) attempted to replicate previous findings using new dynamic and static images involving both humans and cartoons. Arguing that cartoons simulate humans while removing the social demands of viewing actual human images, the authors also included a variety of static and dynamic stimuli from the cartoon *The Adventures of TinTin.* Participants included 20 CWA (M_{age} = 13) and 20 typical participants matched in chronological age and 20 participants matched in nonverbal ability. The authors found that across all stimuli CWA spent less time looking at faces and significantly more time looking at the background and body areas of characters when compared to the control groups. Additionally, across both cartoon and human stimuli CWA spent less time than controls looking at the eyes of characters. These results contrasted those of van der Geest et al. (2002b) and suggest CWA differentially process both cartoon images and human images. One possibility for these divergent findings is that the cartoon images used by van der Geest were drawings and therefore less realistic than images used from *The Adventures of TinTin* (Riby & Hancock, 2009).

As noted by Riby and Hancock (2009) the use of cartoon images in eye tracking methodology may allow for an assessment of facial processing while removing a degree of social demand inherent in viewing more naturalistic human interactions (e.g. photographs and movie clips with human actors). The use of cartoon images within eye-tracking methodology, however, may have other important implications. First, a variety of treatments designed to teach skills to CWA incorporate the use of cartoon images (e.g., the Headsprout Early Reading program, *The Transporters*, etc.). The use of cartoons may serve to create a more engaging learning environment and increase motivation to interact with materials. Given the wide spread use of cartoon images within the intervention literature (especially in teaching emotion recognition skills), it may be important to identify the ways in which facial processing may differ for cartoon stimuli. Furthermore, in the event that cartoon images assist CWA in improving their facial processing skills or emotion recognition skills, it may be possible to develop interventions that capitalize on the motivating factors associated with cartoon images, while still programming for generalization of skills to more naturalistic environments or stimuli (as attempted in a study by Golan et al. discussed in greater detail later). Finally, some evidence exists to suggest CWA show fMRI activation in the fusiform gyrus and amygdala to cartoon characters, but not human faces. In a study by Grelotti et al. (2005), the authors demonstrated normal activation of these brain regions when a child with ASD viewed Digimon characters (the object of his circumscribed interest), but not human faces or random objects. The conclusions drawn from this research suggest the use of cartoon images or circumscribed interests can be used as a powerful motivating tool.

It should be noted that several investigators have suggested visual processing deficits in ASD may not be specific to faces. That is, facial processing deficits may simply comprise a subset of visual processing deficits within this population. Support for this notion comes from a series of investigations documenting impairments in processing biological motion in individuals with ASD. Although young typically developing children can readily discriminate biological motion (actions of a human) from non-biological motion, CWA and adults with ASD demonstrate difficulty labeling biological motions (Moore, Hobson, & Lee, 1997) and identifying whether or not they have just viewed a person or not (Hubert et al., 2007). Furthermore, individuals with ASD show atypical neural activation while viewing biological motion (Freitag et al., 2008). Thus, these results imply that impairment in processing human motion in general (rather than just human emotion or faces) may be characteristic of ASD.

Summary. Review of the facial processing literature suggests individuals with ASD demonstrate difficulties processing naturalistic scenes depicting socially relevant information. Nevertheless, deficits in processing are also documented when participants are asked to view simple static images of another person’s face. Individuals with ASD appear to gaze at the eyes less frequently than typical individuals, and gaze longer at the mouth. Additionally, focus on less socially relevant information (e.g., the background, the actor’s body) is often observed in individuals with ASD. Differences in the strategy by which individuals with ASD process facial information are also suggested by findings in this literature. Specifically, individuals with ASD may interpret faces as objects (in a piece-meal fashion) and fail to benefit from a holistic processing approach. Finally, although little research has been conducted on the use of cartoon images, preliminary evidence suggests these deficits persist when cartoon images are realistic and depict social scenes.

A Theoretical Analysis of Emotion Recognition and Facial Processing Deficits

A variety of theoretical explanations have been espoused in an effort to explain emotion perception difficulties and face processing abnormalities in individuals with ASD. Three social-cognitive theories will be briefly described in the following section: Attention/Motivational, Weak-Central Coherence, and Theory of Mind. Importantly, it should be noted that although these hypotheses will be referred to as “theories,” these accounts all suggest that other “core” deficits in ASD (i.e., attentional deficits, motivational deficits, central-coherence deficits, or theory of mind deficits) can account for facial and emotional processing deficits.

Attention/Motivational Deficits. Attentional and motivational theories suggest individuals with ASD fail to attend in a typical manner to facial stimuli. While typical individuals show an affinity towards faces as compared to non-facial stimuli, individuals with ASD fail to show any specific interest or attention to faces (Bacon et al., 1998; Joseph & Tager-Flusberg, 1997; Vivanti, Nadig, Ozonoff, & Rogers, 2008). The lack of overall attention paid to facial stimuli is thought to lead to the difficulty individuals with ASD exhibit in identifying emotional expressions (Begeer, Rieffe, Terwogt, & Stockmann, 2006; Dalton et al., 2005). Support for this theory comes from eye-tracking evidence suggesting individuals with ASD gaze less at the facial area and important facial features (e.g., the eyes). Additionally, some investigators have found that by cuing individuals with ASD to attend to facial stimuli, performance on a part-whole facial matching task (Lopez, Donnelly, Hadwin, Leekam, 2004) and a sorting task (Begeer et al., 2006) improves. This finding suggests lack of attention may directly lead to poor emotion recognition and facial processing performance.

Further evidence for attentional/motivational theories comes from fMRI evidence showing reduced activation in areas associated with facial and emotion recognition (i.e., the amygdala and fusiform gyrus) (Grelotti et al., 2005; Koshino, Kana, Keller, Cherkassky, Minshew, & Just, 2008; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004). Interestingly, activation in these areas is associated with eye gaze, suggesting that brain abnormalities associated with impaired facial recognition may be due to the lack of attention individuals with ASD show to the eyes or other areas of the face (Dalton et al., 2005). Finally, lack of activation in these regions may serve to explain the lack of motivation individuals with ASD exhibit towards faces (as demonstrated by Grelotti et al., 2005, these areas do become activated when individuals with ASD gaze at objects of a circumscribed interest).

Despite face validity and empirical support for attentional/motivational theories, several investigators have failed to find support for these theories. First, some researchers have found that individuals with ASD gaze at faces and the eye region in a similar manner to individuals with ASD (e.g., van der Geest et al., 2002a; van de Geest et al., 2002b). Second, a paradigm to test for motivation is not yet well established within this literature. Only a few studies (Begeer et al., 2006; Grelotti et al., 2005) have attempted to assess the role of motivation in facial and emotional processing. Finally, attentional and motivational deficits do not fully explain some of the findings observed within the ASD population. For example, it is difficult to explain the lack of an inversion effect observed in individuals with ASD using attentional and motivational theories alone. Thus, although attention and motivational deficits may serve to explain a portion of emotion recognition and facial processing difficulties in individuals with ASD, these theories appear to fall short of explaining the full extent of these impairments.

Weak Central Coherence. In addition to attentional or motivational deficits, Uta Frith (Frith, 1989) posited that individuals with ASD have “weak central coherence”—a processing difference that explains social deficits in individuals with ASD. The main tenant of this theory suggests individuals with ASD show difficultly integrating “information into meaningful representations” (Lopez et al., 2004, pg 674). While typical individuals tend to ignore minor details and focus on the “gestalt” of an object, individuals with ASD tend to attend to the local features of objects and demonstrate impairment in what has been termed “global perception.” Support for this theory comes from a number of studies demonstrating that individuals with ASD tend to perform exceptionally well on tasks that require local perception. For example, several investigators have found individuals with ASD tend to be less likely to succumb to visual illusions than typically developing individuals (Happé, 1996; Ishida, Kamio, Nakamizo, 2009). Individuals with ASD also outperform typical peers on the embedded figures task (a task which requires individuals to select a simple shape within a complex design) (Jolliffe & Baron-Cohen, 1997; Pellicano, Maybery, Durkin, & Maley, 2006). Individuals with ASD and their family members are also particularly adept at completing the Block Design subtest of the Wechsler

Intelligence Tests (i.e., WISC and WPPSI-IV), another task requiring local, rather than global processing, (Happé et al., 2001; Happé & Frith, 2006).

Furthermore, research from the facial processing literature also appears to support the notion that individuals with ASD demonstrate weak central coherence. Specifically, the finding that individuals with ASD fail to demonstrate the "inversion effect" is often used as support for this theory (e.g., Hobson, Ouston, & Lee, 1988; Tantam et al., 1989). Thus, individuals with ASD may attend preferentially to the features of the face while failing to process the face as a holistic unit. The weak central coherence theory is noteworthy in its ability to explain a wide range of deficits in individuals with ASD. For example, weak-central coherence would predict the difficulty individuals with ASD experience in understanding the nuances of language (Booth & Happé, 2010) and the high prevalence of circumscribed interests within this population (Atwood, 2003). Importantly, this theory is unique in its focus on the pattern of cognitive *strengths* and weaknesses in individuals with ASD. That is, rather than employing a "deficits-only" model, this theory has aimed to describe the unique ways in which individuals with ASD possess both processing strengths (i.e., local processing) and weaknesses. It should also be noted attentional/motivational theories and the weak central coherence hypothesis are not necessarily at odds—rather, weak central coherence can be described as a refined theory that describes the specific way in which individuals with ASD may allocate their attention.

