An Investigation of Attention to Social and Non-Social Stimuli in Autism Spectrum Disorder and Typical Development

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ABSTRACT

ANTOINETTE SABATINO: An Investigation of Attention to Social and Non-Social Stimuli in Autism Spectrum Disorder and Typical Development
(under the direction of J. Steven Reznick and Gabriel S. Dichter)

Autism Spectrum Disorder (ASD) is a pervasive, neurodevelopmental disorder that can be characterized by deficits in three symptom domains: significant impairments in language, social deficits, and restricted and repetitive behaviors. Narrowed interests, perseverative patterns of attention and reduced visual exploration have been conceptually linked to repetitive behaviors in ASD, specifically what are known as circumscribed interests (CI) within a narrow range of subject areas. Individuals with ASD that have CI partake in activities around their interest (collecting, manipulating, reading, playing, conversing, etc.) and these activities often lead to functional impairments. Eye-tracking research has investigated different responses to categories of images reflecting CI that capture attention during passive viewing tasks. Children and adults with ASD display an attentional bias towards certain categories of nonsocial images (e.g. train, automobiles, electronic devices, computers). This bias has been conceptualized to reflect an increased salience of nonsocial images relative to social images (e.g. faces) or other, more commonplace, nonsocial information (e.g. furniture, clothing, dishes). This dissertation aimed to extend these findings regarding atypical patterns of attention to social and nonsocial information in children with ASD by investigating reflexive attention and cognitive control over attention of images related to CI, skills essential for behavioral and brain development in children with ASD. Analyses included group comparisons across children with ASD and typically developing controls. Children with ASD demonstrated a visual preference for non-social objects relative to social information during a passive viewing attention task. During a visual saccade task, though children with ASD did demonstrate an increased rate of directional errors, task performance did not differ across social and non-social targets. Eye-tracking measures were found to be significantly related to symptom measures of social-communication impairments and restricted and repetitive behaviors in ASD. Exploratory comparisons across children with ASD and a pediatric OCD sample, another development disorder characterized by repetitive behaviors, are also discussed. This study provides support for the use of visual attention and oculomotor behavior to quantify impairments in ASD as well as discrete aspects of the repetitive behavior phenotype.

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GENERAL INTRODUCTION

Though not one of the core diagnostic features of Autism Spectrum Disorder (ASD), aberrant patterns of attention are frequently observed in individuals with ASD. Early investigations of children with ASD reported atypical gaze patterns. Children with ASD were frequently described as making fewer back and forth eye movements and having difficulty orienting towards and focusing on information in their visual environment (Rincover & Ducharne, 1987). Children with ASD were described as having "tunnel vision" and being overly focused in visual discrimination tasks, narrowing in and focusing on specific aspects of their environment while seemingly blocking out others (Rincover & Ducharne, 1987; Lovaas & Schreibman, 1971). Aberrant social attentional processes are one of the earliest possible identifiable features of ASD and frequently distinguish children with the disorder from typically developing children. Although there are obvious impairments seen within the social domain early in development into adulthood in ASD, other impairments suggest a more domain-general impairment in visual attention (Landry & Bryson, 2004; Allen & Courchesne, 2001; Zwaigenbaum et al., 2005; Townsend et al., 2001). Basic deficits in attention skills such as orienting, disengaging, shifting, and controlling attention may create a developmental cascade resulting in abnormal social attention processes that have become characteristic in ASD.

It is widely accepted that individuals with ASD frequently display atypical patterns of attention towards social information like faces and social scenes (Pelphrey et al., 2002; Dawson et al., 1998; Sasson et al., 2007). Marked impairments in processing social information may be most characteristic of ASD (Dawson et al., 1998); however, irregularities have consistently been reported when social and non-social information are presented jointly (Klin et al., 2002; Sasson et al., 2008). Current research indicates that individuals with ASD disproportionately attend to non-social information (Klin et al., 2004; Sasson et al., 2008). Not only are individuals with ASD viewing social information in an atypical manner, but they are also attending to these classes of stimuli significantly less than other non-social information. These patterns of attention have been hypothesized as being due to the increased saliency of non-social information. Important questions have arisen such as (1) what are the potential reasons attention is captured by non-social information, (2) are there specific classes of non-social information that may be driving such patterns of attention, and (3) what are the implications of having attention disproportionately and narrowly allocated to segments of the environment (Jones & Klin, 2008)? Human attention is limited in capacity, and social and non-social information compete for processing resources. Due to these restrictions, more salient information likely captures attention over less salient information.

The studies described in this dissertation will replicate and extend previous research regarding aberrant patterns of attention. The overall aim is to use passive viewing attention tasks and tasks requiring cognitive control in conjunction with eye-tracking technology to identify effects of social and non-social stimuli on visual attention in ASD. The specific aims are to 1) describe and quantify patterns of attention in children with ASD in comparison to age-matched controls, 2) display how non-social information related to circumscribed interests can influence the cognitive control over attention in ASD, and 3) address questions regarding what makes non-social information more salient for individuals with ASD. Experiment 1 addresses questions regarding disproportionate patterns of reflexive attention in response to social and non-social information in ASD. Experiment 2 focuses on the volitional control over attention in response to social and non-social information in ASD. To thoroughly address their separate research and discuss their analysis and results, these experiments are described separately from one another.

In order to investigate unique patterns of attention within ASD, a small amount of data from a clinical control group with a similar behavioral phenotype was collected and exploratory analyses were carried out. Across both experiments, eye-tracking data was collected on a small sample of children with pediatric obsessive compulsive disorder (OCD). Patients with OCD have often been reported as having a similar behavioral phenotype to that of ASD, displaying increased impairments in selective attention tasks and visual search paradigms (Rosenburg et al., 1997; Maruff et al., 1999; Kaplan et al., 2006).

EXPERIMENT 1: PATTERNS OF ATTENTION IN RESPONSE TO COMPETING SOCIAL AND NON-SOCIAL STIMULI (PAIRED SOCIAL VS OBJECT TASK)

Marked impairments in prioritizing social information is a primary characteristic of ASD (Dawson et al., 1998). Early indicators of ASD include social disinterest, absence of pointing and/or responding to bids for joint attention, reduced eye contact, and failure to orient to one's own name (Maestro et al., 2005; Osterling et al., 2002). In comparison to typically developing controls, a number of experiments report that children and adults with ASD spend less time looking at the eye region of the face (Chawarska & Shic, 2009; Klin, Sparrow, de Bilt, Cicchetti, D, & Volkmar, 1999). Other studies have indicated that differences in ASD are also present in response to other socially relevant visual stimuli, such as those portraying biological motion or tasks requiring processing of emotional expression (Klin & Jones, 2008; Rump, Giovanelli, Minshew, & Strauss, 2009).

From early on in development, typically developing infants are more attracted to social-like stimuli rather than other stimuli equated on lower-level properties (i.e., scrambled or inverted faces) (Johnson et al., 1991; Turati et al., 2002). This pattern continues throughout development and, in adults, social preference has been shown to be a strong predictor of attention orienting. In a study with typically developing adults, participants viewing two scenes presented side by side- one with a person present and the other without- attended more to the scene with the person present than without, and while viewing that scene, spent significantly more time looking at the person (Fletcher-Watson et al., 2008). Not only is attention naturally drawn to social stimuli, but also the salience of social information appears to be superior to that of non-social information in typical development. Experimental evidence, from studies utilizing variations on change detection tasks with social stimuli (i.e., faces) and non-social objects, suggests that typical adults are more accurate at identifying changes in the identity of faces as well as discriminating unfamiliar faces that resemble one another than performing the same task with non-social objects (Kikuchi et al., 2009; Bruce et al., 1991).

In contrast to typical development, this prioritization of social information is reduced in ASD leading to anomalous patterns of attention and eye gaze (Senju and Johnson, 2009) and negative consequences for the development of social cognition (Chevallier et al., 2012). Dawson et al. (1998) compared the ability to shift attention towards social stimuli (e.g., name calling, hands clapping) versus non-social stimuli (e.g., rattle, jack-in-the-box) in children with ASD, typically developing children, and children with Down syndrome. When compared to control and developmental delay groups, children with ASD failed to orient to a social stimulus. Instances of social aloofness, absence of pointing and responding to joint attention bids, reduced eye contact, and failure to orient towards a social stimulus are currently considered early indicators of ASD (Maestro et al., 2005; Osterling et al, 2002) because they mimic core symptoms such as lack of spontaneously seeking to share enjoyment or interests, lack of social and emotional reciprocity, and marked impairments in the use of non-verbal behaviors (i.e., eye-to-eye gaze)(APA 1994; Lord et al., 2000).

Diminished and anomalous attention to social information has been repeatedly reported in both children and adults with ASD (Jones and Klin, 2008; Klin et al., 2004; Chawarska et al., 2012); however, reports are not consistent. Klin and colleagues (2002) reported increased fixation on the mouth region of the face in adolescents and adults with ASD. These findings were not reproduced in studies including children with younger participants (Van der Geest et al., 2002; von Hofsten et al., 2009) suggesting that gaze behaviors may change with development. Other studies have indicated that although both children and adults with ASD avert their gaze from faces earlier than control groups, both typically developing children and those with ASD display a particular preference for the mouth rather than eyes during speech, but this preference is reversed within typical development over time (Nakano et al., 2010). Other research suggests that the context in which social information is presented and the inclusion of dyadic cues may be important driving factors for limited social attention in ASD. In a study of attention to social scenes in toddlers with and without ASD, children were shown naturalistic social scenes including and devoid of social information (e.g., eye contact and speech) (Chawarska et al., 2012). When social information was absent, the distribution of attention was comparable to that of typically developing and developmentally delayed children. However, when explicit social cues were introduced, children with ASD spent less time looking at faces and monitoring lip movements during speech than the other control groups. Despite inconsistencies in results, taken together these findings further support the widely accepted view that social information in ASD is not granted the same a priori weight as in typical development in the competition for attentional resources. In other words, ASD appears to involve an overall decreased deliberate interest in social information (Chevallier et al., 2012).

Several hypotheses and/or models have been proposed as to why these aberrant patterns of attention are observed. Experimental evidence reporting domain general impairments in attention in ASD (i.e., impairments in attention not specific to social information) suggest that due to general, impaired abilities, children and adults with ASD have difficulty processing and representing social information (Landry and Bryson, 2004). Other theories have discussed attention in relation to task demands, cognitive load, and available attentional resources (Dawson, 1991; Courchesne, Chisum, and Townsend, 1995). Social stimuli are complex, variable, and unpredictable. Social exchanges require rapid shifting of attention and high level of skill at selective attention. Therefore, processing social information requires a large amount of attentional resources that are not functioning efficiently or being allocated correctly. Children and adults with ASD are not drawn towards social information due to their processing demands (Dawson, Meltzoff, & Osterling, 1998). However, irregularities have consistently been reported when social and non-social information are presented concurrently. Klin et al. (2002) compared attention towards social and non-social information and found that the ASD group attended significantly more to non-social elements (i.e., objects) and non-critical social elements (i.e., mouths, hairlines, or bodyparts vs. eyes) than did control participants. These findings support a model that ASD is characterized by not only decreased visual attention to social stimuli but also increased visual attention to non-social stimuli (Klin, Jones, Schultz, Volkmar, & Cohen, 2002).

Measures of attention, specifically passive visual exploration, provides a means for quantifying degrees of impairment related to the presence of circumscribed or narrowed interests, a sub-domain of restricted and repetitive behaviors in ASD (Pierce and Courchesne, 2001; Sasson et al, 2008). Attention to social stimuli may be moderated by the presence of non-social stimuli related to circumscribed interests. Sasson et al., (2008; 2011) investigated visual attention in children and adults with and without ASD to arrays containing both social stimuli (i.e., people) and non-social stimuli. Non-social stimuli were divided into two categories: those related to circumscribed interest in ASD (e.g. trains, automobiles, electronic devices) (South, Ozonoff, S, & McMahon, 2005) and other items such as plants, food, furniture, and clothing. Individuals with ASD disproportionately explored and fixated longer on objects commonly associated with circumscribed interests. Social attention was reduced specifically in the context of only objects related to circumscribed interests.

Standard preferential looking paradigms have shed light on differences between individuals with ASD and comparison groups and have even become indicators of risk for an eventual diagnosis of ASD in infants and toddlers. With a standard, passive, preferential looking paradigm, individuals are given a simple choice between two images. In addition to observing what an individual is immediately “drawn to” from a stimulus pair, by including social and non-social information, clearly observable differences regarding the effects of competing stimulus categories on attention can be distinguished. When presented inverted and upright point light displays portraying biological motion, toddlers with ASD displayed significantly reduced preference for salient human biological motion (Klin et al., 2002). Pierce and colleagues (2011) utilized a preferential looking paradigm in toddlers with and without ASD; however, more directly addressed social versus non-social competition. Pairs of video presentations were shown side by side, displaying moving geometric patterns and children in high action (e.g., dancing, yoga, running). Toddlers with ASD spent significantly more time fixating on dynamic geometric regions than typically developing and developmentally delayed children. If a toddler spent more than 69% of his or her time fixating on the geometric patterns over the course of the entire experiment, the positive predictive value for accurately classifying that toddler as having an ASD reached 100% (Pierce et al., 2011). Atypical patterns of attention to competing social and non-social stimuli in adolescents and adults with ASD suggest these abnormalities may remain consistent across development. Attention continues to be disproportionately allocated to non-social images when they are concurrently displayed with social images (i.e., faces) (Sabatino et al., 2012). A pattern of increased focus on objects supports a model of decreased salience of social information. Decreased saliency likely explains the atypical and inefficient processing of social information (Klin et al., 1999; Pelphrey et al., 2002) as well as the inability to interpret emotional states and social situations (Rump et al., 2009) and a lack of directed attention towards faces (Dichter et al., 2010).

Several studies have explored and interpreted findings as examples of distinct alterations in visual salience in ASD. Rather than experiencing heightened saliency and perceptual strength for social information as is seen in typical development, attention is directed elsewhere in ASD and alternate sets of expertise are developed. These narrowed areas of interest in which the individual becomes “expert” in are frequently non-social in nature and become increasingly salient (i.e., special or “circumscribed” interests or even savant skills) (Jones and Klin, 2008; Hermelin, 2001; Thioux et al., 2006). Few studies have investigated the direct effects of highly salient non-social images competing for attentional resources with social stimuli. A previous study from our group (Dichter et al., 2010) investigated visual attention to simultaneously presented social and non-social stimuli related to circumscribed interests in adults with and without ASD. Results indicated that the ASD group attended disproportionately to non-social stimuli related to circumscribed interests relative to social stimuli in comparison to the control group (see Figure 1).