Theory of Mind. A final theory described is known as the "theory of mind" hypothesis put forth by Simon Baron-Cohen and his colleagues (often referred to as "mindblindness"). This theory is arguably one of the most popular theories within the ASD literature and is supported by decades of research with individuals with ASD. Theory of mind (TOM) is a term used to refer to the ability to understand that other's minds are distinct from our own—that is that other individuals think, feel, or believe things that are different from our own feelings, thoughts, and beliefs (Baron-Cohen, Leslie, & Frith, 1985). TOM appears to develop naturally in typical children and can be referred to as “intact” in children by the age of four years old. At this age, typically developing children begin to recognize false-beliefs and the concepts of desire and intention (Gopnik & Slaughter, 1991; Ruffman, Olson, Ash, & Keenan, 1993). Generally, the majority of false-belief tasks involve a scenario in which the child is shown a reality that contrasts with expectations (e.g., legos inside a crayon box). The child is then asked to predict what another individual (who has yet to observe what is inside the crayon box) will believe regarding the particular scenario.

Despite the relatively young age at which typical children master these tasks, CWA often fail these types of TOM tasks (Baron-Cohen et al., 1985; Happé, 1995; Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998). High-functioning adolescents and adults with ASD also fail advanced TOM tasks. A well validated advanced TOM task known as the Strange Stories task (Happé, 1994) has been employed in many studies with high-functioning individuals with ASD. During this task participants are shown several vignettes in which the characters say things they do not mean. Participants are asked to explain *why* the characters would engage in this type of behavior (e.g., to deceive another, to make a joke, etc.). As predicted by the TOM hypothesis, participants with ASD perform significantly worse on this task than typical participants matched in verbal ability and chronological age (Happé, 1994; Jolliffe & Baron-Cohen, 1999; Kaland, Callesen, Moller-Nielsen, Mortensen, & Smith, 2007).

Advanced TOM tasks that relate specifically to emotion recognition have also been developed. For example, the Eyes Task (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) requires participants to label mental states of others when presented with only the eye area of the face. Participants with ASD have shown difficulty completing this task compared to typical participants—especially, in the case of complex emotions (Baron-Cohen, Whellwright, & Jolliffe, 1997; Kaland et al., 2007).

These findings, as well as evidence that TOM and emotion recognition appear to be correlated (Heerey, Keltner, & Capps, 2003), has led to the suggestion that TOM deficits underlie emotion recognition and facial processing difficulties (e.g., Baron-Cohen et al., 1985; Baron-Cohen, 2000). Although this hypothesis appears to be supported by a plethora of research findings, it should be noted that the constructs of emotion recognition and TOM are often inadequately distinguished by researchers in this area. Thus, many emotion recognition tasks can also be described as “theory of mind” tasks. This becomes problematic when researchers then attempt to explain poor performance on these tasks by suggesting individuals with ASD lack a theory of mind (i.e., circular logic). Furthermore, although TOM skills appear to be amenable to intervention, TOM improvements during the course of a randomized control trial did not appear to translate to improved social skills in the natural environment (Begeer et al., 2010). These results suggest TOM skills taught did not generalize to in vivo social scenarios or that TOM deficits can only partially explain the social difficulties of individuals with ASD.

These three theories are by no means the only theories proposed to explain emotion recognition and facial processing deficits. Nevertheless, they comprise a large portion of the literature related to these deficits and have yielded considerable research within this area.

Circumscribed Interests

Until very recently, circumscribed interests (CI) were rarely mentioned within the emotion recognition and facial processing literatures. However, the utility of these interests in teaching CWA how to correctly identify emotions and process faces has sparked a degree of empirical interest in CI.

A primary domain of impairment within ASD is known as restricted and repetitive behaviors (RRBs). Compared to social and communicative behaviors, this set of impairments has received considerably less research interest (Atwood, 2003; Klin, Danovich, Merz, & Volkmar, 2007; Turner, 1999); however, recent advances in this area have led to a greater understanding of these behavioral excesses. RRBs are often classified as “lower order” and “higher order,” with lower order RRBs including stereotypy, tics, and self-injurious behavior and higher order behaviors including repetitive language, insistence on sameness, object attachment, and circumscribed interests (Turner, 1999). Although the presentation of RRBs varies across individuals with ASD, a vast majority of the ASD population can be defined as exhibiting a CI (Bashe & Kirby, 2001; Klin et al., 2007; Danovitch, Rhea, Volkmar, & Klin, 2009). A CI can be defined as an interest that is unusual in its intensity or focus (Boyd, Conroy, Mancil, Nakao, & Alter, 2006). CI are typically characterized by the amassing of large amount of facts (Atwood, 2003; Klin et al., 2007, South, Ozonoff, & McMahon, 2005) and are found to be relatively stable across time (South et al., 2005). Furthermore, although social and language improvements may be obtained throughout the lives of CWA, the intensity of circumscribed interests is thought to increase with age (Atwood, 2003). CI can disrupt appropriate social interactions due to their unusual focus (e.g., vacuum cleaners) or their intensity (e.g., an individual with ASD may dominate the conversation in order to continue discussing a particular CI). As noted, a large portion of the ASD population exhibits at least one CI; in fact, across two distinct investigations, Klin et al., (2007) and Danovitch et al. (2009) found the prevalence of CI within a sample of individuals with ASD to be over 75%.

Interestingly, although (and perhaps because) individuals with ASD find their CI to be highly reinforcing (Mercier, Mottron, & Belleville, 2000), other reinforcers are often difficult for parents and therapists to identify. That is, although a child with ASD may obtain reinforcement from discussing toilet bowls, he may respond neutrally to the presentation of other stimuli (i.e., edibles, non-CI related toys, social praise) (Atwood, 2003). Often, the lack of available reinforcers and the highly preferred nature of RRBs lead to the delivery of CI-related reinforcers within the context of intervention. In fact, researchers commonly note the use of a “preferred item” during an intervention or experimental procedure. Although these researchers often fail to describe the preferred item as a CI, it is likely the case that several investigations have used CI-related items as intervention tools. In fact, using CI within the context of intervention is often recommended to clinicians (e.g., Atwood, 2003; Mancil & Pearl, 2008). Furthermore, some investigators have explicitly attempted to use CI to obtain intervention effects. For example, CI-related stimuli have been used to improve social interaction (Boyd et al., 2007), increase joint-attention (Kryzak, Jones, & Strumey, 2013; Vismara, & Lyons, 2007), decrease inappropriate behavior (Charlop-Christy & Haymes, 1996), and improve task performance (Charlop-Christy & Haymes, 1998). Despite the popular use of CI-focused interventions, only one study known to date has measured the effect of the use of CI stimuli on the strength of the CI following the intervention (Kryzak, Jones, & Strumey, 2013). Kryzak et al. (2013) found parent’s reported similar severity levels for the child’s CI pre and post-intervention; however, ceiling effects were evident.

Although individualized CI programs (i.e., a child’s specific CI is used for his specific intervention program) are more frequently presented within the research literature, some researchers argue that normative information related to CI can be used to develop group-wide intervention programs for individuals with ASD (Baron-Cohen, Golan, Chapman, & Granader, 2009; Golan et al., 2010). There is some evidence that CI in individuals with ASD cluster around certain themes. For example, Baron-Cohen and Wheelwright (1999) used a parent-based questionnaire in an attempt to categorize CI within six core domains: “folk physics,” “folk mathematics,” “folk biology,” “folk psychology” “language,” and “taxonomy.” The term folk was used to indicate knowledge in these areas was not explicitly taught to individuals, rather interest and knowledge appeared to be “intuitive.” The authors found a relatively high proportion (84%) of CI fell within the category of folk physics (e.g., an interest in mechanical objects). Consistent with Baron-Cohen and Wheelwright’s finding that individuals with ASD are often most interested in mechanical objects, the National Autistic Society (NAS) (2002) found a surprisingly high percentage of CWA appear to be “obsessed” with Thomas the Tank Engine. Of approximately 81 parents surveyed, one-third reported their child had an obsessive interest in Thomas. Additionally, the majority of children appeared to maintain an interest in Thomas for approximately 2 years longer than typically developing siblings. Although the results of this study would have been strengthened with the use of a control group, the high percentage of children who displayed a specific interest in Thomas is striking. As noted, by obtaining information regarding the common types of CI exhibited in CWA, it may be possible to create group-based or general interventions that appeal to a large segment of the ASD population.

This approach is epitomized in a recent study conducted by Golan et al. (2010). These authors created an animated series designed to teach CWA emotion recognition skills, known as *The Transporters*. The animated series is modeled on the show *Thomas the Tank Engine and Friends (TTE)* and centers around eight vehicles running on tracks and cables. The authors based their show on TTE given the findings by the NAS (2002) described above and their own research related to CI. Furthermore, the authors supported their use of trains and cable cars by suggesting individuals with ASD tend to be strong "systemizers;" that is, they display a tendency to find predicable, rule-base systems reinforcing. Thus, according to this theory, vehicles with rule-governed systems (e.g., cable cars, trains) should be preferred over vehicles or other objects that display unpredictable motion (e.g., cars, planes, cartoon animals or people) (Baron-Cohen, Golan, Chapman, & Granader, 2009). By capitalizing on this general CI within the ASD population, Golan et al., reasoned *The Transporters* would effectively teach individuals with ASD emotional expressions. Although the authors wanted to utilize the CI of individuals with ASD, they attempted to program for generalization to human emotions by grafting real-life faces of actors onto each of the animated vehicles. The show is comprised of 15 episodes (5 minutes each) and is designed to teach both basic (e.g., angry) and complex (e.g., proud) emotions.

Currently, The Transporters has been evaluated in three separate investigations. Golan et al. (2010) administered *The Transporters* intervention (a prescription to watch at least episodes a day and parent guided homework assignments for four weeks) to 20 CWA (ranging in age from 4 to 7 years). The authors compared the performance of this ASD treatment group to a group of wait-list controls and a group of typically developing children (matched in age and verbal ability). Pre and post assessments were administered to all participants and included a battery of emotion recognition assessments. Participants who received *The Transporters* intervention scored higher on an emotion vocabulary test and were better able to match scenes to emotions in both animated and human conditions (participants were shown a scene with *The Transporters* characters and humans and asked to choose the matching emotion). Importantly, during the post-assessment the treatment group performed at the same level as the typical group across all assessments of emotion recognition.