The present study was designed to extend this line of research to examine visual attention in ASD using a preferential looking paradigm that simultaneously presented social stimuli and non-social stimuli- faces, objects related to circumscribed interests, and other everyday objects not related to circumscribed interests. Although the complex array paradigm used in Sasson et al (2008, 2011) recapitulates the complexity of real-world visual scenes by including multiple stimuli, the presentation of only two stimuli simultaneously in the paired preference paradigm decreased perceptual load associated with the task. Given that perceptual load moderates selective attention and visual selection in ASD (Remington et al, 2009; Remington et al, 2012), this parameter is an important consideration in studies of visual attention in ASD. Previous studies of attention in ASD have primarily compared individuals with autism to typically developing control individuals or those with other developmental disorders (i.e., developmental delay) (Chawarska et al., 2012; Mitchell et al., 2011). Patients with obsessive compulsive disorder (OCD) have often been reported as having difficulty completing selective attention tasks and visual search paradigms (Rosenburg et al., 1997; Maruff et al., 1999; Kaplan et al., 2006); however, the extent for dysfunctional basic attention abilities is still unclear (see also Kuelz et al., 2004). Aside from primary analyses that compared ASD to typical developing, the current study also compared children with ASD to those with OCD, another neurodevelopmental disorder that is characterized by restricted and repetitive behaviors and aberrant patterns of attention, to specifically characterize the impact of circumscribed interests on the allocation of attention in ASD.

Based on previous research (Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008; Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pierce & Courchesne, 2001), it was hypothesized that the ASD group would be characterized by relatively greater visual attention to the nonsocial than social stimuli, specifically those non-social stimuli related to circumscribed interests. Sasson et al. (2008; 2011) reported children with ASD view stimuli in a detail-oriented manner as indicated by the number of discrete fixations on an image. Due to these findings, it is also hypothesized that children with ASD will display a more detail-oriented visual style when looking towards non-social images rather than social images. Also, results from research regarding the prioritization of attention in passive viewing paradigms have been inconsistent (i.e., looking first at faces over objects and vice versa) (van der Geest et al., 2002; Dalton et al., 2005; see also Freeth et al., 2011). The current study will investigate the location of first fixation, face or object, across groups. Finally, exploratory analyses will investigate the extent to which patterns of visual attention in the ASD sample would predict the magnitude of symptoms in the ASD sample.

METHODS

Participants

Participants included three groups of children (9-18 years): 39 children with ASD (17 were identified as having autism; whereas, the remainder reached criteria for a spectrum disorder), 13 children with Obsessive Compulsive Disorder (OCD), and 20 typically developing children (TYP). 2 children with autism were excluded due to receiving a diagnosis of lower functioning autism (LFA)

(Composite IQ < 70) (Kaufman and Kaufman, 1990); 4 participants from the TYP group, 5 participants from the OCD group, and 14 additional participants with ASD were excluded due to reduced data acquisition during the eye-tracking task. Final sample size and demographic information on each group are reported in Table 1. Groups were matched on age, socioeconomic status (SES), and gender distribution. The ASD group was recruited through the UNC Autism Research Registry. The Autism Registry is a tool for subject recruitment available to UNC researchers through the NICHD-funded Intellectual and Developmental Disabilities Research Center at the Carolina Institute for Developmental Disabilities (CIDD). Autism spectrum diagnoses were based on a history of clinical diagnosis informed by scores on the Autism Diagnostic Observation Schedule (ADOS-G) (Lord, et al., 2000) administered by a research reliable assessor and using standard cutoffs. Children with OCD were recruited with the help of the Program in Child Affective and Anxiety Disorders (PCAAD; Director: co-I John March, PhD) with multiple and varied methods, including providing information to psychology and psychiatry clinics, pediatricians, schools, and other professional and community settings (e.g., health fairs, parent groups). Typically developing children and adolescents were recruited via mass emails sent through the UNC-CH listserv. Inclusion/exclusion criteria are listed below. All participants consented to protocols approved by the Human Investigations Committees at UNC-Chapel Hill.

Inclusion / exclusion criteria

Children with ASD met the following criteria:

1) Clinical diagnoses of autism;
2) Between the ages of 9-18 years, inclusive;
3) No known genetic/medical conditions;
4) No known sensory deficits (e.g., not blind or deaf);
5) Ambulatory status;
6) No comorbid diagnosis of psychosis, bipolar disorder, or OCD;

7) No nonverbal learning disability (NVLD); IQ above 80 and no MRI contraindications.

Children with Obsessive Compulsive Disorder (OCD) met the following criteria:

1) Primary diagnosis of OCD;
2) Between the ages of 9-18 years, inclusive;
3) No known genetic/medical conditions;
4) No mental retardation;
5) No known sensory deficits (e.g., not blind or deaf);
6) Ambulatory status;
7) No comorbid diagnosis of psychosis, bipolar disorder, or any PDD.

Children with neurotypical development met the following criteria:

1) Between 9-18 years of age, inclusive;
2) No known genetic/medical conditions;
3) No mental retardation;
4) No known sensory deficits (e.g., not blind or deaf);
5) Ambulatory status;
6) No significant features of any PDD or OCD;
7) Lifetime-free of Axis I psychiatric and neurological disorders;
8) No family history of psychosis, bipolar disorder, PDD, and OCD;
9) No psychotropic medication use;
10) The older TYP subgroup will have no MRI contraindications.

Symptom Measures

Parents or legal guardians of children in all three groups completed parent-report versions of (a) The Repetitive Behavior Scale-Revised (RBS-R) (Bodfish, Symons, Parker, & Lewis, 2000) and (b) the Social Reciprocity Scale (SRS-SR) (Constantino & Gruber, 2002), in addition to standardized measures of intelligence taken via the Kaufman Brief Intelligence Test (K-BIT) (Kaufman and Kaufman, 1990) and, within the autism group, diagnostic measures via the ADOS-G (Lord et al., 2000). Participant characteristics are reported in Table 1.

Task & Stimuli

Eyetracking was measured during a passive viewing, paired preference visual task (see Figure 2). Stimuli were pairs of social and non-social stimuli, either related to circumscribed interests or other everyday objects not related to circumscribed interests, presented simultaneously (one on the left of center and one on the right of center; see Figure 2). Twenty stimuli (each containing one social and one nonsocial stimulus) were presented to each participant, and each stimulus was presented for 5 seconds with a 1.5-3.5 inter-stimulus interval. Ten social stimuli were presented with a stimulus related to circumscribed interests, while ten social stimuli were presented with everyday objects not related to circumscribed interests. Images were approximately 4.5 x 3.5 inches. Whether social or nonsocial stimuli were presented on the left or right was counterbalanced across trials. Subjects sat approximately 50-60 cm from a 23.5 in display and viewed stimuli subtending a visual angle of approximately 6^{o}, left and right of center. Participants were instructed to remain attentive to the display for the duration of each stimulus presentation.

Social stimuli were pictures of mildly pleasant faces (with equal numbers of male and female faces), from the NimStim set of facial expressions (Tottenham, et al., 2009). The non-social images were systematically derived by our research group in the following manner (see Sasson et al, 2012 for a fuller description). First, a large number of potential nonsocial images was selected based on response profiles from semi-structured parent-report interviews about circumscribed interests in ASDs (e.g., machines, mechanical systems, trains and electronic devices) (South, Ozonoff, S, & McMahon, 2005; Turner-Brown, Lam, Holtzclaw, Dichter, & Bodfish, 2011). Next, the visual salience of these images was evaluated via passive-viewing visual exploration eye-tracking studies of children and adults with and without ASDs (Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011; Sasson et al., 2008). These eye-tracking studies identified 40 images without social content that garnered relatively greater visual attention (i.e., the number of fixations and duration of fixations) in ASD samples. These images are conceptually linked to circumscribed interests in ASD and thought to be of higher interest to individuals with ASD based on these results; therefore, these images are labeled as “High ASD Interest” images (HAI). Finally, 56 adults with self-identified ASDs provided significantly higher valence ratings of these nonsocial images relative to 213 adults without ASD, while the groups did not differ in their valence ratings of other everyday objects not associated with circumscribed interests (Sasson et al., 2012). These images are labeled as “Lower ASD Interest” images (LAI). HAI object categories included: trains, tractors, cars, planes, electronics, road signs, and blocks/block designs. These HAI and LAI nonsocial images were used in the present study and are depicted in the Appendix of Dichter et al (2012).

Eye-tracking Analysis

Eye-movement data were recorded with a Tobii X120 eye-tracker (Tobii Technology, Stockholm, Sweden). The system is a stand-alone eye-tracking unit that monitors movement of the participant’s pupil at 50 Hz by using infrared light to produce reflection patterns on the corneas and then monitors the movements of these reflections relative to eye position. Eye movement patterns were analyzed by conducting fixation analyses. A single fixation was defined as remaining within a radius of 30 pixels for a minimum of 10 msec.

There were three areas of interest (AOIs) within each stimulus: face, object, and exterior (defined as gaze on the screen but not on either stimulus). One trial from the task was discarded for due to technical error during data collection that resulted in lack of data collection for that trial across all three groups. Areas of interest were defined as the smallest possible rectangle needed to outline each stimulus. The primary dependent variables of interest were (1) the gaze time to face and object AOIs, (2) the latency to first fixate on the face, and (3) the number of discrete fixations made within each AOI in each stimulus pair. As stated previously, 4 participants from the TYP group, 5 participants from the OCD group, and 14 additional participants with ASD were excluded due to reduced data acquisition during the eye-tracking task defined by <50 seconds of recorded eye-tracking data.

RESULTS

Gaze Time Analyses

Between groups t-tests indicated that groups did not differ significantly in total gaze time summed across the task. Gaze time to faces and objects was extracted for each participant for each stimulus type: faces (when paired with an HAI image) and HAI objects, faces (when paired with an LAI image) and LAI objects. A ratio of gaze time for each type of stimulus pair was then created (e.g., gaze time to faces: gaze time to HAI objects; gaze time to faces: gaze time to LAI objects) for each participant and, finally, compared across groups. See Figure 3. Results addressing the primary aims of the study (i.e., comparisons between ASD and typical development) are reported first. Between groups t-tests of Face:HAI ratios indicated a significant decrease in looking time to faces in the ASD group when faces were presented concurrently with HAI objects relative to the control group, $t(38)=3.90$, $p<.0004$. Between groups t-tests of Face:LAI ratios also indicated a significant decrease in looking time to faces in the ASD group when faces were presented concurrently with LAI objects relative to the control group, $t(38)=2.26$, $p<.02$. Between groups t-tests of Face:HAI ratios indicated a significant decrease in looking time to faces in the ASD when faces were presented concurrently with the HAI objects relative to the OCD group, $t(30)= -2.14$, $p<0.04$. There were no significant differences in gaze time proportions between the control and OCD groups. Follow-up within groups analyses of gaze time indicated that looking time to faces increased across all groups when faces were paired with LAI objects, $p<.01$. See Figure 4.

First Fixation Analyses

The average time to first fixate on faces and objects was analyzed between groups. In other words, this was a metric of the amount of time it took each participant to make their first fixation to faces and their first fixation to objects. Between-groups t-tests indicated that groups did not differ significantly in average time to make a first fixation to faces, $p<.30$. However, the ASD group did look faster towards objects (M= 0.81 sec; SD= 0.38) relative to typical controls (M=1.18 sec, SD= 0.55), $t(38)=2.54$, $p<.01$. Difference in time to make a first fixation to objects between the ASD and OCD groups (M=1.07, SD= 0.59) approached significance, $t(30)= -1.46$, $p<.15$. There were no significant differences in time to first fixate on objects between the typical control and OCD groups. See Figure 5.

Discrete Fixation (Individual Fixation Count) Analyses

The total number of discrete fixations on faces and objects was analyzed between groups. This metric represented the number of individual fixations made within an AOI. Between-groups t-tests indicated that ASD and typical control groups did not differ significantly in number of discrete fixations when looking at faces, $t(38)= -0.16$, $p<.80$. However, the ASD group did display a reduced number of discrete fixations when looking at faces (M=170.9, SD=108.2) relative to the OCD group (M= 332.5, SD= 337.7), $t(30)= -2.10$, $p<.04$. Between-group analyses of discrete fixations to faces between OCD and typical control groups approached significance, $t(22)= -1.94$, $p<.06$. Analyses of discrete fixations to objects, indicated that the typical control group displayed a reduced number of discrete fixations to objects (M= 159.4, SD= 47.87) relative to both the HFA group (M= 273.9, SD= 113.6), $t(38)=-3.80$, $p<.0005$, and the OCD group (M=383.5, SD= 462.2), $t(22)=-2.12$, $p<.04$. Within group analyses of number of discrete fixations indicated that only the ASD group differed on the number of fixations to faces and objects, $t(23)=-3.86$, $p<.0008$. See Figure 6.

Symptom Measures

Correlations between eye-tracking measures and the SRS-SR (total score and five subscales), the RBS-R (total score and six subscales), and the ADOS (three subscales) were evaluated within the ASD group. Within the ASD group, the amount of time to make an initial fixation to faces was positively correlated with both the number of items endorsed (r = 0.63, p<.0008) and the score on the self-injurious subscale (r = 0.68, p<.0002). It was also correlated with the number of items endorsed (r = 0.43, p<.03) and the score on the ritualistic behavior subscale (r = 0.44, *p*<.02) of the RBS-R.

Within the ASD group, the number of discrete fixations while looking at objects was positively correlated with scores on the social communication (r = 0.47, *p*<.02) and social motivation (r = 0.56, *p*<.004) subscales of the SRS-SR in addition to the total raw score (r = 0.57, *p*<.003). Correlations between the number of discrete fixations and the score on the autistic mannerisms subscale of the SRS-SR approached significance (r = 0.40, *p*<.055). Number of discrete fixations while looking at objects was also positive correlated with both the number of items endorsed (r = 0.61, *p*<.001) and the score on the self-injurious subscale (r = 0.63, *p*<.0009), the number of items endorsed (r = 0.56, *p*<.004) and the score on the compulsive behavior subscale (r = 0.51, *p*<.01), the number of items endorsed (r = 0.78, *p*<.0001) and the score on the ritualistic behavior subscale (r = 0.72, *p*<.0001), and the number of items endorsed (r = 0.61, *p*<.0001) and the score on the sameness behavior subscale (r = 0.50, *p*<.01) on the RBS-R in addition to total items endorsed (r = 0.70, *p*<.0002) and total score (r = 0.63, *p*<.001). No other correlations were significant. See Figure 7.

DISCUSSION

Individuals with ASD disproportionately explore and perseverate their attention on objects commonly associated with circumscribed interests (Sasson et al., 2008; 2010). The aim of the present study was to investigate visual attention while children and adolescents with and without ASD viewed pairs of concurrently displayed social and non-social stimuli. Non-social stimuli included either (a) common, everyday object images or (b) object images related to circumscribed interests known to be salient and rewarding to individuals with ASDs (Sasson et al, 2012; Dichter et al., 2012). It was hypothesized that children with ASD would preferentially look at non-social objects, specifically those related to circumscribed interests, over concurrently present social images more than control participants and those with OCD, another neurodevelopmental disorder characterized by patterns of restricted and repetitive behaviors.