Despite impressive results, a few limitations of this study deserve mention. First, the authors did not control for the number of episodes watched by participants (in fact this varied from reports of 49 episodes watched to 382 episodes). Second, parental involvement in the intervention was not monitored and may have greatly contributed to treatment effects. Third, as noted by Young and Posselt (2011), the authors failed to include a control with an alternate task (rather they relied on a wait-list control). In an effort to improve this study, Young and Posselt created a new DVD comprised of emotion-laden episodes from *Thomas the Tank Engine and Friends*. The authors improved upon the design of Golan et al. by administering *The Transporters* intervention to 13 CWA (ages 4-8) and administering the "purpose-built" TTE DVD to a second group of CWA (*N* = 12) matched in nonverbal IQ, language ability, and age. The authors instructed parents to have their children watch three episodes a day for three weeks. Interestingly, children who watched *The Transporters* showed significantly greater improvements on tasks measuring emotion recognition than children who watched TTE. The authors also reported improvements in social interaction and eye contact for both groups (unfortunately, these measures were assessed via parent report, rather than by objective measures). A limitation of this study is the lack of a true control group; thus, maturation and placebo effects cannot be ruled out. Additionally, as in the study by Golan et al. (2010), parental involvement was not monitored.

A third investigation, aimed at extending intervention results to lower functioning CWA found the intervention to be ineffective (Williams, Gray, Tonge, & 2012). Two large groups of CWA were randomly assigned to *The Transporters* intervention (*N* = 28) or a control Thomas the Tank Engine DVD group (*N* = 27). Participants were of similar ages as in previous studies (4-7) and the intervention lasted 4 weeks. Participants in the Williams et al. study were lower functioning on average than participants in previous investigations (FSIQ range = 42-107). The authors found the although children in the intervention group initially showed improvements in recognizing anger, this result did not maintain at 3-month follow up. Furthermore, no changes in TOM or social skills were identified following the intervention. These findings suggest the intervention may have more limited efficacy than previously reported, especially for lower-functioning children on the spectrum.

Despite limited research, the use of vehicles and TTE specifically in improving emotion recognition (and presumably facial processing) deserves attention. First, both studies described above showed significant effects in a fairly low-effort, low intensity intervention. Given the cost of services for ASD and the level of expertise often required to administer these services, low cost (*The Transporters* can be purchased online for $65), low effort, and low intensity interventions demonstrating dramatic effects should be welcomed by the ASD community as a supplemental intervention to more intensive evidence based therapies (e.g., as a supplemental component of Early and Intensive Behavioral Intervention programs). Nevertheless, a considerable amount of research investigation of *The Transporters* and TTE needs to be conducted before this intervention and others can be recommended for wide-spread use.

A systematic analysis of TTE and his effect of emotion recognition and facial processing is warranted for a variety of reasons. First, a large percentage of the ASD population appears to have an interest in TTE and “folk physics.” (Baron-Cohen & Wheelwright, 1999; NAS, 2002) Substantiation of these claims may lead to a better understanding of circumscribed interests in ASD and may lead to the advancement of therapeutic interventions within the literature.

Second, although Baron-Cohen et al. (2009) and Golan (2009) suggest *The Transporters* is effective because CWA are inherently drawn to trains and rule-based systems, the mechanism by which the series leads to improvements in emotion recognition has yet to be delineated. For reasons unknown, CWA may attend more closely to TTE and TTE's facial features than images of people or other cartoons. For example, as a train, Thomas has no ambulatory features, allowing his face to represent a larger portion of the visual field. Given visual perception difficulties discussed above in CWA, it is possible that Thomas' presentation (not necessarily the fact that he is a train) is what contributes to his appeal or his ability to enhance emotion recognition abilities. It is also possible that certain features of TTE contribute to the ease with which CWA interpret his emotions. If features of TTE, rather than TTE himself assist CWA to identify emotions, then researchers may be able to refine their intervention strategies by capitalizing on these features.

Finally, if TTE improves emotional recognition and facial processing in only a subset of CWA, the characteristics of this group of individuals needs to be identified such that specific intervention recommendations can be made. For example, it may be the case that *The Transporters* is only effective for children with a CI in Thomas, trains, or other automobiles.

Research Questions

The overarching aim of this study was to identify the effect of cartoon stimuli that varied in their popularity within the ASD population and in their similarity to human stimuli on the emotional and facial processing abilities of CWA. Mixed findings from both the emotion recognition literature and facial processing literature present an unclear understanding of these deficits, yet researchers have begun to delineate the stimulus variables that may contribute to deficient emotion recognition and processing (i.e., dynamic socially complex stimuli). Thus, this study first attempted to assess for differences in emotion recognition across CWA and typically developing children across a variety of stimulus presentations. Specifically, differences across these two groups in recognizing emotions in TTE, a human animated character (Woody from Toy Story), and human faces was examined. We hypothesized that CWA would perform worse in identifying the emotion of each character as compared to typically developing children. The use of Thomas was specifically chosen due to findings from the CI literature suggesting individuals with ASD may respond differentially to objects of strong personal interest (e.g., trains).

Second this study attempted to assess differences in facial processing across TTE, Woody, and human emotional stimuli. Gaze fixation data was collected in order to assess attending to specific areas of interest (AOI; i.e., eyes, mouth, and face). It was expected that CWA and typically developing individuals would differ in the duration and number of gaze fixations to these AOI. Specifically, CWA were expected to attend less to the eyes and face than typically developing individuals.

A third and final aim of this study was to identify features of TTE that may contribute to his purported appeal. Four conditions were developed in an attempt to assess this question. Human faces and cartoon human faces (i.e., Woody) were imposed onto static TTE scenes. It was expected that emotion recognition and facial processing would improve in this condition (Woody-TTE condition > Human-TTE condition). Thomas' face was also imposed on Woody's body and a human body in static scenes in order to assess for features of TTE's face that may improve emotion recognition and facial processing in CWA. Due to the systemizing theory of ASD and documented difficulty for this population in perceiving biological motion, it was expected that this manipulation would lead to further impairments in emotion recognition or facial processing for CWA.

An exploratory aim included the examination of correlates of emotion recognition and gaze to the eyes and face. We were thus interested in the relationship between Theory of Mind (TM)[4] and Affect Recognition (AR) scores as measured by the NEPSY-II and their relationship to the primary dependent measures in this study. It was expected that TOM and AR scores on the NEPSY-II would positively correlate with emotion recognition tasks developed for this study and appropriate gaze.

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[4] TM is the abbreviation used by the NEPSY-II to define the Theory of Mind subtest. Throughout the manuscript TM is used to refer to the NEPSY-II subtest while TOM is used to refer to the general concept of Theory of Mind.

Method

Measures

In order to assess for the presence and severity of ASD the *Childhood Autism Rating Scale-Second Edition* (CARS-2; Schopler, Van Bourgondien, Wellman, & Love, 2010), the *Social Communication Questionnaire* (SCQ; Rutter, Bailey, & Lord, 2003), and a diagnostic checklist were administered. The CARS-2 is an observational measure designed to distinguish CWA from children with other developmental disabilities, and to provide a measure of the severity of autism symptomatology. The CARS-2 contains fifteen 4-point scales for rating a child's behavior as *within the normal limits (1)* to *severely abnormal (4)*. Total scores obtained from the CARS-2 are then used to distinguish between non-autistic, mild to moderate autistic, and severely autistic groups. The CARS-2 is extensively used as a pre-diagnostic measure, and validity and reliability estimates for the CARS-2 range from moderate to excellent. The SCQ is a parent completed rating scale designed to assess symptomatology associated with ASD. The scale includes 40 yes/no questions and can be completed in approximately 10 minutes. The scale is scored to generate a Total Score; typically scores of 15 or greater denote the possibility of an ASD. The SCQ correlates highly with "gold-standard" assessments of ASD (i.e., the Autism Diagnostic Interview-Revised; ADI-R) (Rutter et al., 2003). Typically, the SCQ is not used as a diagnostic tool, rather it is used to identify CWA who require a diagnostic evaluation (Rutter et al., 2003). In addition to these two instruments, a DSM-IV-TR diagnostic checklist was be used to obtain a research diagnosis. Per standard protocol for use of a DSM-IV-TR checklist, parent interview and behavioral observations served to provide information related to the checklist. The checklist assesses symptoms corresponding to the three primary domains of autism (i.e., social, communication, repetitive behavior), and differentiates between AD, AS, and PDD-NOS. See Appendix 1 for the diagnostic checklist.

Cognitive ability was assessed using the Wechsler Preschool and Primary Scale of Intelligence-Third Edition (WPPSI-III) and the Wechsler Intelligence Scale for Children-Forth Edition (WISC-IV). Children ages 4 to 5 years 11 months were administered the WPPSI-III and those 6 years and older were administered the WISC-IV. The standard battery for each IQ test was used, yielding a verbal IQ score (VIQ for the WPPSI-III, VCI for the WISC-IV), performance IQ score (PIQ, PRI, respectively), and full scale IQ score (FSIQ). The WPPSI-III was standardized using a diverse and representative sample of 1,700 children in the United States, with 200 children included at each 6-month interval between ages 2 and 6. Reliability for each subtest of WPPSI-III is acceptable to excellent across all ages (.83 to .95), and internal consistency coefficients for FSIQ are excellent (.95 or higher for all age groups). Validity for the WPPSI-III is also extensively established, and FSIQ scores on the WPPSI-III correlate highly with other measures of similar constructs for preschoolers, .87 for the Differential Ability Scales (Elliot, 1990), and .80 for the Bayley Scales of Infant Development-Second Edition (BSID-II; Bayley, 1993) (Wechsler, 2002). Administration of the WPPSI-III takes approximately 30 minutes. The WISC-IV is also a Wechsler intelligence test. The WISC-IV was standardized using a national sample of approximately 2,200 children between the ages of 6 and 16. Reliability and validity for the WISC-IV is also well established. Reliability coefficients for subtests across age groups range from .72 to .94 and from .96 to .97 for FSIQ (Wechsler, 2003).