Analysis of gaze time indicated an overall significant reduction in looking time to faces relative to object stimuli in the ASD group in comparison to both control and OCD groups. However, specific classes of non-social information (i.e., those images related to circumscribed interests and those everyday, common images) did not produce differential effects on attention across all groups. When faces were presented concurrently with non-social objects related to circumscribed interests (Face:HAI), the proportion of gaze time to faces in the ASD group was significantly less than the typical control and the OCD group. However, when faces were presented with everyday non-social objects (Face:LAI); the ASD group differed significantly from the control group while the two clinical groups displayed no significant differences in proportion of gaze time. Although images related to circumscribed interests paired with faces disproportionately captured attention away from social stimuli and differentiated the ASD group from both typical control and clinical control groups, attention patterns in the ASD group continued to differ from the typical controls when faces were paired with other everyday non-social items. A pattern of relatively increased visual attention on objects supports models of increased salience of nonsocial information specific to ASD in addition to an overall decreased salience of social information. Decreased salience of social information likely contributes to the atypical and inefficient processing of social information, lack of directed attention towards faces (Klin, Sparrow, de Bilt, Cicchetti, D, & Volkmar, 1999; Sasson, et al., 2007) as well as the inability to interpret social situations (Rump, Giovanelli, Minshew, & Strauss, 2009).

Further analyses of latency to first look at faces and objects indicated that the ASD group was quicker to look at objects than both the control and OCD groups, though these results were not statistically significant and only represent trend level effects. In addition, not only were children and adolescents with ASD looking more quickly and more often to object stimuli, results pertaining to discrete fixations indicated they were also doing so with greater detail. Increased detail orientation may support mechanisms of reduced visual exploration and impairments in visual disengagement consistently reported in other studies of attention in ASD (Courchesne et al., 1994; Landry and Bryson, 2004; Zwaigenbaum et al., 2005; Sasson et al., 2008; 2011).

Over-focused, detail-oriented styles of attention may be unique and distinctive to ASD in comparison to other developmental disorders characterized by under-focused attention, such as ADHD, or those characterized by perseverative and repetitive behavior patterns, such as OCD. Few studies to date have investigated unique patterns of attention across ASD and OCD. Research in OCD has indicated that behavioral phenotypes appear similar across the two disorders (i.e., perseverative thoughts and deficits in inhibitory control); however, increased detail-orientation and overall increased attention to objects has not been reported in OCD. Studies investigating interrelations between autism spectrum disorders and OCD (Cath et al., 2008; Anholt et al., 2009) have reported associations between OCD symptom severity and impairments in social processing and attention switching quantified by an autism symptom measure (Autism Spectrum Quotient, AQ; Baron-Cohen et al., 2001). Taken into consideration with the current preliminary findings, disproportionate and detail-oriented attention to non-social information relevant to circumscribed interests may reflect a behavioral phenotype specific to ASD in comparison to another neurodevelopmental disorder characterized by restricted and repetitive behaviors. These findings suggest that it is necessary for future research to further address patterns of attention in ASD relative to other developmental disorders with overlapping behavioral and cognitive phenotypes, such as OCD.

These results are also consistent with previous research that has utilized comparable measures of preference and has found that children and adults are “drawn to” non-social elements (Pierce, Conant, Hazin, Stoner, & Desmond, 2011; Klin & Jones, 2008). For example, Klin and Jones (2008) reported reduced preference for up-right versus inverted biological motion displays in two-year olds with ASD. Children with ASD looked less often at up-right point light displays and more often at inverted displays than both developmentally delayed and typically developing children. Additional reports of atypical patterns of attention in adolescents and adults with ASD to concurrent social and non-social stimuli consistent with the current findings suggest these abnormalities may remain consistent across development (Rice, 2012; Freeth, Chapman, Ropar, & Mitchell, 2010; Fletcher-Watson, Leekam, Findlay, & Stanton, 2008; Elison, Sasson, Turner-Brown, Dichter, & Bodfish, 2012).

Significant relations between ASD symptoms and distinct patterns of attention to object images were also reported within the ASD group. Increased detail-orientation to object images was positively correlated with several subscales and total scores on both the SRS-SR (Constantino & Gruber, 2002) and the RBS-R (Bodfish, Symons, Parker, & Lewis, 2000), particularly those involving social communication and motivation impairments and severity of ritualistic and sameness behaviors. This replicates and extends previous reports of associations between repetitive behavior symptom severity and, in ASD, more attention to non-social information (Sasson et al., 2008). These relations are not surprising within ASD. Greater attention to, and interest in, non-social as opposed to social information is an archetypal pattern of behavior and attention in individuals with ASD (Sasson et al., 2008; 2011; Pierce and Courchesne, 2001; Klin et al., 2002; Jones and Klin, 2008; Chawarska et al., 2012). Measures of global repetitive behavior severity and impairment in social communication may serve as an index of a tendency of individuals with ASD to engage less with the social environment and more with non-social information or objects. This is apparent in those types of repetitive behaviors such as circumscribed interests and those involving the preoccupation with and repetitive use of objects. Finally, the positive correlations between the latency to initially attend to faces and score on the self-injurious subscale of the RBS-R supports previous research regarding the significant relationships between rate of self-injury and social skill impairment and symptoms of social withdraw in children and adolescents with ASD (Waters and Healey, 2012).

Limitations of the present study should be addressed in future research. First, all participants viewed the same set of object images, whereas circumscribed interests in ASD are idiosyncratic and person-specific. In this regard, object images in the current task were not used as a proxy for person-specific interests but rather as a ‘press’ to investigate differences in visual attention to social and salient non-social images across groups. The use of these standardized object images is likely a conservative estimate of patterns of reflexive visual attention to person-specific interests, but future research with person-specific, age-appropriate images will be necessary to address this.

Previous research has outlined the moderating effects of lower level visual properties (e.g., luminance, contrast) on patterns of attention (Tseng, Cameron, Pari, Reynolds, Munoz, & Itti, 2012). Studies that control for these visual properties or more thoroughly investigate their effects may provide further evidence for the moderating effects of stimulus category on the allocation of attention. The passive viewing, reflexive attention task used in the current study design is unable to precisely determine the degree to which circumscribed interests in ASD are impacting cognitive control over attention. More research is needed to determine whether disproportionate patterns of attention to social and non-social information also affect volitional control over attention in ASD. Despite these limitations, the present study extends previous lines of research to address concurrently presented social stimuli and nonsocial stimuli related to circumscribed interests in ASD. Social and non-social stimulus pairs elicit disproportionate patterns of attention in ASD. The proportion of gaze time to faces within the ASD group was reduced when faces were paired with high interest items; however, when faces were presented with lower interest items, the proportion of gaze time afforded to faces increased. Although, these findings differed only relative to the control group and findings in this condition did not demonstrate group differences between ASD and OCD. Proportion of gaze time to faces differentiated the ASD group from another clinical control group only when faces were paired with objects relevant to circumscribed interests. These findings support models of decreased saliency of social information coinciding with an increased saliency of non-social information within ASD. Assessment of visual attention may be used to quantify discrete aspects of the repetitive behavior phenotype in ASD, including the modulating effect of circumscribed interests on social attention.

TABLE 1. Experiment 1: SvO. Means (SDs) of demographic data and symptom profiles from sample.

	Autism (n=24)	Control (n=16)	OCD(n=8)
# of Males	23	14	5
Age	14.39(3.12)	13.48(2.88)	14.95(3.16)
ADOS			
Comm	4.33(1.46)		
SI	7.5(2.15)		
SBRI	2.54(1.67)		
K-BIT			
Verbal	103.1(20.78)	114(13.95)	111(13.07)
Non-verbal	109.4(15.97)	111.8(14.18)	113.1(15.64)
Full	107.3(17.95)	115.2(14.76)	114.0(15.90)
RBS-R	21.54(14.90)*	0.88(1.41)* †	17.38(13.66) †
SRS-SR (raw scores)	80.96(19.10)* Ω	49.31(7.91)* †	63.25(13.70) † Ω

× MA & IQ-matched

* Indicates significant difference between ASD and TYP group, *p*<.05.
† Indicates significant difference between TYP and OCD group, *p*<.05.
Ω Indicates significant difference between ASD and OCD group, *p*<.05.

Abbreviations:

WASI: Wechsler Abbreviated Scale of Intelligence (Weschler, 1999);

ADOS: Autism Diagnostic Observation Scale (Lord et al., 2000); Comm: Communication; SI: Reciprocal Social Interaction; SBRI: Stereotyped Behaviors and Restricted Interests;

RBS-R: Repetitive Behavior Scale-Revised (Bodfish, Symons, & Lewis, 1999).

SRS-SR: Social Reciprocity Scale- Self Report (Constantino, 2002).

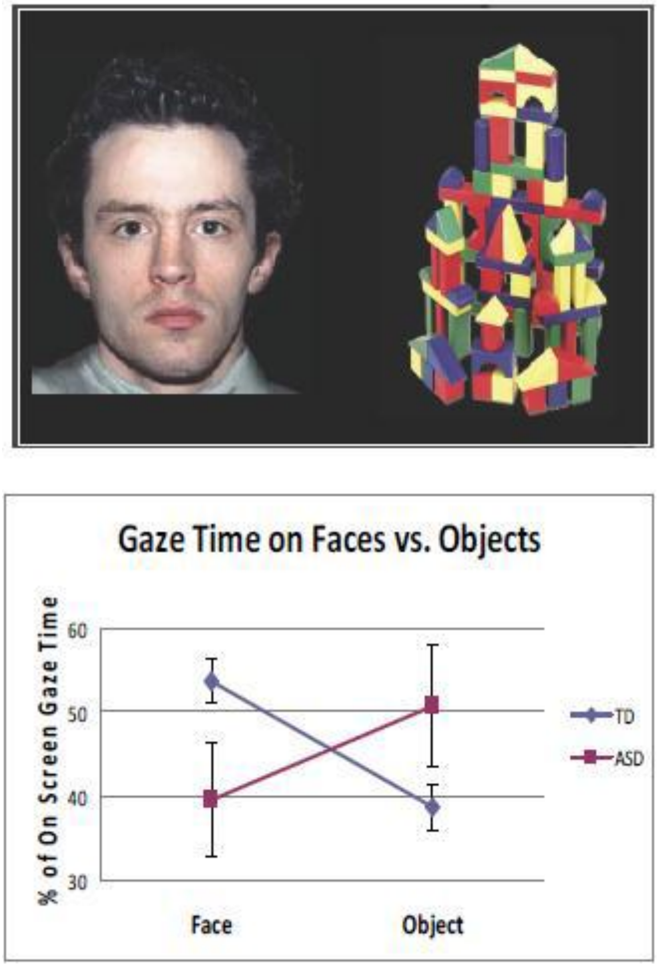

Figure 1. Results from Dichter et al. (2010). Adults with and without ASD were shown stimulus pairs containing a social (neutral expression face) with a non-social stimulus (object image related to circumscribed interests in ASD). Analysis of looking time indicated significant differences in looking time to faces and object between the ASD and control groups. The current study aims to both replicate and extend this design by investigating differential patterns of attention social stimuli, non-social stimuli both related to circumscribed interests and everyday, common objects.

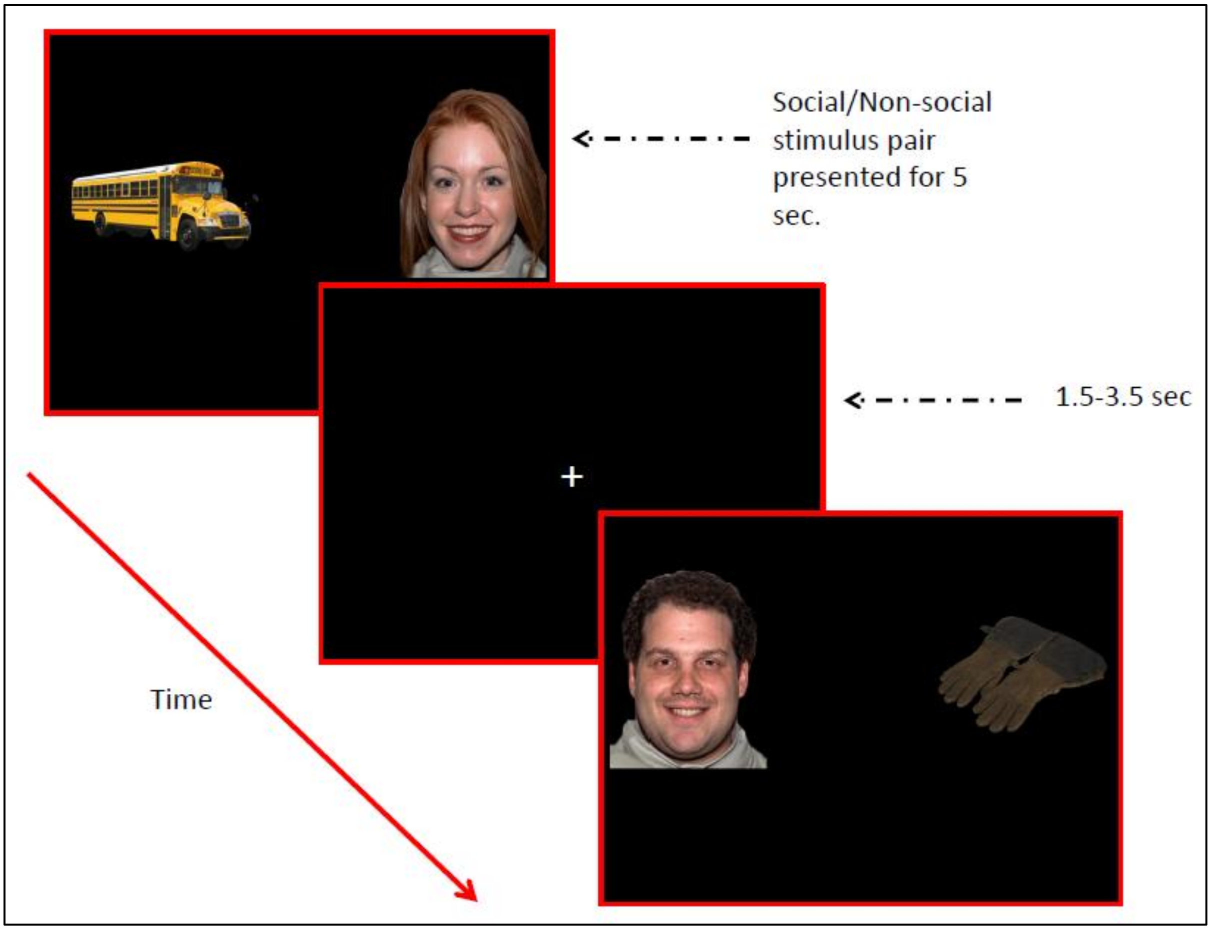

Figure 2. Passive viewing Task. Stimuli included 20 image pairs of social (i.e. neutral NimStim faces) and non-social images (i.e., “High Autism Interest” (HAI) objects or “Low Autism Interest” (LAI) objects derived from Sasson et al., 2008). Each stimulus was displayed for 5 seconds and with an inter-stimulus image (ISI) displayed for a variable period of 1.5-3.5 seconds.

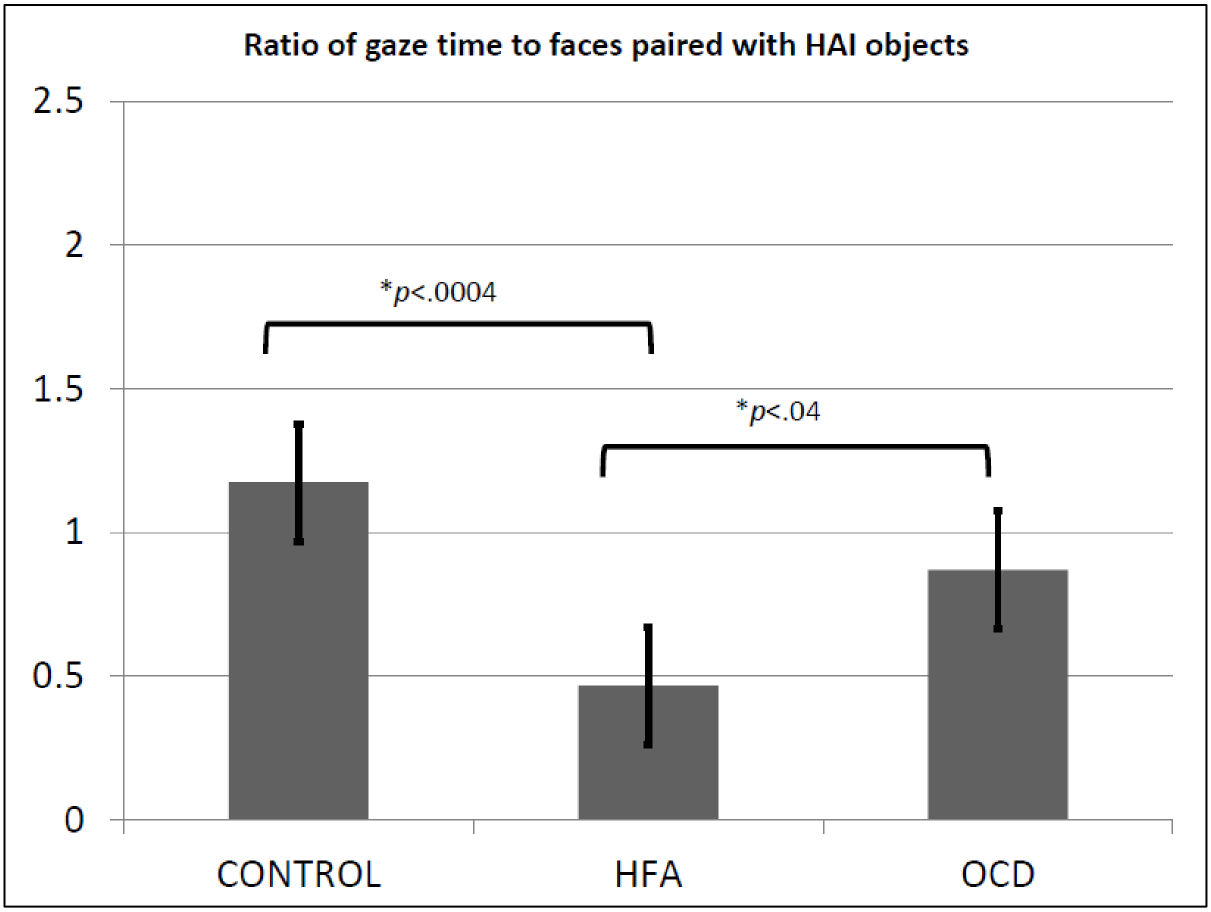

Figure 3. Gaze Time data- presented as a ratio of gaze time to faces and high interest objects. Errors bars represent group standard errors of the mean.

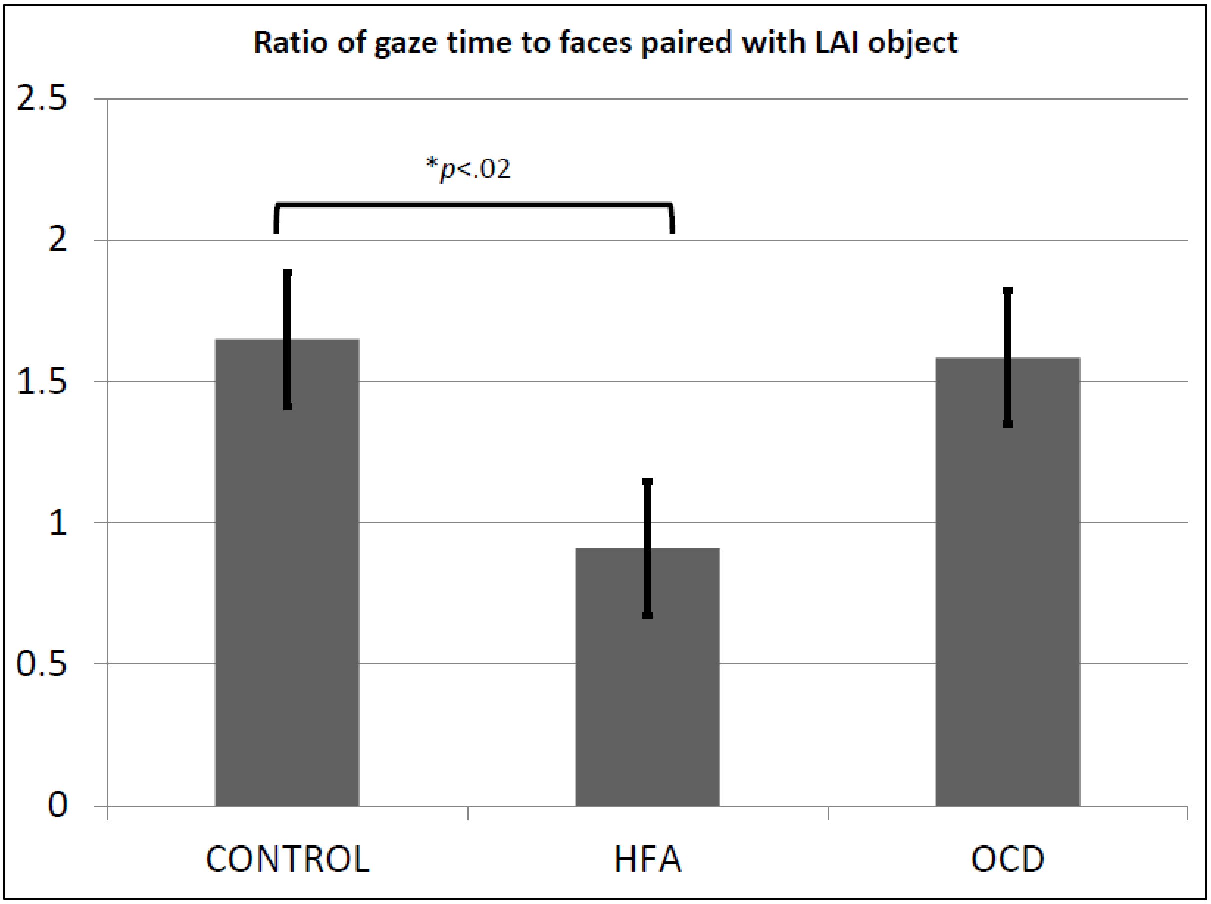

Figure 4. Gaze Time data- presented as a ratio of gaze time to faces and lower interest objects. Errors bars represent group standard errors of the mean.

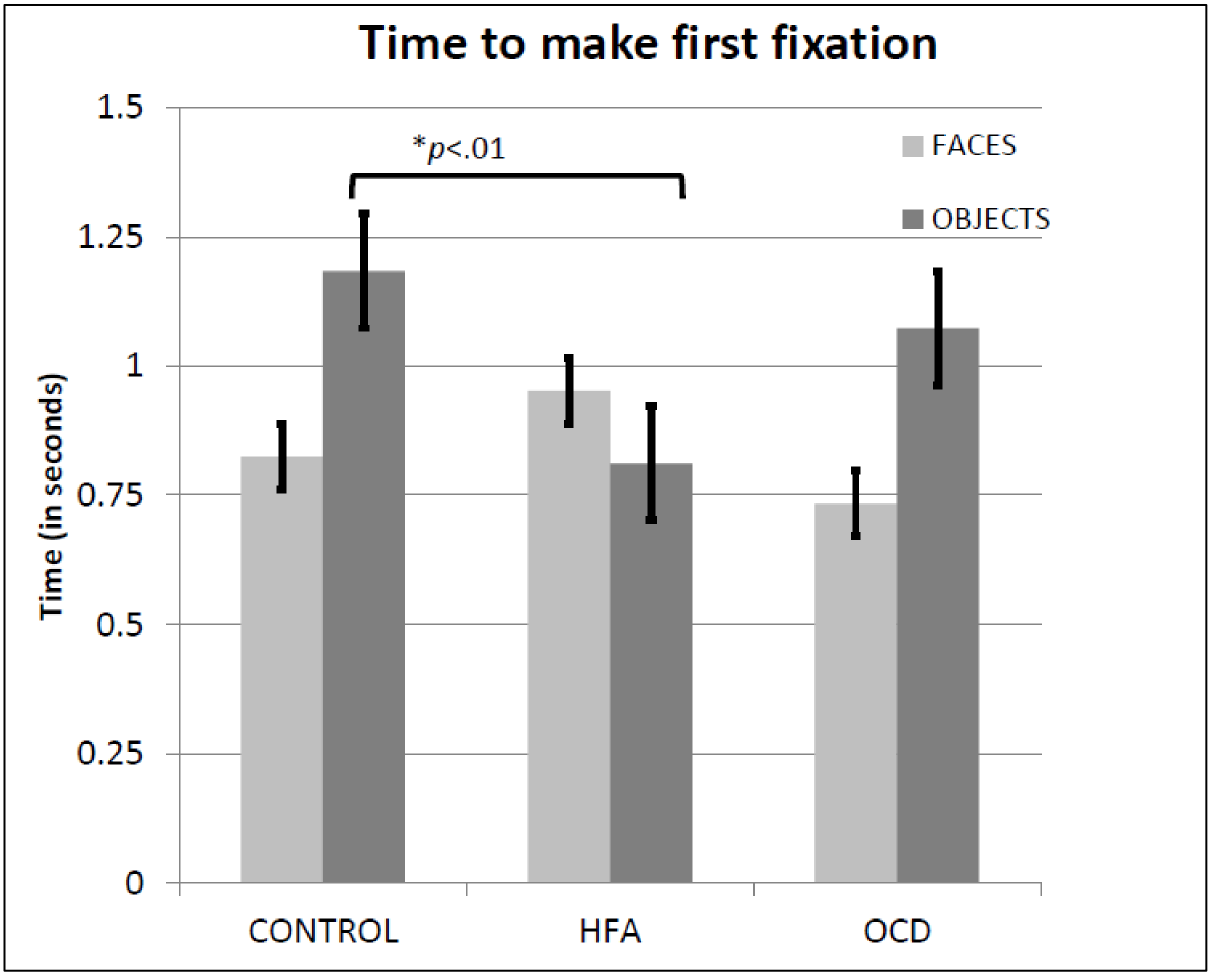

Figure 5. Average time to make first fixation to faces and objects (in seconds). Errors bars represent group standard errors of the mean.

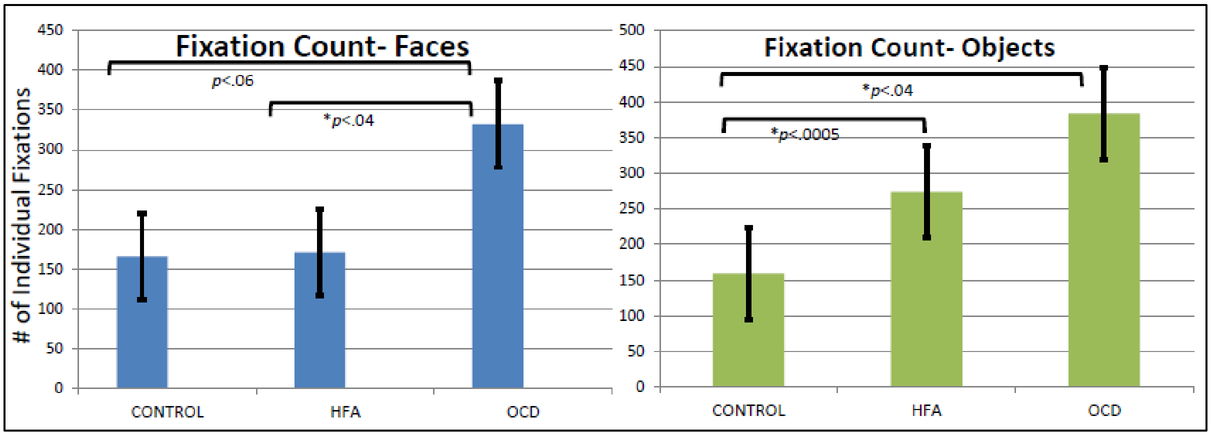

Figure 6. Fixation Count- metric of the number of individual, discrete fixations within each "face" (left) and "object" (right) area of interest (AOI). Errors bars represent group standard errors of the mean.