The WISC-IV correlates highly with other measures of intelligence (e.g., the Wechsler Abbreviated Scale of Intelligence and Wechsler Adult Intelligence Scale) and achievement (i.e., the Wechsler Individual Achievement Test) (Wechsler, 2003). Furthermore, the composite scores (e.g., VIQ and VCI) generated from the WIPPSI-III and WISC-IV correlate highly (ranging from .65 to .89). Administration of the WISC-IV standard battery takes approximately 60 minutes (Wechsler, 2003).

Circumscribed interests were assessed using both an interview format and a behavioral measure of preference. The *Yale Survey of Special Interests* (YSSI; Klin & Volkmar, 1996, unpublished manuscript) was administered to parents. The YSSI is an open-ended questionnaire designed to identify CI topics in individuals with ASD, the extent to which those topics are pursued (e.g., number of hours per day engaging in the CI), and the manner in which CI is manifested (e.g., by reading extensively on the topic). The YSSI can be administered in both written (e.g., Klin et al., 2007) and interview format (e.g., South, Klin, & Ozonoff, 1999). Although South, Ozonoff, and McMahon (2005) report strong psychometric properties for the YSSI survey format, no published psychometric studies of the YSSI exist.[5] Furthermore, although South et al. (2005) used an interview format of the questionnaire, they did not report on the psychometric properties of the interview and relied on the strong properties of the survey format to justify their use of the interview. Despite limited psychometric data, the YSSI is the only currently developed measure designed specifically to assess CI in CWA. Given unavailable psychometric data for the YSSI, a behavioral measure of CI (i.e., an MSWO) was also be administered to participants.

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[5] The author was unable to obtain a copy of Volkmar and Klin, 1996 unpublished manuscript, despite personal communication with Ami Klin, Fred Volkmar, Rhea Paul, and Judith Danovitch.

A multiple-stimulus without replacement (MSWO) preference assessment was conducted with each participant to confirm the parent report of CI. The MSWO preference assessment is a well validated behavioral observation measure for assessing preference in children and individuals with developmental disabilities (Carr, Nicolson, & Higbee, 2000; DeLeon & Iwata, 1996). An array of approximately 6-8 stimuli is presented and the child is prompted to "pick one." Subsequently, the child is allowed access to the selected item for approximately 30 seconds. The item is then removed from the array and the process is repeated until no items are left. The assessment allows for an easy method of ranking items or developing a preference hierarchy. The MSWO was recently used to confirm parent report of CI in CWA (O'Brien, 2009). A TTE figurine and a Woody doll were included in the array; other non-CI related items were also included (e.g., a slinky). Children with a circumscribed interest in Thomas were defined for the purposes of this study as children whose parents reported a strong interest in Thomas on the YSSI or children who selected Thomas as one of the top 3 items in the MSWO.

The Affect Recognition subtest of the NEPSY-II was administered to all participants (Korkman, Kirk, & Kemp, 2007). Two different versions of this subtest are available for use depending on the child's age. Children ages 3-4 are administered a shorter version (16 items) than children ages 5-16 (35 items). The subtest is designed to assess the ability to recognize affect (i.e., happy, sad, neutral, fear, angry, disgust) in a series of photographs. The subtest is comprised of four tasks in which the child is asked to: state whether or not two photographs depict the same affect, select two photographs of faces with the same affect from a series of photographs, select the photograph from a series of photographs that matches a particular affect, and after observing a photograph for 5 seconds select from memory the photograph that depicts the same affect as the face previously shown from a series of new photographs.

Theory of mind (TOM) was assessed using the Theory of Mind subtest of the NEPSY-II. As is the case with the Affect Recognition subtests, two different versions of this subtest are available for use depending on the child's age. Although items differ across versions, children ages 3-4 and children ages 5-16 are administered an equal number of items (21). Two task types are included in this subtest: Verbal and Contextual. The verbal tasks include a series of items that include stories, pictures, and questions asked by the examiner. These tasks are designed to assess general TOM skills in addition to comprehension of figurative language. Contextual tasks include items in which a picture is depicted (e.g., a child falling off a bike) and the child is asked to select the emotion from a series of pictures that matches the social context (in this case an expression indicating pain). Items 1-15 are verbal items and items 16-21 are contextual items. The subtest yields a "TM Total Score" and a "TM Verbal Score."

Reliability for the NEPSY-II Social Perception subtests (Affect Recognition and Theory of Mind) is adequate. Reliability coefficients range from.64 to .88 across age subsets within normative samples (Korkman et al., 2007). Although the NEPSY-II is validated across measures of cognitive ability (e.g., the WISC-IV) and measures of achievement (e.g., the WIAT), the Social Perception subtests have not been cross-validated with other measures of emotion recognition or theory of mind (Korkman et al., 2007). Nevertheless, a strength of the NEPSY-II is the establishment of norms for CWA. As part of standardization methods the authors administered the NEPSY-II to 23 children with a diagnosis of Autistic Disorder (AD) and 19 children with a diagnosis of Asperger's Disorder (AS). Children with a diagnosis of AD scored significantly lower on the Affect Recognition subtest and the Theory of Mind subtest than typical controls; interestingly, children with AS scored significantly lower than controls on the Theory of Mind subtest, but not the Affect Recognition subtest. This difference across diagnostic categories may be explained by the fact that children with AS were on average approximately 3 years older than the Autism group.

Procedures

An assessment session and an eye tracking session were required for participation in the study. During the assessment session, parents completed the following measures: YSSI, CARS-2, the SCQ, and the demographic questionnaire (parents of typically developing children did not complete the CARS-2 or SCQ as these are measures related to ASD severity). During this session, children also completed the WPPSI-III or the WISC-IV, the Affect Recognition and Theory of Mind subtests of the NEPSY-II, and the MSWO. A second session was scheduled on a separate date during which participants were administered a series of experimental tasks described in detail below (for participants who commuted from outside of the nearby area, a one hour break was provided before participants returned in the afternoon for the eye tracking session).

Setting and Materials. Participants completed WPPSI-III or WISC-IV, the NEPSY-II, and the MSWO in a room (8 feet by 8 feet) at the psychological center of a large southeastern university. The room was equipped with one table and two chairs. Aside from the materials required for administering these measures, no other materials (e.g., toys) were present.

Eye tracking sessions were conducted in a lab space approximately 18 feet by 5.5 feet. The room is equipped with an eye tracker and Tobii Studio 2.2.8. The child sat in a large chair in the middle of the room in front of a computer screen (Acer T231H). Behind the chair is a partition that served to conceal a table, chair, 3 computers, and a media cart. Participants were first introduced to the room and equipment and told how the eye tracker “works.” Participants then underwent a calibration procedure with the eye tracker. The calibration process within the software package requires participants to follow a blue bounding ball around the screen to nine locations. Calibration was repeated until participants succeeded in the task. The purpose of calibration is to determine that the eye tracker is accurately tracking the participants' eye gaze. Once calibration was completed, a training procedure began.

Training procedure. Participants completed a short training procedure prior to viewing eye tracking stimuli in order to allow for familiarization with the task demands. Participants viewed a series of 3 static images (a triangle, a square, and a circle) and completed a series of questions to indicate the shape they observed (e.g., "Which shape did you see?"). Participants who correctly completed 2 out of 3 trials continued participation (all participants met this criterion). For young participants, a research assistant controlled the mouse, and indicated the child's verbal response. Additionally, if participants were unable to read fluently (a brief reading measure of emotional words was included in the training procedure), then questions were read aloud by a research assistant. Fifteen of twenty-five participants required assistance in reading questions and controlling the mouse (eight of these fifteen were CWA).

Experimental tasks. Naturalistic stimuli were collected by the primary author and a team of research assistants. Thomas clips were selected from several popular Thomas the Tank Engine DVDs (e.g., Thomas and the Magic Railroad). Woody the Cowboy from the Toy Story trilogy was chosen as a cartoon character due to his human like characteristics. Clips of the actor Ben Stiller from the movie Night at the Museum and the sequel, Night at the Museum: Battle of the Smithsonian were selected in an attempt to match the age-range/preferences of children who were expected to participate in the study. Static scenes displaying the following emotions were selected for each character: happy, sad, scared, angry, and surprised. One screenshot for each emotion for each character was selected at the height of the emotion in the scene. Attempts were made to select scenes in which only the main character appeared and minimal background distractions were present; however, given the use of naturalistic stimuli, differences in the level of background distractions and the prominence of the character with respect to the background in the scene existed. A total of 15 naturalistic static emotional scenes were presented to participants.

Given limitations in using naturalistic stimuli, computer-generated stimuli were also developed by a graphic designer. Woody, Thomas, and male human stimuli were created for the following six basic emotions: happy, sad, scared, angry, surprised, and disgust[6]. The use of computer-generated stimuli also allowed for the development of “fused” stimuli. Thus, Woody’s face and human faces were grafted onto TTE’s body. Additionally, TTE’s face was grafted onto Woody’s body and the body of a person in order to assess for the impact of these additional stimulus features (i.e., body parts) on the emotion recognition abilities of CWA and children without ASD. Grafted stimuli were developed for each emotional condition. Thus, participants viewed 54 computer-generated images and 15 naturalistic images for a total of 69 static images.

Stimuli were presented for 3 seconds and then disappeared. A multiple-choice question “How did he feel?” and six possible emotional labels were presented. The procedure was repeated with each subsequent stimulus following the participant’s response. No consequences were provided to the participant following the response. Correct responses for the question were given a score of 1 and incorrect responses were given a score of 0. This measure was used to comprise a Total Emotion Recognition score (Total ER).

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[6] Attempts were made to include naturalistic stimuli displaying the emotion disgust; however, very few naturalistic scenes displayed this emotion.