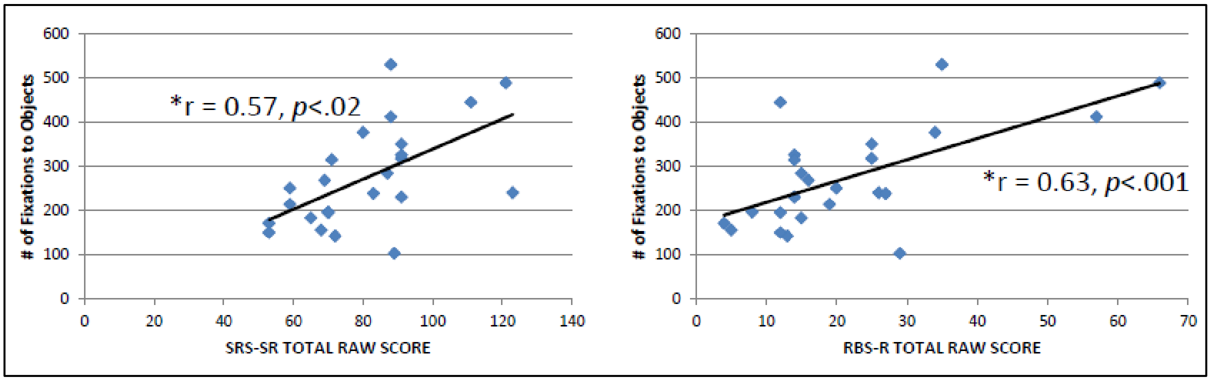

Figure 7. Relations between eye-tracking measures and the SRS-SR (Constantino and Gruber, 2002) and RBS-R (Bodfish, Symons, Parker, & Lewis, 2000). Within the ASD group, the number of discrete fixations made to objects was positively correlated with total score on the SRS-SR in addition to social communication and social motivation subscales. The number of discrete fixations to objects was also positively correlated with total score on the RBS-R in addition to the self-injurious, ritualistic behavior, and sameness behavior subscales.

EXPERIMENT 2: COGNITIVE CONTROL OVER ATTENTION TO SOCIAL AND NON-SOCIAL STIMULI

Perseverative patterns of attention, failure to visually disengage, and reduced visual exploration have been conceptually linked to repetitive behaviors in ASD (Ozonoff et al., 2000; Bodfish et al., 2000; South et al., 2005). Of particular interest is the circumscribed interests (CI) subdomain of restricted and repetitive behaviors. Findings on CI are primarily regarding their rate of occurrence independent of intellectual impairment, their prevalence across the autism spectrum and descriptions of common examples (e.g., gadgets, vehicles, electronics, particular animals, schedules, and numbers). CI appear to be the norm rather than the exception, occurring with equal prevalence in both high- and low-functioning autism and at similar rates between high-functioning autism and Asperger's Syndrome (Bartak and Rutter; 1976; Freeman et al., 1981; South et al., 2005; Klin et al., 2007). Parent reports have indicated that CI can interfere with functional and more appropriate forms of play, interaction with peers, and successful day-to-day activities (South et al., 2005). However, the association between higher-order cognitive processes (i.e., cognitive control) and CI in autism has not been firmly established. Experimental evidence has illustrated that, within individuals with ASD, these patterns of narrowed, perseverative attention and reduced visual exploration are elicited in response to stimuli related to CI (Sasson et al., 2008; 2011). The purpose of this study was to extend these findings and utilize eye-tracking methodology in conjunction with an empirically-derived CI image set (Sasson et al., 2008; 2011; 2012) to investigate differential patterns of attention and the ability of individuals with and without ASD to volitionally control saccadic behavior in response to social and non-social stimuli.

Visual saccade tasks provide a behavioral component and are useful for examining differential levels of ability to shift, disengage, and control the allocation of attention in response to different classes of stimuli (Sweeney, Levi, and Harris, 2002). Saccadic eye movements during these tasks provide objective measures of response inhibition and cognitive control. Depending upon the specific task, individuals are instructed to generate eye movements in response to a peripheral target. Visually guided or prosaccade tasks tap into reflexive sensorimotor systems when an individual is required to attend to a peripheral target when it appears. Another saccade task used to more directly investigate cognitive deficits and attention is the antisaccade task. The task requires inhibition of a reflexive saccade to a peripheral target, and instead asks the participant to saccade to the mirror image location. In other words, these tasks require an individual to look away from a target, making an *anti*-saccade (AS), thus measuring the ability to voluntarily suppress a prepotent response to saccade towards an image when it appears. Studies applying AS paradigms across various ages have consistently reported deficits in the ability of ASD participants to inhibit prepotent responses and a tendency to make an increased number in saccade errors (Luna et al., 2007; Goldberg et al., 2002; Manoach et al., 2011; Mosconi et al., 2009; Minshew et al., 1999). A basic deficit in response inhibition in ASD seems to be present throughout development. Though improvement with age in ASD has been reported, proficiency is not achieved and individuals with ASD continue to display more errors than control groups (Luna et al., 2007).

Confirmation of intact saccade dynamics (i.e., latency, velocity, duration/amplitude) in adolescents and adults with autism (Minshew et al., 1999) indicate that reports of increased directional errors reflect an impaired capacity of the prefrontal cortex to suppress context-inappropriate reflexive responses rather than lower-level deficits in disengaging and shifting attention. More recent research has replicated these findings and suggests that increased latency in AS is unrelated to saccade errors (Manoach et al., 2011). Manoach and colleagues have suggested that the deficits in saccadic inhibition may be quantitatively and qualitatively distinct in ASD in comparison to other disorders such as social-emotional processing disorder (SEPD), schizophrenia, and obsessive-compulsive disorder (OCD). Specifically in contrast to SEPD and schizophrenia, individuals with ASD have normal latencies, velocities, and amplitudes and make fewer AS errors; therefore, impairments are primarily within prefrontal regions and response inhibition rather than subcortical oculomotor functions associated with the cerebellum and brainstem regions. Attention in ASD is more qualitatively constrained and a saccade inhibition deficit may be less severe than other psychotic disorders. If saccade dynamics are intact but errors are made appropriately suppressing saccades, this strengthens support for disturbances in the prefrontal cortex and connections that subserve the capacity to suppress behavioral responses to salient stimuli when responses are not context appropriate.

As indicated previously, eye movement research offers a translational approach for examining disturbances in frontostriatal systems, controlling the allocation of attention and the inhibition of prepotent responses when social and non-social information are presented in conjunction with one another. Studies of saccadic behavior in ASD, such as those cited previously, have primarily used non-social stimuli such as LED lights and geometric shapes. No studies to date have utilized these paradigms to investigate differences in control over visual saccades in response to different categories of images. Eye-tracking research has focused primarily on the extent to which individuals with ASD show deliberate attention to social information, while few studies have investigated the distracting power of social versus non-social stimuli nested within a task requiring cognitive control. Previous eye-tracking results have indicated that the presence of CI can impose a significant limitation on normative visual search and exploration processes that are important for experience-dependent learning (Sasson et al., 2008; 2009). Passive-viewing forced-choice paradigms, like that described in Experiment 1, have also clearly indicated that relative visual salience is altered in individuals with ASD and, in many cases, attention is being disproportionately captured by specific types of non-social information (Dichter et al., 2010).

Although there is reduced deliberate interest in social information as is measured by passive looking paradigms, these findings do not necessarily imply that social information has reduced distracting power for available cognitive resources (Vaidya et al., 2011). Studies using standard attention tasks and Posner cueing paradigms argue that individuals with ASD, just like typically developing individuals, automatically orient attention based on perceived gaze to detect a peripheral target (Posner and Dehaene, 1994; Greene et al., 2011; Dichter and Belger, 2007). Although, control groups show effects specific to social cues; individuals with ASD are able to interpret both social and non-social stimuli (e.g. arrows) with equal proficiency (Vlamings et al., 2005; but see also Goldberg et al., 2008). Riby et al. (2012) recently quantified the degree to which face stimuli cause distraction when searching for an identified target. Typical adults were slower to detect a target when a face was present in a visual array, but the same effect was not observed in adults with autism. Social stimuli, such as faces, do not appear to capture attention in ASD. An additional important question is whether the relative salience of various stimuli, both social *and* non-social, is altered in ASD. In other words, while research suggests that deliberate attention to social information appears to be reduced in ASD, is it also true that non-social information thought to be of increased salience in autism disproportionately captures cognitive resources controlling attention. Measures of reflexive attention suggest that non-social stimuli related to circumscribed interests capture attention in children and adults with ASD (Dichter et al., 2012; see also results from Experiment 1); however, it remains unclear whether stimuli conceptually linked to this sub-domain of restricted behaviors in ASD also has an effect on the cognitive control over attention.

It is important to also question whether distinct patterns of attention as a function of stimulus type in ASD are syndrome-specific or relevant to other disorders that impact attentional and behavioral control. Studies of attention and visual saccades in children with ASD have primarily compared ASD to typically developing children or children with other developmental disorders and many studies of cognitive control have compared ASD to other psychotic disorders such as schizophrenia. This study will explore differences in cognitive control over attention between ASD and obsessive compulsive disorder (OCD), another neurodevelopmental disorder that is associated with repetitive behaviors. Experimental evidence from the implementation of antisaccade paradigms with OCD samples suggests that adults and especially children with OCD have difficulty inhibiting prepotent responses, exhibiting both an increased number of reflexive glances towards the peripheral target and, when accurate antisaccades are made, significantly increased latencies in order to do so (Rosenberg et al., 1997; Maruff et al., 1999). These patterns of results, in comparison with those reported in ASD, suggest that impairments on antisaccade tasks in OCD are based on guiding visual saccades and a slowing of psychomotor function as well as some deficits in inhibiting responses (Mosconi et al., 2009).

The current experiment explored whether social and non-social stimuli, particularly non-social stimuli related to circumscribed interests, can influence the cognitive control over attention in children and adolescents with ASD. This is an important extension of previous research, which unlike the current study, has focused on reflexive attention to social and non-social stimuli embedded in passive-viewing tasks. By including the antisaccade task and utilizing social and non-social stimuli hypothesized to be highly salient for individuals with ASD as well as comparing performance to different diagnostic groups, qualitatively different constraints on patterns of visual attention specific to the ASD phenotype can be explored. It is hypothesized that children and adolescents with ASD and pediatric OCD will display an increase in saccadic directional errors during an antisaccade task in comparison to typically developing controls; however, only children and adolescents with ASD will display an increase in directional errors to non-social object targets, specifically those related to circumscribed interests. Previous findings regarding oculomotor properties such as saccadic latency and effects of visual hemifield on attention are inconsistent (Rosenburg et al., 1997; Luna et al., 2004; Mosconi et al., 2009). Analyses will also include group differences on such measures. In addition to measures of task performance, exploratory analyses will be carried out to investigate the extent to which patterns of visual attention in the ASD group would predict the magnitude of autism symptoms.

METHODS

Participants

Participants included three groups of children (9-18 years): 24 children with ASD (14 were identified as having autism; whereas, the remainder reached criteria for a spectrum disorder), 9 children with Obsessive Compulsive Disorder (OCD), and 17 typically developing children (TYP). Four participants from the TYP group, 1 participant from the OCD group, and 2 participants with ASD were excluded due to reduced data acquisition during the eye-tracking tasks (i.e., missing data > 50% of trials). Final sample size and demographic information on each group are reported in Table 2. Groups were matched on age, socioeconomic status (SES), and gender distribution. The ASD group was recruited through the UNC Autism Research Registry. The Autism Registry is a tool for subject recruitment available to UNC researchers through the NICHD-funded Intellectual and Developmental Disabilities Research Center at the Carolina Institute for Developmental Disabilities (CIDD). Autism spectrum diagnoses were based on a history of clinical diagnosis informed by scores on the Autism Diagnostic Observation Schedule (ADOS-G) (Lord, et al., 2000) administered by a research reliable assessor and using standard cutoffs. Children with OCD were recruited with the help of the Program in Child Affective and Anxiety Disorders (PCAAD; Director: co-I John March, PhD) with multiple and varied methods, including providing information to psychology and psychiatry clinics, pediatricians, schools, and other professional and community settings (e.g., health fairs, parent groups). Typically developing children and adolescents were recruited via mass emails sent through the UNC-CH listserv. Inclusion/exclusion criteria are listed below. All participants consented to protocols approved by the Human Investigations Committees at UNC-Chapel Hill.

Inclusion/Exclusion criteria

Children with autism met the following criteria:

8) Clinical diagnoses of autism;
9) Between the ages of 9-18 years, inclusive;
10) No known genetic/medical conditions;
11) No known sensory deficits (e.g., not blind or deaf);
12) Ambulatory status;
13) No comorbid diagnosis of psychosis, bipolar disorder, or OCD;
14) No nonverbal learning disability (NVLD); IQ above 80 and no MRI contraindications.

Children with Obsessive Compulsive Disorder (OCD) met the following criteria:

8) Primary diagnosis of OCD;
9) Between the ages of 9-18 years, inclusive;
10) No known genetic/medical conditions;
11) No mental retardation;
12) No known sensory deficits (e.g., not blind or deaf);
13) Ambulatory status;
14) No comorbid diagnosis of psychosis, bipolar disorder, or any PDD.

Children with neurotypical development met the following criteria:

11) Between 9-18 years of age, inclusive;
12) No known genetic/medical conditions;

13) No mental retardation;

14) No known sensory deficits (e.g., not blind or deaf);

15) Ambulatory status;

16) No significant features of any PDD or OCD;

17) Lifetime-free of Axis I psychiatric and neurological disorders;

18) No family history of psychosis, bipolar disorder, PDD, and OCD;

19) No psychotropic medication use;

20) The older TYP subgroup will have no MRI contraindications.

Symptom Measures

Parents or legal guardians of children in all three groups completed parent-report versions of (a) The Repetitive Behavior Scale-Revised (RBS-R) (Bodfish, Symons, Parker, & Lewis, 2000) and (b) the Social Reciprocity Scale (SRS-SR) (Constantino & Gruber, 2002), in addition to standardized measures of intelligence taken via the Kaufman Brief Intelligence Test (K-BIT) (Kaufman and Kaufman, 199) and, within the ASD group, diagnostic measures via the ADOS-G (Lord et al., 2000). Participant characteristics are reported in Table 2.

Prosaccade and Antisaccade Tasks (PS and AS) & Stimuli

Prosaccade and antisaccade tasks were administered to assess automatic visual attention and components of cognitive control over voluntary saccades. In the **prosaccade task**, participants were instructed to look towards the peripheral target, making a “pro”saccade. A central target was presented for a variable period (1500-2500 milliseconds) prior to being extinguished and then followed by the presentation of a peripheral stimulus. Sixty total trials were administered: 20 trials with a social stimulus as the peripheral target, 20 with an object related to CI as a peripheral target, and 20 with an everyday object as a peripheral target. The peripheral target was presented for a variable period of 2500-3500 milliseconds. Based on previous oculomotor and visual saccade research, 10 degrees either left or right of center was chosen as the ideal target location (Mosconi et al., 2009). The **antisaccade task** was identical; however, participants were instructed to look to the opposite, mirror location of the peripheral target essentially making an "anti"saccade (See Figure 8). Every participant completed 10 practice trials before being administered both the prosaccade and antisaccade task and reached a minimum cut off of 8 of the 10 correct trials before beginning the formal task. During practice trials, participants were asked to verbalize the correct on-screen location to attend to (i.e., "Did you look in the box on the right or the box on the left?", "Did you make a mistake?", "Why do you think you made a mistake?").

Social stimuli were pictures of mildly pleasant faces (with equal numbers of male and female faces), from the NimStim set of facial expressions (Tottenham, et al., 2009). The non-social images were systematically derived by our research group in the following manner (see Sasson et al, 2012 for a fuller description). First, a large number of potential non-social images was selected based on response profiles from semi-structured parent-report interviews about circumscribed interests in ASDs (e.g., machines, mechanical systems, trains and electronic devices) (South, Ozonoff, S, & McMahon, 2005; Turner-Brown, Lam, Holtzclaw, Dichter, & Bodfish, 2011). Next, the visual salience of these images was evaluated via passive-viewing visual exploration eyetracking studies of children and adults with and without ASDs (Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011; Sasson et al., 2008). These eyetracking studies identified 40 images without social content that garnered relatively greater visual attention (i.e., the number of fixations and duration of fixations) in ASD samples. These images are conceptually linked to circumscribed interests in ASD and thought to be of higher interest to individuals with ASD based off these results; therefore, these images are labeled as "High ASD Interest" images (HAI). Finally, 56 adults with self-identified ASDs provided significantly higher valence ratings of these nonsocial images relative to 213 adults without ASD, while the groups did not differ in their valence ratings of other everyday objects not associated with circumscribed interests (Sasson et al., 2012). These images are labeled as "Lower ASD Interest" images (LAI). HAI object categories included: trains, tractors, cars, planes, electronics, road signs, and blocks/block designs. These HAI and LAI non-social images were used in the present study and are depicted in the Appendix of Dichter et al (2012).

Eye-tracking Analysis

Eye-movement data were recorded with a Tobii X120 eye-tracker (Tobii Technology, Stockholm, Sweden). The system is a stand-alone eye-tracking unit that monitors movement of the participant's pupil at 50 Hz by using infrared light to produce reflection patterns on the corneas and then monitors the movements of these reflections relative to eye position. Eye movement patterns were analyzed by conducting fixation analyses. A single fixation was defined as remaining within a radius of 30 pixels for a minimum of 10 msec.

There were two areas of interest (AOIs) within each stimulus: the correct on-screen location and the incorrect on-screen location which was dependent upon the task being PS or AS. Areas of interest were defined as the outline around the a-priori identified on-screen fixation locations (e.g., outlined boxes to left and right of center). The primary dependent variables of interest were (1) the saccadic accuracy and (2) the latency to saccade to the correct on-screen location. In conjunction with previous research (Manoach et al., 2011), a saccadic error was defined as a saccade being made within 3 degrees of the incorrect on-screen fixation location (dependent upon the task being PS or AS). See Figure 9 for example.

RESULTS

Directional Errors

All groups made more antisaccade than prosaccade errors (task: $F(1,40) = 53.40$, $p<0.0001$). A group by task interaction approached significance ($F(1,40) = 2.45$, $p<0.09$). See Figures 10 and 11.

Prosaccade Task

Both the ASD (M = 11.27, SD = 7.96) and OCD groups (M = 9.5, SD = 7.15) showed a significantly higher prosaccadic error rate than did the control group (M = 4.08, SD = 2.63) (*p*'s<0.02). There was no significant difference in number of prosaccadic errors between the ASD and OCD groups (*t*(28)= 0.58, *p*<0.6). A repeated measures analysis of variance did not indicate an effect of stimulus (F(2,4) = 0.56, *p*<0.57) nor a significant group x stimulus type interaction (F(2,4) = 0.40, *p*<0.81). Follow up between groups t-tests were carried out to investigate group differences in prosaccadic errors in response to each of the 3 stimulus types. Results related to the primary aims of the study, comparisons between ASD and typical development are presented first. Relative to the control group, participants with ASD made an increased number of prosaccadic errors across all 3 stimulus categories: faces (*t*(33)= -2.50, *p*<0.01); HAI images (*t*(33)= -3.75, *p*<0.0007); and LAI images (*t*(33)= -2.19, *p*<0.03). There were no significant differences in number of prosaccadic errors between the ASD and OCD groups across any of the stimulus categories, *p*'s<0.60. Additional within-groups analyses detected no significant differences in prosaccadic errors across any of the stimulus categories. The OCD and control groups differed only in the number of prosaccadic errors in response to HAI images (*t*(19)= -2.19, *p*<0.04).

Antisaccade Task

The ASD group (M = 31.14, SD = 12.19) showed a significantly higher antisaccade error rate than both the control group (M = 16.61, SD = 11.42) and the OCD group (M = 20.36, SD = 10.57) (*p*'s<0.03). A repeated measures analysis of variance did not indicate an effect of stimulus (F(2,4) = 1.90, *p*<0.15) nor a significant group x stimulus type interaction (F(2,4) = 1.19, *p*<0.32). Follow up between-groups t-tests were calculated to investigate group differences in antisaccade errors in response to each of the 3 stimulus types. Results related to the primary aims of the study, comparisons between ASD and typical development are presented first. Relative to the control group, participants with ASD made an increased number of antisaccade errors across all 3 stimulus categories: faces ($t(33) = -3.01$, $p<0.004$); HAI images ($t(33) = -3.33$, $p<0.002$); and LAI images ($t(33) = -3.41$, $p<0.001$). The OCD and ASD groups differed only in the number of antisaccade errors in response to LAI images ($t(28) = 2.96$, $p<0.004$). There was no significant difference in the total number of antisaccade errors between the control and OCD groups ($t(19) = -0.75$, $p<0.46$). There were no significant differences in number of antisaccade errors between the control and OCD groups across any of the stimulus categories. Additional within-groups analyses detected significant differences in the number of antisaccade errors across the stimulus categories only in the ASD group. Participants with ASD made significantly more antisaccade errors in response to LAI images than to faces ($t(21) = -2.08$, $p<0.04$). Difference in antisaccade errors in response HAI images and errors in response to faces approached ($t(21) = -1.93$, $p<0.06$). Within the ASD group, there was no significant difference in the number of antisaccade errors between LAI and HAI images ($t(21) = -0.39$, $p<0.69$).

Latency

Analysis of saccade latencies were calculated using measured latencies to saccade to the correct on-screen location. Antisaccade latencies were longer than prosaccade latencies across all groups (task: $F(1,40) = 30.91$, $p<0.0001$). See Figures 11 and 12.

Prosaccade Task

Average prosaccade latency across the task did not differ across groups, p's<0.07. A repeated-measures analysis of variance of latency to prosaccade to the correct on-screen location indicated a significant group x stimulus type interaction ($F(2,4)=2.88$, $p<0.02$). Follow up between-groups t-tests were calculated to investigate group differences in prosaccade latencies in response to each of the 3 stimulus types. Relative to the control group, participants with ASD made faster prosaccades in response to social stimuli ($t(33)= 2.08$, $p<.04$). There were no significant differences in prosaccade latencies between the ASD and control groups in response to both HAI and LAI images. Relative to the OCD group, participants with ASD made faster prosaccades in response to HAI images ($t(28)= -2.17$, $p<.03$). There were no significant differences in prosaccade latencies between the ASD and OCD groups in response to social stimuli and LAI images. There were no significant differences in prosaccade latencies between the control and OCD groups in response to any of the stimulus categories. Additional within-groups analyses detected no significant differences in prosaccade latencies across any of the stimulus categories.

Antisaccade Task

Average antisaccade latency across the task did not differ across groups, p's<0.08. A repeated measures analysis of variance of latency to antisaccade to the correct on-screen location indicated a group x stimulus type interaction that approached significance ($F(2,4)=2.15$, $p<0.08$). Follow up between-groups t-tests were carried out to investigate group differences in antisaccade latencies in response to each of the 3 stimulus types. Relative to the control group, participants with ASD made faster antisaccades in response to social stimuli ($t(33)= 2.08$, $p<.04$). There were no significant differences in antisaccade latencies between the ASD and control groups in response to either of the non-social stimulus types. There were no significant differences in antisaccade latencies between the ASD and OCD groups as well as between the control and OCD groups in response to any of the stimulus categories. Additional within-groups analyses detected no significant differences in antisaccade latencies across any of the stimulus categories.

Visual Hemifield

Analyses of directional errors across visual hemifield (i.e., whether a target stimulus was presented on the right or left) were also included. Repeated measures analysis of variance did not indicate an effect of visual hemifield nor a significant visual hemifield x group interaction across both the pro- and antisaccade tasks.

Symptom Measures

Correlations between eye-tracking measures and the SRS-SR (total score and five subscales), the RBS-R (total score and six subscales), and the ADOS (three subscales) were evaluated within the ASD group. Within the ASD group, number of directional errors made during the prosaccade task were positively correlated with the social cognition subscale of the SRS-SR ($r=0.47$, $p<0.02$) as well as total raw score of the SRS-SR ($r=0.44$, $p<0.03$).

Number of directional errors made during the antisaccade task were positively correlated with social cognition subscale of the SRS-SR ($r= 0.47$, $p<0.02$), the sameness behavior subscale of the RBS-R ($r=0.44$, $p<0.03$), as well as measurements of stereotyped behaviors and restricted interests according to the ADOS ($r=0.43$, $p<0.04$). Also, number of directional errors made during the antisaccade task was inversely correlated with non-verbal IQ ($r= -0.50$, $p<0.01$). See Figure 14. Within the ASD group, number of directional errors made during the antisaccade, specifically in response to HAI images, was inversely correlated with total IQ ($r= -0.43$, $p<0.04$). There were no significant relations between latency and symptom measures within the ASD group.

DISCUSSION

Studies of attention in ASD have repeatedly reported impairments in inhibiting prepotent responses and making an increased number of saccadic errors relative to control groups. Conceptual links between such impairments and restricted, repetitive behaviors in ASD have been made. Intact voluntary behavioral inhibition is supported by frontostriatal systems (Sweeney et al., 1996; Rubia et al., 2007) and disruption of this neural circuitry can strain the ability to suppress prepotent responses (Christ et al., 2003). However, the impact of circumscribed interests on these voluntary processes, a subdomain of restricted and repetitive behaviors, is unknown. In addition, individuals with ASD disproportionately explore and perseverate their attention on objects commonly associated with circumscribed interests (Sasson et al., 2008; 2010). This pattern of attention emerged in Experiment 1. The purpose of Experiment 2 was to extend these findings on passive, reflexive attention and investigate the degree to which images related to circumscribed interests impact cognitive control over attention in ASD. Social stimuli were mildly pleasant faces. Non-social stimuli included either (a) common, everyday object images or (b) object images related to circumscribed interests known to be salient and rewarding to individuals with ASDs (Sasson et al, 2012; Dichter et al., 2012). It was hypothesized that children with ASD, relative to controls and children with OCD, would make an increased number of saccadic errors during an antisaccade task than in a visually guided prosaccade task. It was also hypothesized that children with ASD would make an increased number of saccadic errors in response to non-social objects related to circumscribed interests than those other everyday objects and social images. Analyses compared task performance and visual saccade characteristics (e.g., latency) across an ASD, a control group, and a pediatric OCD group, another neurodevelopmental disorder characterized by patterns of restricted and repetitive behaviors.

Analysis of directional errors indicated an increase in the rate of saccadic errors between the pro- and antisaccade tasks across all groups. In both the ASD and OCD groups, a significant increase in antisaccade directional errors compared to prosaccade implies that visually guided performance is intact but antisaccade performance was deficient, primarily in the ASD group. Consistent with previous research, both clinical groups made significantly more directional errors relative to the control group in the prosaccade task (Rosenburg et al., 1997; Luna et al., 2004; 2007;

Mosconi et al., 2009; Manoach et al., 2011). However, in the antisaccade task, the ASD group made significantly more errors than both the control and OCD groups. Previous studies have reported mixed findings regarding response inhibition in OCD (Cath et al., 2008). Findings of children and adults with ASD displaying difficulty suppressing prepotent responses have been well established (Luna et al., 2007; Minshew et al., 1999; Lopez et al., 2005; South et al., 2007).

Potential distinct patterns of attentional impairments in ASD in comparison to other clinical populations are also reflected in analyses of the number of directional errors across each stimulus type. Overall, there was a lack of group differences in rate of saccadic errors as a function of target type (i.e., social, objects related to CI, everyday objects). Across all stimulus types, the ASD group demonstrated an increased error rate in comparison to the control group in both the pro- and antisaccade tasks. In comparison to the OCD group, children with ASD did not differ in the rate of directional errors made in the prosaccade tasks. In the antisaccade task, significant differences between the ASD and OCD groups in response to everyday objects were reported; however, differences in response to objects related to circumscribed interests as well as social targets indicated only trend level effects. These findings, in conjunction with the lack of group differences between the OCD and control groups, imply that difficulties in response inhibition may be limited in OCD and more generalized and severe in ASD. Conclusions regarding differences between the ASD and OCD groups are made with caution within the current context due to the stark differences in sample size at the time of this dissertation defense.

Significant relations between autism symptoms and task performance were also reported within the ASD group. The total number of directional errors made during the pro- and antisaccade tasks were directly related to social communication impairments as measured by the SRS-SR (Constantino & Gruber, 2002). Performance during the antisaccade task alone was directly related to measures of restricted and repetitive behaviors as measured by both the RBS-R (Bodfish, Symons, Parker, & Lewis, 2000) and the ADOS (Lord et al., 2000). Of particular interest were negative relations between antisaccade directional errors in response to objects related to circumscribed interests and non-verbal IQ. Participants with ASD and lower non-verbal IQ showed a higher rate of antisaccade errors when responding to non-social targets conceptualized as being of higher interest in ASD. These findings provide further evidence that responses during cognitive control tasks are related to the severity of repetitive behavior symptoms (e.g., Agam et al., 2010), and in particular during a task that requires cognitive control of social and non-social information, stimulus conditions that would be most likely to tap cognitive deficits in ASD (Ozonoff, 1995).

Previous findings on saccade dynamics (i.e., latency) were replicated in the current study (Manoach et al., 2011; Minshew et al., 1999). Groups did not differ in latency to saccade to the correct location across both tasks. However, group differences were reported when parsing apart latency across the three target types. Children with ASD, relative to controls, displayed shorter latencies to saccade to the correct location when social stimuli were peripheral targets in both the pro- and antisaccade tasks. Within the prosaccade task, children with ASD relative to those with OCD displayed shorter latencies to saccade to the correct location when objects related to CI were peripheral targets. These findings of shorter latencies contrast with previous research. Individuals with ASDs consistently demonstrate slower reaction times in a range of cognitive control tasks (Geurts, Corbett, & Solomon, 2009; Hill, 2004).