In order to avoid concerns related to the oddness of fused stimuli, non-fused stimuli were presented first. Half of the participants viewed naturalistic images first and half viewed computer-generated stimuli first in order to counter-balance naturalistic and computer-generated stimuli (within these blocks, stimuli were randomized by emotion). Fused stimuli were presented next (randomized by character type and emotion). The entire eye-tracking procedure took approximately 45 minutes.

Participants were thanked for their participation and provided with monetary compensation ($15 for the assessment session and $15 for the eye-tracking session). All participants and legal guardians completed informed consent procedures. The study was approved by the institutional review board.

Emotion recognition results were recorded using Tobii Studio 2.2.8 and entered into an electronic database. Correct responses were given a score of 1 and incorrect responses were scored as 0 for a total score of 69. Both the Total ER score (emotion recognition scores across all stimuli) and emotion recognition scores within each stimulus set were calculated (e.g., ER score for Human Naturalistic stimuli). AOIs for eyes, face, and mouth were selected for each stimuli. These were grouped across stimuli sets (e.g., eye gaze for all Human Naturalistic stimuli) in order to assess for the effect of character type. Total fixation duration and total fixation count were extracted for each AOI for each stimuli type from Tobii Studio 2.2.8. Total fixation duration is defined as the duration (seconds) for all fixations within an AOI group, whereas total fixation count is the number of times the participants fixates on an AOI group. These two metrics were calculated within Tobii Studio 2.2.8 and then transferred to and analyzed using SPSS.

Participants

CWA and children without ASD ages 4-12 were recruited to participate in this study. See table 1 for participant characteristics. Six low-functioning CWA (VIQ ≤ 70) and six high-functioning CWA (VIQ ≥ 70) participated in the study ($M_{VIQ} = 85$, $SD = 29.95$, $\mathrm{IQ}_{\mathrm{range}} = 53 – 136$). Gender characteristics among the ASD sample were highly skewed; only one of 12 participants was female. The typically developing group was comprised of 13 children all with a VIQ of ≥ 70 ($M_{VIQ} = 102.69$, $SD = 18.01$, $\mathrm{IQ}_{\mathrm{range}} = 73 – 138$). Gender characteristics in this population were more normally distributed (seven females and six males). Mann-Whitney U tests were used to assess differences in age and VIQ. Typically developing children and CWA matched in chronological age, $Z = -.68$, *ns* and VIQ, $Z = -1.63$, *ns*. The present sample of twelve participants with a community diagnosis of an Autism Spectrum Disorder all met checklist criteria for inclusion in the study. Additionally, CARS and SCQ scores appeared representative of an ASD sample ($M_{\mathrm{CARS}} = 32.43$, $SD_{\mathrm{CARS}} = 5.86$; $M_{\mathrm{SCQ}} = 15$, $SD_{\mathrm{SCQ}} = 5.26$). Scores of 30 and above for the CARS and 15 and above for the SCQ suggest a high likelihood of an ASD diagnosis.

Results

Dependent variables (total ER score, total fixation duration and total fixation count) were first analyzed for normality and outliers. One significant outlier was identified for total ER score. A typically developing participant had an ER score that was more than 2 standard deviations from the mean ER score for typically developing participants (Z =2.40; ER score = 25; $X_{\text{ER score}}$ = 58.64). A review of notes from this session indicated this participant was particularly non-compliant and appeared to be guessing when providing answers rather than attending to the computer screen. Thus, this participant was removed from further analyses. No other significant outliers were identified and all other participants remained in the study sample. Skewness and kurtosis was analyzed separately for ER score across participant groups. Skewness of ER scores for the ASD population was in the appropriate range (Skew = -.514); however, for typically developing participants skewness was over twice the SES, indicating ER scores were significantly negatively skewed for the typically developing sample. Kurtosis values for the ASD population was in the appropriate range (Kurtosis = -1.30); however for the typically developing population the Kurtosis value (-2.54) significantly deviated from the SEK, indicating a highly flat distribution of scores.

Values for total fixation duration and total fixation count were also analyzed separately across diagnosis. The same criteria was used to determine normality of skew and kurtosis (a deviation of less than twice the SES and SEK). Significant deviations for skewness and kurtosis were apparent across several stimulus sets. Moreover, Levene's test for equality of variances indicated significantly different variances across groups for measures of total fixation duration and count.

Emotion Recognition

Given non-normality of ER data and the small sample of CWA ($N = 12$) and typically developing children ($N = 13$), the Mann-Whitney U was selected to test for differences in total ER scores. Descriptive statistics showed that typically developing children ($M_{\text{totalER}} = 48.62$, $SD = 8.60$) scored higher in total ER than CWA ($M_{\text{totalER}} = 42.58$, $SD = 13.49$). However, Mann-Whitney U-value was found to be in the non-statistically significant range, $Z = -1.00$, *ns*. A second series of Mann Whitney U Tests was then conducted in order to assess for differences across CWA and typically developing children in ER scores across all stimulus sets (Naturalistic, Computer-generated, and Fused conditions for Human, Woody, and Thomas). Emotion Recognition scores were found to be statistically significant across groups for only Human Naturalistic stimuli. Typically developing children ($M_{\text{HumanNaturalisticER}} = 4.27$, $SD = .65$) obtained higher ER scores than CWA ($M_{\text{HumanNaturalisticER}} = 2.00$, $SD = 1.12$), $Z = -3.81$, $p < .01$. Cohen's effect size indicated this result was large, $r = -.76$.

Fixation Duration and Count across Stimulus Sets

Mann Whitney U was also used to assess for differences in fixation duration and count across groups given that gaze data were non-normally distributed and small samples were utilized. Fixation duration and count across each stimulus set was compared across groups. See Figure 1 for mean fixation duration and count for each stimulus type by group. Results converged, such that analyses of fixation duration and count were found to be in the same direction. Table 2 provides a summary of the results from this analysis. Overall, typically developing participants tended to gaze significantly more at Thomas' face and mouth in both computer and naturalistic conditions than CWA. Additionally, typically developing participants were more likely to direct their gaze towards Woody's mouth and face in the naturalistic condition only when compared to CWA.

Fixation Duration to Eyes and Face across Fused Stimuli for Participants with ASD

The significant across group differences in gaze to Thomas stimuli supported a within group analysis of differences in gaze for CWA. Of particular interest was the difference in performance across fused stimulus sets. Specifically, appropriate gaze to the eyes and face for human stimuli was expected to be facilitated by a removal of complicated background features (i.e., a human body) and the addition of a more easily perceived and purportedly attractive image (i.e., Thomas' body). In order to test within group differences, a series of Wilcoxon-Signed Ranks Tests were conducted. This statistic controlled for comparisons across paired samples, nonnormality of gaze data, and a small *N* (12). Interestingly, differences in gaze to non-fused human conditions and fused-human conditions were not significant; however CWA were much more likely to gaze at Thomas' eyes and face in the standard Thomas conditions and gaze less to the eyes and face in fused conditions for which Thomas' face was superimposed onto a human body and woody's body. Thus, CWA gazed longer at Thomas' eyes in the standard condition than the Thomas/Human fused condition (i.e., Thomas' face superimposed on the human body), $Z = -2.67$, $p < .01$. This was also true with respect to gaze at the face, $Z = -2.39$, $p < .05$. Gaze to the fused Thomas/Woody condition (i.e., Thomas' face superimposed onto Woody's body) also led to significantly less gaze to the eyes ($Z = -2.09$ $p < .05$) and face ($Z = -2.04$ $p < .05$). A similar effect was not found to be as strong across comparisons of gaze to Woody across sets. CWA attended to Woody's face for a longer period of time compared to gaze duration when Woody's face was superimposed onto a human ($Z = -2.35$, $p < .05$); however, all other comparisons were not significant.

Circumscribed Interests: The Thomas Effect

Of the twenty-five participants included in the study, eight met the study's definition of a circumscribed interest in Thomas the Tank Engine. Six participants selected Thomas as one of their top three toys in the MSWO (four of these were CWA) and six parents of participants identified Thomas the Tank Engine as their child's top circumscribed interest in either preschool or elementary school on the YSSI. MSWO results and YSSI results converged in the majority of cases; however one participant who was identified within the MSWO was not identified in the YSSI and the opposite was also true. The majority of participants with a circumscribed interest in Thomas were in the ASD group (six of eight). To assess for differences in emotion recognition scores and gaze to Thomas related stimuli, a comparison among these six participants with a CI in Thomas and the remaining six ASD participants without an established CI in Thomas was conducted. Table 3 provides relevant demographic information for participants with and without a CI in Thomas. Interestingly, participants with a CI in Thomas had a significantly lower VIQ than participants without a CI in Thomas, $Z = -2.085$, $p < .05$. Participants with and without a CI did not differ in their overall emotion recognition scores ($M_{\text{CI}} = 42.83$, $SD = 16.88$; $M_{\text{otherCI}} = 42.33$, $SD = 10.72$. Participants with and without a CI in Thomas also scored similarly on Emotion Recognition for Thomas naturalistic stimuli ($M_{\text{CI}} = 3.50$, $SD = 1.23$; $M_{\text{otherCI}}= 2.83$, $SD =1.72$) and Thomas computer-generated stimuli ($M_{\text{CI}} = 4.00$ $SD = 1.09$; $M_{\text{otherCI}} = 4.17$, $SD = .983$. There was a trend for individuals with a CI in Thomas to perform better on naturalistic

Thomas scenes than individuals without a CI; this is significant, given that participants without a CI in Thomas had a 30-point VIQ advantage on average over the group of participants with a CI in Thomas. Nevertheless, overall, a strong interest in Thomas did not appear to yield a significant advantage in emotion recognition scores within participants with an ASD. Participants with a CI in Thomas also performed similarly on all emotion recognition tasks (naturalistic, computer, and fused), suggesting an interest in Thomas did not lead to improved emotion recognition scores on Thomas-related tasks as compared to Woody or Human tasks: χ^2 (11, N = 6) = 15.87, $p > .05$).