Limitations of the present study should be addressed in future research. An obvious limitation is the significant difference in sample size across all the three groups, particularly between the ASD and OCD groups. It should be noted that the data collection for this study, supported by R01 MH073402-“Restricted Repetitive Behaviors in Autism”, has not been completed and is ongoing. Conclusions drawn in regards to differences between children with ASD and OCD are made with caution, and analyses will be ongoing as data collection continues. In addition, all participants viewed the same set of object images, whereas circumscribed interests in ASD are idiosyncratic and person-specific. From this perspective, object images within the current task were not a proxy for person-specific interests but rather a 'press' to investigate differences in visual attention to social and salient non-social images across groups. The use of these standardized object images is thus a conservative estimate of patterns of reflexive visual attention to person-specific interests, and future research with person-specific, age-appropriate images will be necessary to address this limitation. Previous research has outlined the moderating effects of lower level visual properties (e.g., luminance, contrast) on patterns of attention (Tseng, Cameron, Pari, Reynolds, Munoz, & Itti, 2012). Studies that control for these visual properties or more thoroughly investigate their effects may provide further evidence for the moderating effects of stimulus category on the allocation of attention.

The simplified variation on a widely used Posner attention task precludes determining the moderating effects of different stimulus categories on cognitive load. To investigate the degree to which circumscribed interests in ASD impact cognitive control over attention, an antisaccade task was simplified to minimize the number of factors bearing on cognitive control during the task. Standard designs of visually guided and antisaccade tasks present a peripheral stimulus at varying visual angles left and right of center (Luna et al., 2007). Other implementations have additionally required task switching components (i.e., a visual cue that signals to the participant whether they are to make a pro- or antisaccade) (Manoach et al., 2011). To focus on the effects of circumscribed interests, these other factors were minimized and each peripheral stimulus was displayed in one of two locations. The lack of group differences across each of the stimulus types in the current study may have been due to this simplification. Participants may have been able to adopt a compensatory strategy early in the task that minimized the number of errors.

Despite these limitations, the present study extends previous lines of research to address impairments in response inhibition in ASD in comparison to another phenotypically similar disorder, OCD. Whereas cognitive control in ASD was not moderated by social and non-social information in a way that was unique to comparison groups; results did replicate previous findings of attentional impairments in suppressing response inhibition (Minshew et al, 1999; Luna et al., 2007; Manoach et al., 2011; Mosconi et al., 2009). Participants with ASD displayed an increased rate of saccadic errors in comparison to children in control and OCD groups. Also, saccadic error rate was related to measures of autism symptoms categorized as restricted and repetitive behaviors. These findings are consistent with other studies that have reported relations between symptom behaviors with eye-gaze patterns and attentional impairments. Assessment of visual attention may be used to quantify discrete aspects of the repetitive behavior phenotype in ASD.

TABLE 2. Experiment 2: PS & AS. Means (SDs) of demographic data and symptom profiles from sample.

	Autism (n=22)	Control (n=13)	OCD(n=8)
# of Males	21	10	6
Age	14.36(3.19)	13.55(2.82)	15.58(2.67)
ADOS			
Comm	4.36(1.62)		
SI	7.45(2.68)		
SBRI	2.72(1.88)		
K-BIT			
Verbal	101.1(19.95)	113(16.39)	110(12.21)
Non-verbal	105.9(16.54)	111.3(14.94)	109.9(14.01)
Full	104.2(18.23)	114.1(16.69)	111.6(14.15)
RBS-R	24.00(15.40)*	0.46(0.77)* †	20.37(16.21) †
SRS-SR (raw scores)	81.68(18.42)* Ω	49.69(7.33)* †	62.50(13.87) † Ω

× MA & IQ-matched

* Indicates significant difference between ASD and TYP group, *p*<.05.
† Indicates significant difference between TYP and OCD group, *p*<.05.
Ω Indicates significant difference between ASD and OCD group, *p*<.05.

Abbreviations:

WASI: Wechsler Abbreviated Scale of Intelligence (Weschler, 1999);

ADOS: Autism Diagnostic Observation Scale (Lord et al., 2000); Comm: Communication; SI: Reciprocal Social Interaction; SBRI: Stereotyped Behaviors and Restricted Interests;

RBS-R: Repetitive Behavior Scale-Revised (Bodfish, Symons, & Lewis, 1999).

SRS-SR: Social Reciprocity Scale- Self Report (Constantino, 2002).

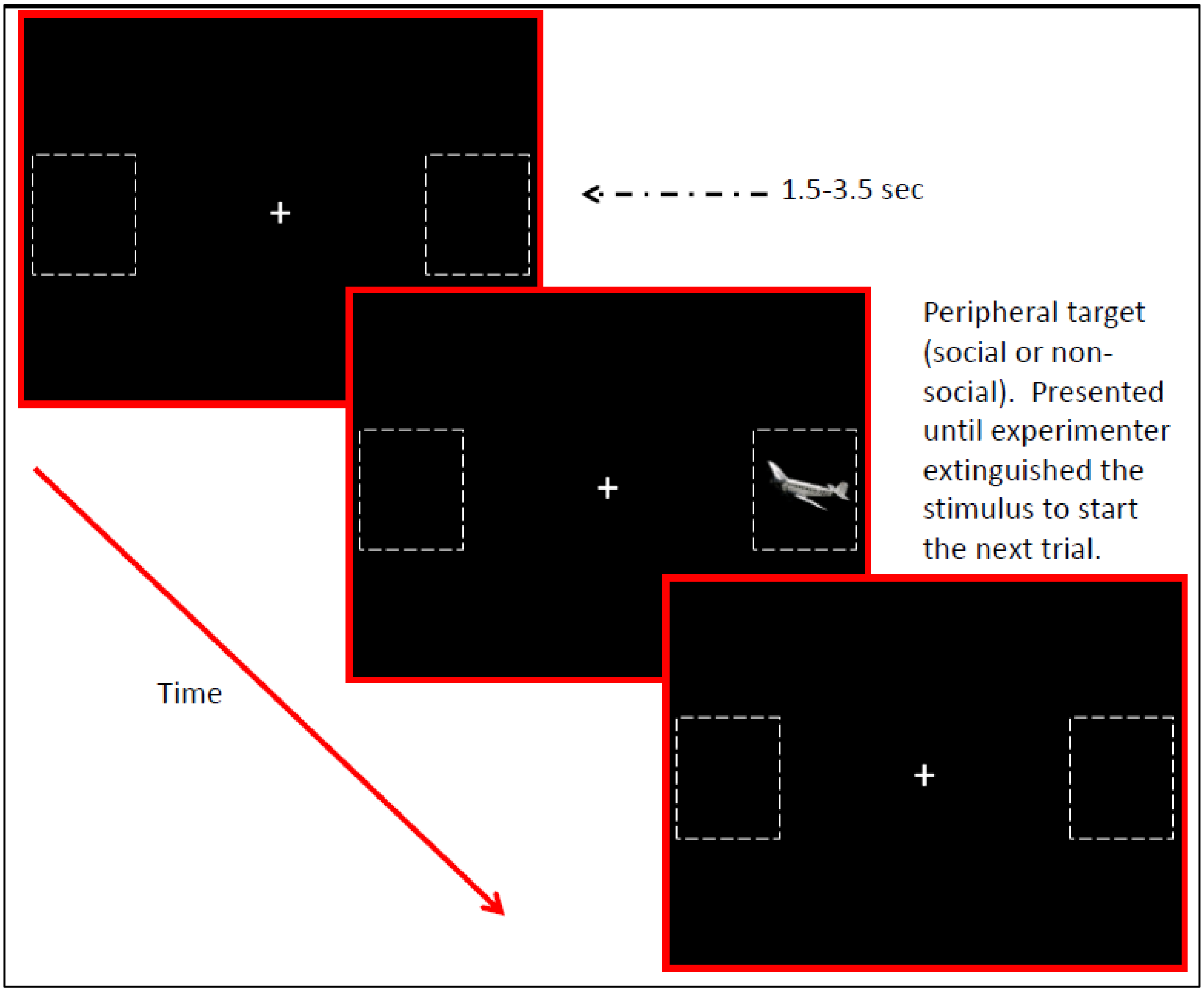

Figure 8. Pro- and Antisaccade Task. Stimuli included 20 images of social (i.e. mildly pleasant NimStim faces), 20 non-social images related to circumscribed interests (i.e., "High Autism Interest" (HAI) objects), and 20 non-social everyday images (i.e., "Low Autism Interest" (LAI) objects) derived from Sasson et al., 2008). Each stimulus was displayed for a variable period that was determined by the experimenter. Each peripheral target remained present until the experimenter extinguished the image, beginning the next trials. An inter-stimulus image (ISI) was displayed for a variable period of 1.5-3.5 seconds.

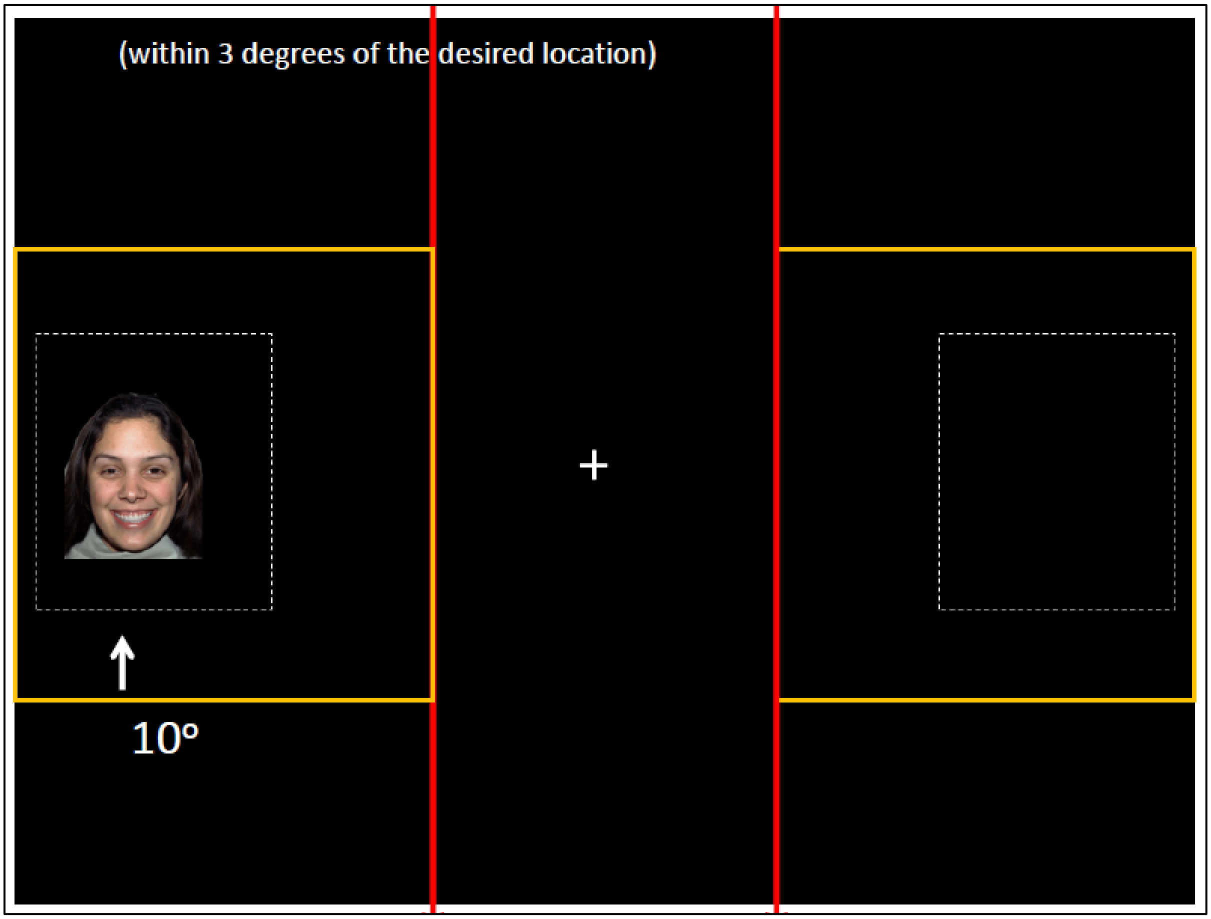

Figure 9. Example of the method employed to draw areas of interest (AOI). Based on previous research (Manoach et al., 2011; Mosconi et al., 2009) stimuli were presented at a visual angle of 10 degrees left and right of center. The boarders of AOIs was within 3 degrees of the edge of the designated looking areas (i.e., those outlined by a dashed line).

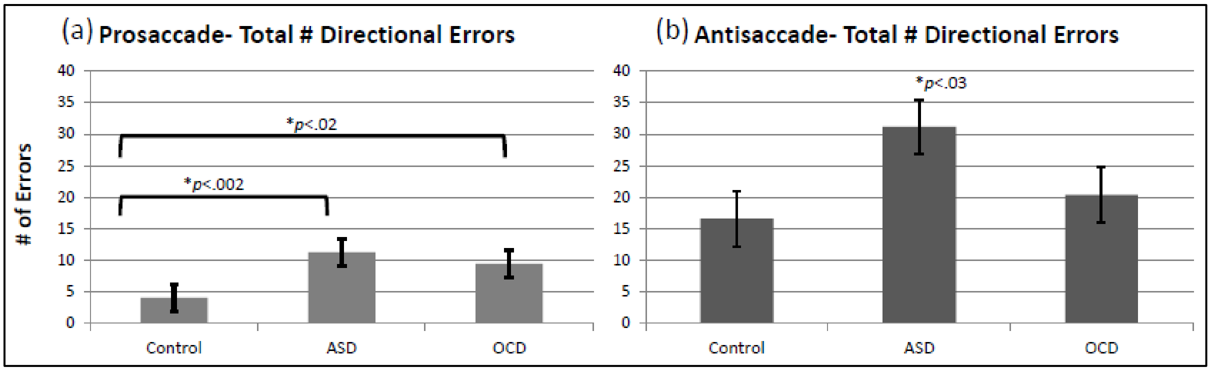

Figure 10. Average total number of directional errors made across groups both in (a) the prosaccade and (b) the antisaccade tasks. Errors bars represent group standard errors of the mean.

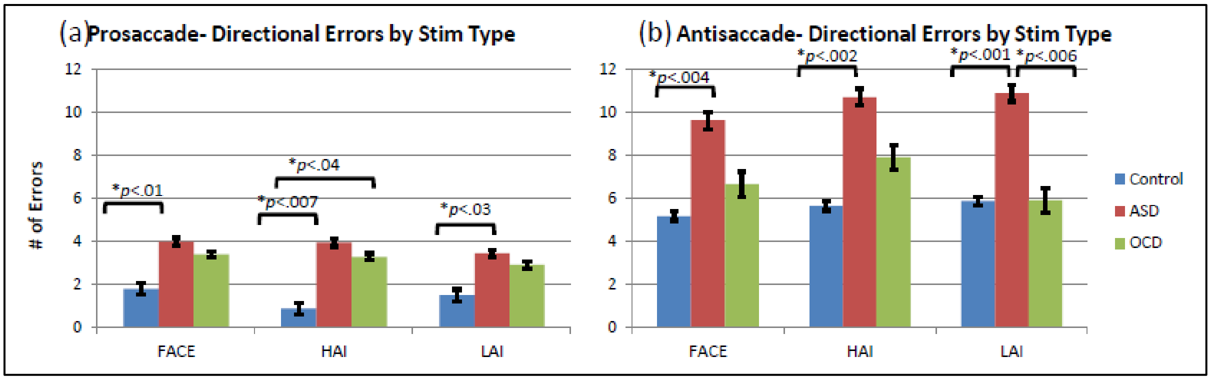

Figure 11. Average number of directional errors by stimulus type in both (a) the prosaccade and (b) the antisaccade tasks. Errors bars represent group standard errors of the mean.