A series of Mann-Whitney Tests were also utilized to analyze differences among CI groups across gaze to stimulus subtypes. Results indicated participants without a CI in Thomas showed more appropriate gaze (significantly more gaze as measured by total fixation duration) in the following conditions: eyes, $Z = -2.09$, $p < .05$ and mouth, $Z = -2.33$, $p < .05$ for Human computer-generated stimuli and eyes in the Thomas computer-generated condition, $Z = -2.34$, $p < .05$. Thus, a CI in Thomas was associated with a disadvantage in appropriate eye gaze to Human and Thomas stimuli. Given the lower VIQ of this sample, it is likely poor gaze is associated with VIQ differences and not a causal link between a CI in Thomas and poor gaze; nevertheless, it is also possible that an interest in Thomas yielded gaze to the background (i.e., Thomas' body) which may also explain the above findings.

Correlates of Emotion Recognition and Appropriate Gaze

Affect Recognition and Theory of Mind scores from the NEPSY-II were expected to correlate with dependent measures in the study (emotion recognition and appropriate gaze). An analysis of predictor variables was limited to the following dependent measures: total emotion recognition score and total fixation duration to eyes, face, and mouth for the Human computer stimulus set. For the total sample of participants ($N = 25$), Affect Recognition (AR) scores were positively correlated with our measure of emotion recognition, $r = .42$, $p < .05$ and total fixation duration to the face for the Human computer stimulus set, $r = .41$, $p < .05$. Interestingly, Theory of Mind (TOM) scores appeared more predictive than AR scores. TOM was positively correlated with our measure of emotion recognition, $r = .76$, $p < .01$ and total gaze duration to the eyes, $r = .40$, $p < .05$, face, $r = .58$, $p < .01$, and mouth, $r = .48$, $p < .05$. Given these findings for the overall sample, a second analysis of correlates was conducted to assess for relationships between independent and dependent variables among typically developing children and CWA. For both groups, the relationship between AR and total emotion recognition and total fixation duration to eyes, face, and mouth for the Human stimuli was no longer evident. TOM scores were positively associated with Emotion Recognition scores for CWA ($r = .76$, $p < .05$) and typically developing children ($r = .76$, $p < .01$). Interestingly, TOM appeared to predict appropriate gaze to different AOIs for each group. For CWA, TOM scores were positively correlated with fixation duration to the mouth, $r = .59$, $p < .05$, whereas for typically developing individuals TOM scores were positively correlated with gaze to the eyes $r = .60$, $p < .05$.

Discussion

The present study examined the ability of CWA and children without ASD to appropriately identify and attend to emotionally salient human and cartoon stimuli. A cartoon of highly reported interest within the ASD population, Thomas the Tank Engine (TTE) and a human-like cartoon, Woody the Cowboy, were selected in an attempt to capture differences in ER and facial processing across stimuli that varied in their resemblance to humans. It was predicted that CWA would have greater difficulty identifying the emotion and attending appropriately (i.e, gaze to the eyes and face) across all stimulus types compared to children without ASD. This study is also the first emotion recognition study known to the authors that attempted to isolate specific features of cartoons that may assist in the ER abilities of CWA. Fused conditions of emotional stimuli were developed in an attempt to begin to isolate features of Thomas that may relate to his appeal within the ASD population. Given prior support for systemizing theory (Baron-Cohen et al., 2009), it was predicted that emotion recognition and gaze would improve for CWA in conditions where the body of characters was removed and replaced by Thomas' "body." Finally, this study aimed to identify correlates of appropriate gaze and recognition. Theory of Mind and Affect Recognition scores were expected to positively correlate with ER scores and gaze to the eyes and face.

Total ER scores between CWA and typically developing children did not differ, although there was a trend for CWA to score lower than their age-matched and VIQ-matched typical peers. This finding correspond with several studies suggesting individuals with ASD are capable of identifying simple human emotions presented in a static format (Capps et al, 1992; Baron-Cohen et al, 1997; Fink, E., de Rosnay, M., Wierda, M., Koot, H.M., & Begger, S., 2014; Jones et al., 2011, Ozonoff et al., 1990; Sasson et al., 2007). The present study also extended this relatively common finding to static cartoon images (Thomas the Tank Engine and Woody from Toy Story); suggesting CWA are also capable of appropriately recognizing basic emotions in popular cartoon characters. The failure to capture a difference in ER scores may be related to the age of participants sampled. In one of the only cohort studies of emotion recognition, Rump et al. (2009) found that while younger CWA (ages 5-7) to displayed difficulty with ER, older CWA (ages 8-12) appeared to “catch up” to their typical peers. The age range of the present sample (4-11) spans the age range of participants captured by Rump et al., suggesting an age effect may serve to explain the lack of ER differences across groups. Interestingly, however, age was not correlated with Total ER score for the ASD sample, suggesting that a cohort effect does not adequately explain the lack of findings. Another possibility that may explain this null finding is the lack of a distinction between different emotions presented in this study. A handful of studies suggest emotion recognition deficits may only be present for negative emotions, such as anger and disgust (Bal, Harden et al., 2009; Enticott, Kennedy, Johnston, Rinehard, Tonge, Taffle, & Fitzgerald, 2013; Rump et al., 2009; Tracy et al., 2011); thus it is possible that a specific analysis of each of the six emotions included in this study may identify a difference in performance among individuals with ASD. Unfortunately, such an examination was outside the scope of the present study.

When ER was examined across each stimulus subset, CWA were found to perform significantly worse than typically developing peers for human naturalistic scenes only. This result converges with several studies that suggest ER and facial processing difficulties increase as emotional stimuli become more realistic and socially complex (Klin et al., 2002; Uljarevic & Hamilton, 2012; Saitovitch et al., 2013). The ecological validity of the human naturalistic scenes was significantly higher than any other subtest as this was the only stimulus type that included a human actor from a popular movie for children (as opposed to a computer-generated human pictured in computer stimuli). Although the complexity of the scenes were not directly compared to other stimulus sets, it is also likely that the human naturalistic scenes were more socially complex than cartoon scenes from Toy Story and the TTE movies.

Although as a group, ER scores for CWA were similar across Thomas, Woody, and Human cartoon and naturalistic stimuli, CWA with a circumscribed interest in TTE were significantly more adept at identifying emotions in naturalistic TTE scenes than CWA who did not display a significant interest in TTE. This finding is particularly surprising as CWA *without* a CI in TTE had a 30 point VIQ advantage over CWA with a CI in TTE. Notably, the same effect was not found for computer-generated scenes, suggesting prior exposure to TTE movies may best explain this finding. As naturalistic scenes were collected from popular TTE movies, it is highly likely that CWA with a CI in TTE had previously viewed the static images presented. Although the TTE movies do not explicitly aim to teach ER skills to CWA, TTE's emotions are often labeled in the movies (Williams, Gray, Tonge, 2012; Young & Posselt, 2011), thus prior exposure likely provided a strong advantage for children with a CI.

The tendency for typically developing children to gaze more at the face and mouth of Thomas (computer-generated) and the face and mouth of Thomas and Woody naturalistic scenes than CWA, but *not* to human stimuli was unexpected. One possible explanation for these unpredicted results is that CWA are more likely to direct their attention to the eyes of cartoon characters than to the eyes of human faces. Although the proportion of human eyes to face and cartoon eyes to face was not directly measured, both cartoon characters have much larger eyes than the human characters. The increased salience of the eyes for cartoon characters may thus cue CWA to attend to the eyes in a more typical fashion; leading to reduced gaze at the face and mouth in these conditions. Although outside the direct scope of the present study, the divergent findings across ER and facial processing data deserves mention. Although CWA demonstrated distinct gaze fixation patterns, they were still able to correctly identify emotions across human (computer-generated) and cartoon scenes. Indeed, gaze patterns to human naturalistic stimuli, which yielded poorer ER performance, were not significantly different from typically developing children. The lack of consistency across facial processing and ER data suggest CWA may be using compensatory strategies to select emotional labels. The current study used a forced choice matching to sample task, which may be susceptible to guessing effects (Russell, Bachorowski, & Fernandez-Dols, 2003; Uljarevic & Hamilton, 2012). Additionally, participants were not provided with time constraints in responding to the question ("How does he feel?"). Taken together, these factors may have contributed to a ceiling effect that obfuscated the relationship between facial processing and emotion recognition.

Children with a CI in Thomas gazed less at the eyes in the Thomas computer-generated condition and less at the eyes and mouth in the Human-computer generated condition compared to their peers with ASD without a CI in Thomas. It is possible that VIQ differences across the CI and non-CI sample account for differences in gaze, nevertheless the specific pattern of results is interesting. If VIQ served to fully explain gaze differences, unilaterally poorer gaze is expected. The tendency of CWA with a CI in Thomas to gaze less at his eyes is interesting in light of other gaze fixation studies that indicate CWA have a tendency to direct their gaze away from faces when likely CI stimuli are present (e.g., trains, airplanes) and not when unlikely CI stimuli are present in the scene (e.g., plants, furniture) (Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011; Sasson & Touchstone, 2014; et al., 2013). Thus, a CI in Thomas may have directed gaze away from emotionally relevant stimuli and towards the background in the scene (i.e., Thomas' body). If CI stimuli direct attention away from faces and emotional cues, then incorporating CI stimuli to teach emotional and social skills may be counterproductive.

A primary hypothesis in this study was that gaze for CWA would improve when complex characters were superimposed on a simpler field (i.e., gaze to the human and woody face would improve when placed on Thomas' body) and deteriorate when placed on more complex fields (i.e., appropriate gaze to Thomas' face would decrease when imposed onto the human body and woody's body). The opposite finding was supported; that is, CWA gazed *more* to the eyes and face in the standard Thomas condition and significantly less in the Thomas/Human and Thomas/Woody conditions. A similar effect was found for Woody, wherein CWA gazed more at Woody's face in the standard Woody condition as compared to the Woody/Human condition. Thus, these findings do not appear to support the systemizing theory of ASD. One possibility for this null finding relates to a few methodological issues. First, an a priori decision was made to present fused stimuli at the end of the study; thus all participants viewed standard Thomas, Woody, and Human conditions and then viewed the fused conditions. The rationale for this decision, and a potential second explanation for the null result, was that fused stimuli may appear particularly odd to many of the children whom were very familiar with these cartoons in their "natural" format. Thus, poorer gaze to fused conditions may be due to fatigue and lack of maintained attention towards the later portion of the experimental session. Second, given the admitted oddness and natural novelty inherent in the fused stimuli, it is perhaps expected that gaze would be diverted from the eyes and face of each character and onto the “new” body or background field. Finally, as demonstrated by Riby, Hancock, Jones, and Hanley (2013) appropriate gaze is dependent on instructions. In the present study, participants viewed an image, which disappeared before a forced choice question was presented asking the participant to label the previously viewed emotion. Participants had thus already viewed all the faces that were now imposed onto a new body for fused conditions, and thus, presumably, did not need to coordinate their gaze in the same manner. This finding also suggests that improved social processing may not immediately result from a reduction of social or visual complexity. Thus, the effect of interventions, such as *The Transporters*, which rely on a reduction of visual/social complexity may not be immediate.

Theory of Mind and Affect Recognition scores were expected to positively correlate with our measure of emotion recognition and appropriate gaze (gaze to the eyes, mouth, and face). TOM scores from the NEPSY-II were positively correlated with Total ER scores for both groups of participants, supporting prior results by Heerey et al. (2003) who also established a positive relationship between these two constructs. Notably, the distinction across these two constructs is somewhat questionable, especially given that several items on the NEPSY-II specifically relate to identifying the emotions of others. For example, items in the Contextual Task require the child to select a photograph from four options that depicts the appropriate affect a particular social situation. The direct assessment of facial affect in the TOM subtest of the NEPSY-II suggests that positive correlation between TOM and Total ER in this study should be interpreted cautiously. For CWA, TOM scores were positively associated with gaze to the mouth, but not eyes or face and for typically developing children, TOM was positively correlated with gaze to the eyes. The tendency of CWA to gaze disproportionately at the mouth when viewing faces is supported in several investigations (Dalton et al., 2005; Dalton et al., 2008; Klin et al., 2002; Neumann, Spezio, Piven, & Adolphs, 2006; Pelphrey et al., 2002). Thus, a general tendency to view faces in a particular fashion by CWA and typically developing children may explain divergent findings across groups with respect to this relationship.

The same relationship did not hold for the second predictor variable, Affect Recognition. AR scores were not correlated with ER scores or gaze. Affect Recognition from the NEPSY-II consists of several emotion recognition tasks: 1) the child simply states whether or not two photographs depict faces with the same affect 2) the child selects two photographs of faces with the same affect from three or four photographs 3) the child is shown a page with five faces and selects one of the four faces that depicts the same affect as a face at the top of the page 4) the child is briefly shown a face and, from memory, selects two photographs that depict the same affect as the face previously shown. As AR score was positively correlated with Total ER for the entire sample, the lack of a positive finding when groups were differentiated suggests a lack of power likely explains this null finding. Another possibility relates to differences in verbal ability required for the AR task and the ER task in the current experiment. The AR subtest includes a series of highly complicated instructions to be read by the examiner. For children who have poor verbal abilities and difficulty maintaining focus, the task is thus rather cumbersome. In contrast, the ER tasks in this experiment required very simple verbal abilities given that the same question was read aloud to participants (if necessary) at the end of each trial (i.e. “How does he feel?”). Despite a lack of significant differences in ER between groups, AR scores were almost twice as high for the typically developing group compared to the group of CWA. Thus the inclusion of more complicated emotion recognition tasks, verbal instructions, and higher memory load may have led to a differentiation in scores for AR, but not ER scores and the null correlation between the two measures.

Limitations and Future Directions

The findings of this study should be interpreted in light of several limitations. First, typical in most studies within the ASD literature, the sample of CWA in this study was both small and diverse. CWA ranged in verbal ability, intellectual ability, and level of ASD severity. Although such a diverse sample more accurately represents the ASD population at large, such variation complicates an interpretation of the findings. As an example, the present study did not attempt to assess for differences across high-functioning CWA (children with a VIQ > 70) and low-functioning CWA (children with a VIQ <70); although it is possible differences in ER and gaze exist within these two samples of children. Similarly, differences across ASD severity were not assessed, although it is possible that differences in ER and gaze exist among these populations of CWA. The inclusion of a wide age range of participants is also a potential limitation, as differences in emotion recognition across cohorts of age ranges was documented in a study by Rump et al. (2009).

A second limitation relates to matching of participants. Although statistically the sample of CWA were matched in VIQ to the sample of typically developing participants, the average VIQ of typically developing children was approximately 15 points higher than CWA. The range of VIQ for CWA was also much larger than the range of VIQ represented in the typically developing group. The practical significance of 15 VIQ points is rather large and may serve to account for some of the findings in this study. The practice of matching based on VIQ is also relatively unestablished; arguments to match based on NVIQ when examining ER and facial processing are also suggested (Harms et al. 2010). VIQ differences were also statistically significant across the sample of CWA with a CI in Thomas and CWA without a CI in Thomas, complicating interpretation of results from these analyses.

Third, this study included an examination of static stimuli only. Our findings suggest differences in ER for static stimuli are not present in CWA; however, an inclusion of dynamic human, Thomas, and woody stimuli is warranted given previous literature suggesting dynamic and static stimuli yield differences in ER and facial processing performance (Speer et al., 2007; Saitovitchetal et al., 2013). Similarly, our attempt to control static stimuli for emotional complexity (inclusion of simple emotions) and scene complexity (the presence of only one character) may account for the lack of significant findings in emotion recognition and gaze. As demonstrated by Speer et al. (2007) more drastic differences in ER and gaze appear to occur in dynamic scenes depicting socially complex scenes (i.e., more than one character) and across complex emotional stimuli (Capps et al.,, 1992; Garcia-Villamisar et al., 2010).

Other methodological issues include the use of total duration and count as opposed to the use of a proportional gaze measure. The eye-tracking literature within ASD has yet to establish norms with respect to gaze data; thus, best practice is unclear. In this study, a proportional measure may have yielded different results as the size of cartoon and human features ranged. This is particularly relevant for within group analyses, and less relevant for across group differences presented. Moreover, it is possible that statistical power in this study was low, given the small sample size and the limited range possible in ER scores (ER scores within sets ranged from 0-6 for computer-generated stimuli and 0-5 for naturalistic stimuli).

Attempts to correct for limitations inherent in the present study are currently underway. Recruitment of CWA, especially high-functioning participants has continued. Additionally, an examination of dynamic stimulus clips of naturalistic stimuli is in the process of being analyzed. The use of a larger, and potentially more cohesive sample may allow for a more extensive investigation of emotion recognition differences and gaze across both static and dynamic stimuli.

Future studies may also attempt to assess for gaze differences that occur following treatment of emotion-recognition deficiencies in CWA. The findings from *The Transporters* intervention are significant and suggest that after the term of 4 weeks, emotion recognition difficulties improve among CWA. These data may be strengthened by an assessment of eye-gaze measures pre- and post-intervention. The current study suggests the effect of "fused" stimuli is not immediate (ER differences across fused stimuli were nonexistent); however if emotion recognition improves following a course of 4 weeks of *The Transporters* treatment, it is possible that gaze patterns are improved as well. An analysis of this relationship may serve to provide further support that emotion recognition and gaze fixation patterns are related and to isolate the change agent of *The Transporters* intervention.

Only a handful of studies have attempted to analyze differences across gaze to cartoons and gaze to human stimuli among CWA. Given the frequent use of cartoon stimuli to teach emotion recognition skills and more basic social skills (e.g., appropriate eye contact) in interventions for this population, an increase in such studies is warranted. Especially as interventions targeted towards CWA begin to include cartoon, and perhaps more importantly, CI related stimuli, research should serve to establish the differences that may exist in processing among cartoons and human stimuli. Generalizability of cartoon interventions is unknown and the effects of garnering interest through the use of CI stimuli are unclear. This latter point is highlighted by research suggesting purported CI stimuli divert the attention of CWA *away* from faces (Sasson et al., 2011; Sasson & Touchstone, 2014; et al., 2013), making it imperative that future research establish guidelines with respect to CI related interventions targeting emotion recognition or facial processing.

Conclusion

In summary, the results of this study suggest the need to continue to examine emotion recognition and facial processing in stimuli that vary across the dimension of social realism and ecological validity. Our findings suggest deficient emotion recognition for human naturalistic scenes for CWA, but not for human computer-generated scenes and cartoon scenes. Significant facial processing differences also emerged across stimuli, with a tendency for typically developing children to gaze longer and for more fixations at the face and mouth of cartoon characters in both naturalistic and computer-generated conditions. Children with a circumscribed interest in Thomas tended to perform differentially when presented with Thomas stimuli in that they appeared to demonstrate an advantage in identifying the emotion of naturalistic Thomas scenes and demonstrated a distinct gaze fixation pattern compared to CWA without a CI in Thomas. Nevertheless, support for the systemizing theory was not found in the present study. The effect of removing complicated parts of characters and superimposing them onto Thomas' "body" did not immediately improve ER or facial processing abilities in CWA; thus, the effects of *The Transporters* intervention require continued investigation.

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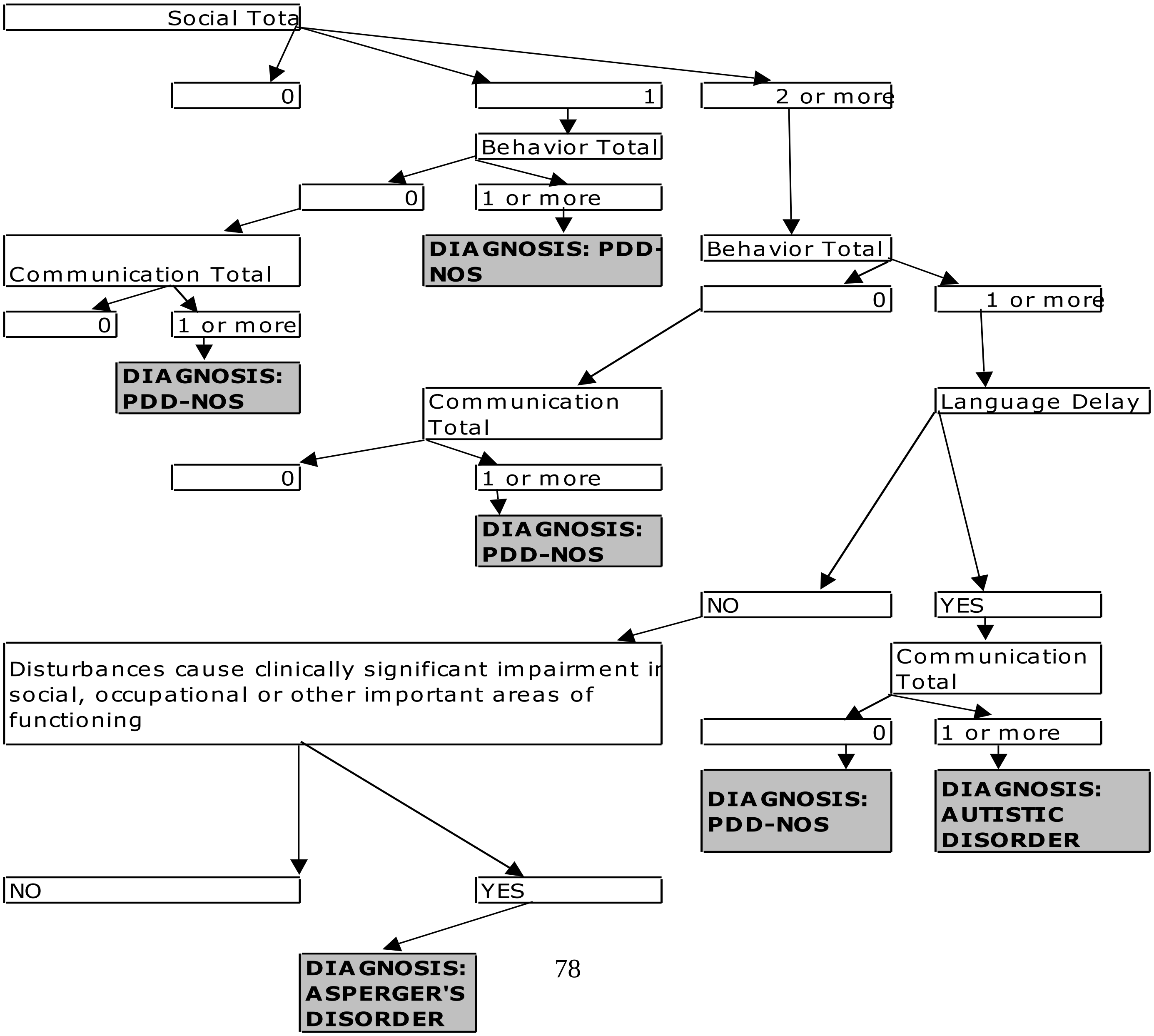
Appendices

Appendix 1

Diagnostic checklist

Child/Participant #:___________________ Rater:____________ Date:___________

Social Total	
Communication Tota	
Behavior Total	



DIAGNOSIS:_________________________

Table 1

Participant Characteristics (N=25)

	N	*Mean Age in Years (SD)*	*Age Range*	*Mean VIQ (SD)*	*VIQ Range*
Typically Developing	13	7.98 (1.83)	4 – 10.42	102.69 (18.01)	73-138
Autism Spectrum Disorders	12	7.54 (2.99)	4.67 – 11.83	85.00 (29.95)	53 - 136

Table 2

Gaze across Stimulus Type for Typically Developing Children and CWA

	Fixation Duration						**Fixation Count**					
	Computer		***Naturalistic***				***Computer***		***Naturalistic***			
	Thomas Face	Thomas Mouth	Thomas Face	Thomas Mouth	Woody Face	Woody Mouth	Thomas Face	Thomas Mouth	Thomas Face	Thomas Mouth	Woody Face	Woody Mouth
Typical Mean (SD)	1.16 (.53)	.15 (.14)	.93 (.45)	.14 (.12)	.78 (.38)	.13 (.11)	3.90 (1.71)	.46 (.43)	3.13 (1.38)	.40 (.30)	2.60 (1.22)	.32 (.24)
ASD Mean (SD)	.53 (.39)	.05 (.07)	.48 (.33)	.04 (.09)	.35 (.25)	.04 (.06)	1.91 (1.30)	.17 (.25)	1.98 (1.33)	.16 (.33)	1.36 (.88)	.14 (.21)
Z Statistic	-2.94	-2.13	-2.58	-2.58	-2.83	-2.27	-2.94	-2.74	-2.04	-2.47	-2.6	-1.98
P	<.01	<.05	<.05	<.05	<.01	<.05	<.05	<.01	<.05	<.05	<.01	*p* = .05
Cohen's D	-0.59	-0.43	-0.52	-0.52	-0.57	-0.45	-0.59	-0.55	-0.41	-0.49	-0.52	-0.40

Table 3

ASD Participant Characteristics

	N	*Mean Age in Years (SD)*	*Mean VIQ (SD)*	*Mean CARS (SD)*
Thomas CI	6	7.25 (3.16)	70 (30.00)	34.75 (5.75)
Other CI	6	7.83 (3.09)	100 (23.00)	30.08 (5.43)

Figure 1

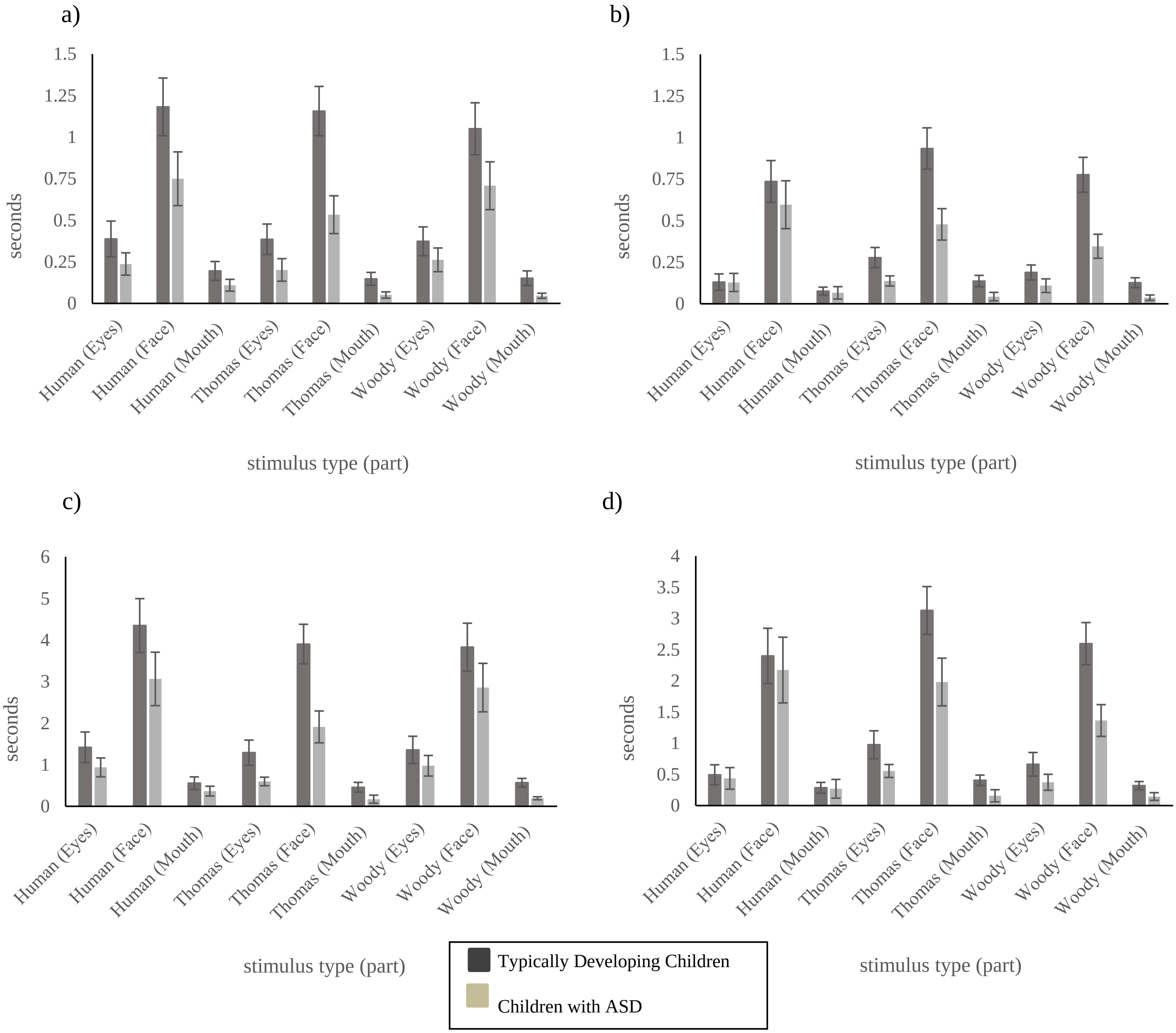


Figure 1. Gaze data for a) total fixation duration for computer stimuli b) total fixation duration for naturalistic stimuli c) total fixation count for computer stimuli b) total fixation count for naturalistic stimuli.

Figure 2

a) Naturalistic Stimuli

b) Computer-generated stimuli

c) Fused stimuli

Figure 2. Sample naturalistic, computer-generated, and fused stimuli