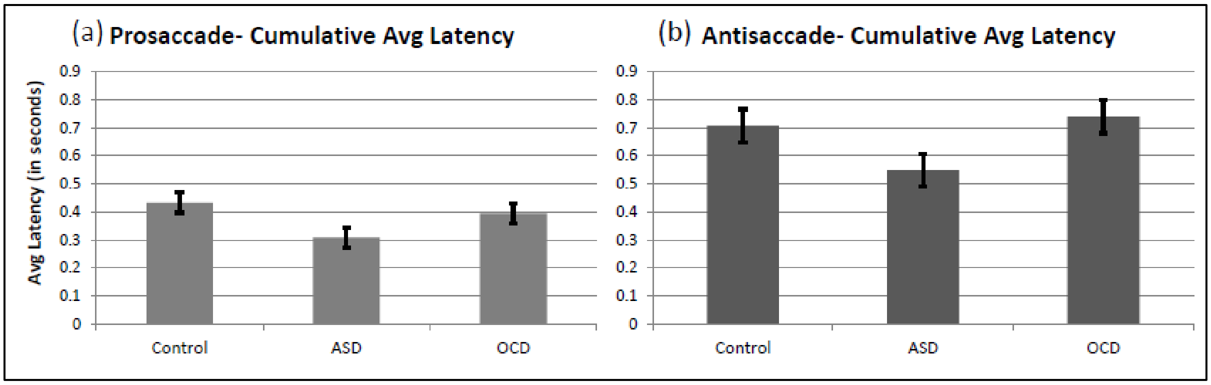

Figure 12. Cumulative average latency made across groups both in (a) the prosaccade and (b) the antisaccade tasks. Errors bars represent group standard errors of the mean.

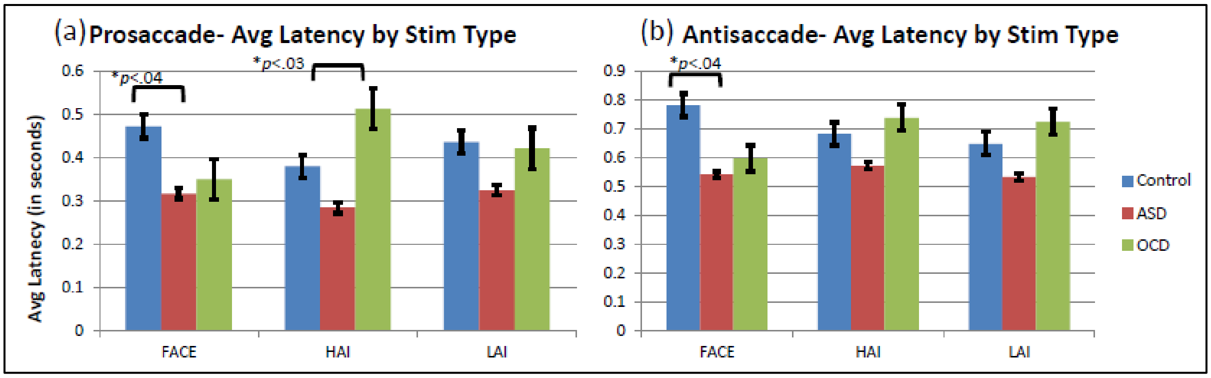

Figure 13. Average latency by stimulus type in both (a) the prosaccade and (b) the antisaccade tasks. Errors bars represent group standard errors of the mean.

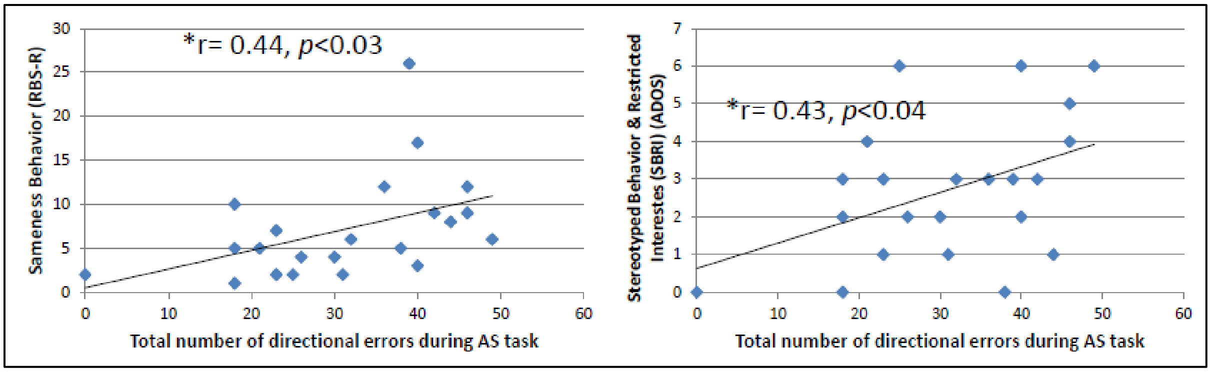

Figure 14. Relations between the number of directional errors during the antisaccade task (AS) and the sameness behavior subscale of the RBS-R (Bodfish, Symons, Parker, & Lewis, 2000) as well as measures of the stereotyped behavior and restricted interests on the ADOS (Lord et al., 2000). Within the ASD group, the number of directional errors during the AS task was positively correlated with behavioral measures of restricted and repetitive behaviors.

GENERAL DISCUSSION AND CONCLUSIONS

Experimental evidence has frequently reported that individuals with ASD demonstrate reduced attention to social information (Pelphrey et al., 2002; Dawson et al., 1998; Sasson et al., 2007). Eye movement research has also reported that children and adults disproportionately allocate attention to non-social information relative to control groups during passive viewing visual tasks (Sasson et al., 2008; 2011; Chawarska et al., 2012). Irregularities have consistently been reported when social and non-social information are presented concurrently. Narrowed and perseverative patterns of attention have been conceptually linked to restricted and repetitive behaviors in ASD, specifically circumscribed interests (Pierce and Courchesne, 2001; Klin et al., 2002; Sasson et al., 2008; 2011). The overall aim was to use both passive viewing attention tasks and tasks requiring cognitive control in conjunction with eye-tracking technology to identify effects of social and non-social stimuli on visual attention in ASD. To identify unique patterns of attention in ASD, eye-tracking measures were compared to typically developing children. Additional comparisons were made to children with pediatric OCD, another neurodevelopmental disorders characterized by restricted and repetitive behaviors. Overall, it was hypothesized that children with ASD would demonstrate disproportionate patterns of attention and impaired volitional control over attention in response to non-social objects related to circumscribed interests relative to control groups. These hypotheses were tested using a combination of tasks- passive viewing visual preference as well as pro- and antisaccade tasks requiring cognitive control over attention.

During a visual preference task, individuals with ASD demonstrated significantly decreased looking time to social stimuli when presented with non-social objects relative to the control group.

Reduced attention in ASD specifically due to concurrently displayed non-social, circumscribed interest images was not reported. When faces were presented with other every day common objects, individuals with ASD differed only from the control group. These findings are in line with previous experimental evidence using preferential looking paradigms (Klin et al., 2002; Pierce et al., 2011). As opposed to in typical development, the overall weight of social information in ASD has been shown to be altered (Chevallier et al., 2012a; 2012b) leading to atypical patterns of eye-gaze and attention allocation (Senju and Johnson et al., 2009). When social information is paired with non-social information, there also appears to be a disproportionate shift in attention in ASD towards non-social information (Klin et al., 2002; Nakano et al., 2010; see also Kuhl et al., 2005 for research regarding the auditory modality) particularly information related to circumscribed interests. Findings in the current task, regarding preferential looking to objects in conjunction with increased detail orientation when looking at objects, support previous research using visual search paradigms. While viewing complex visual arrays containing both social and non-social images, individuals with ASD have been characterized as displaying reduced visual exploration in conjunction with perseverative and detail-oriented patterns of attention (Sasson et al., 2008; 2011).

Current results more directly address the result of social and non-social competition, specifically the impact of non-social information conceptually related to circumscribed interests within ASD. Not only are individuals with ASD viewing social information in an atypical manner as has been reported consistently through previous research, but they are also attending to social information significantly less than other non-social information. Previous models have been proposed that suggest decreased attention to social information paired with increased attention to concurrently presented non-social information reflects altered saliency of social and non-social information in ASD (Pierce and Courchesne, 2001; Klin et al., 2002). Findings presented here extend these hypotheses regarding altered saliency, to specifically highlight the saliency of non-social information in ASD and their impact on attention. Human attention is limited in capacity (Dawson, Meltzoff, & Osterling, 1998); therefore, classes of information that are increasingly salient or given a higher a-priori weight win the battle for attentional resources. In the current context, not only is attention drawn to non-social object based information, but the salience of non-social objectsappears to be superior to that of social information.

The preferential looking paradigm in Experiment 1 was able to explore unique patterns of attention between two clinical groups, ASD and OCD, with overlapping behavioral phenotypes. Preferential looking to objects versus faces as well as detail-oriented styles of attention may be distinctive to ASD. Though studies investigating interrelations between ASD and OCD (Cath et al., 2008; Anholt et al., 2009: see also Ivarsson and Melin, 2008 for a review of pediatric OCD and ASD) have reported an overlap in impairments in social processing and attention switching, to date no studies of attention in OCD have reported increased detail-orientation and an increased focus on objects. Beyond unique patterns of attention, the stimuli chosen for Experiment 1 serves as a conservative proxy of circumscribed interests in ASD. Results support hypotheses of distinct patterns of reflexive attention in ASD associated with non-social information; however, specific results regarding the impact of non-social information related to circumscribed interests were not upheld. Additional research is necessary to investigate qualitative differences in attention in ASD in comparison to other neurodevelopmental disorders characterized by under-focused attention, such as ADHD, and similar perseverative and repetitive behavioral patterns, such as OCD seen here. Experiment 1 illustrates how assessment of visual attention may be used to quantify discrete aspects of behavior specific to ASD, including the important modulating effect of competing social and non-social information.

While Experiment 1 measured reflexive attention in response to social and non-social stimuli, Experiment 2 investigated volitional control over attention in response to these social and non-social stimulus categories. Parent reports of children with ASD have indicated that circumscribed interests can interfere with play, interactions with peers, as well as obstruct day to day activities (South et al., 2005). Studies of visual attention have demonstrated that children and adults with ASD display patterns of narrowed, perseverative attention and reduced visual exploration in response to visual stimuli related to circumscribed interests (Sasson et al., 2008; 2011). In Experiment 2 it was explored whether social and non-social stimuli, particularly non-social stimuli related to circumscribed interests, can influence cognitive control over attention in children and adolescents with ASD. Overall, it was hypothesized that children and adolescents with ASD would display an increased rate of directional errors during visual saccade tasks, particularly in response to non-social objects.

During a visually guided prosaccade task, the ASD and OCD groups displayed an increased total directional error rate relative to typically developing controls. When directional error was compared across groups according to stimulus type, the ASD group made more directional errors in comparison to typically developing controls across all stimulus categories. During an antisaccade task, the ASD group displayed an increased total directional error rate relative to both typically developing controls and participants with OCD. Just as in the prosaccade task, the ASD group made more directional errors in comparison to typically developing controls across all stimulus categories. The only reported difference in directional error between the ASD and OCD groups was in response to LAI images; however, other differences represented trend level effects and approached but did not reach significance.

Though differential effects of social and non-social stimuli on cognitive control over attention were not reported, findings replicated previous reports of deficits in ASD participants' ability to inhibit prepotent responses in an antisaccade task (Minshew et al., 1999; Mosconi et al., 2009; Manoach et al., 2011; Luna et al., 2004; 2007; Goldberg et al., 2002). Conclusions made regarding differences between ASD and OCD groups are conservative and made with caution due to drastic differences in sample sizes. These results are considered preliminary and exploratory and serve as foundation from which to build additional research on ASD and OCD upon. In addition, few studies to date have investigated differences in response inhibition between ASD and OCD utilizing similar tasks. Within OCD, reports of saccadic behavior are unclear and inconsistent. More recent experimental evidence indicates that patients with OCD display a normal rate of saccadic errors; however, differ significantly from typically developing controls in physical aspects of saccadic behavior (i.e., latency, impairment in smooth pursuit) (McDowell and Clementz, 1997). Other research comparing OCD to other clinical populations such as schizophrenia has suggested that impairments in response inhibition may be more severe in other clinical disorders and differences observed in OCD may be specific to reaction times and smooth pursuit performance (Niewenhuis et al., 2004). However, these studies are primarily concerned with saccade performance in adults and impairments in response inhibition have been reported in pediatric OCD samples (Rosenberg et al., 1997).

As was stated previously following Experiment 2, studies of volitional control over attention should be readdressed in order to better understand the impact of stimulus category on these cognitive processes. In order to address the moderating effects of different stimulus categories on the cognitive control over attention, a simplified version of Posner visual tasks was employed to more directly address the effects of stimulus category. Previous studies that have employed such a task (Luna et al., 2004; 2007; Manoach et al., 2011: Golderg et al., 2002) have implemented the task with geometric shapes and/or LED light displays. The current study design is novel in comparison both in research question and design; therefore, to specifically address impact of stimulus category other variations (i.e., stimulus location and task demands) were minimized. This simplification may have introduced a confound in internal validity to answering our question regarding cognitive control over attention in response to varying social and non-social stimuli.

Saccade tasks are commonly used to study cognitive deficits in various psychiatric illnesses outside of ASD, such as schizophrenia, mood disorders, and anxiety disorders. The current study has replicated previous experimental evidence of impaired response inhibition in ASD in comparison to typically developing controls and children with pediatric OCD; however, to address research questions on the effects of stimulus category either (a) standard antisaccade tasks should be employed (see Thakkar et al., 2008; Luna et al., 2007) or (b) the use of additional executive attention tasks should be explored. Variations on other executive function tasks have been used to measure the distractibility of social and non-social information in ASD. During a visual search paradigm where an individual was asked to locate a “target” (i.e., a blue butterfly) within a visual array, typically developing children were slower at detecting a target when a face was present within the visual array. This same effect was not reported in children with ASD (Riby et al., 2012). Additional research has adapted the Stroop task to include both social and non-social distractor stimuli placed on screen while participants complete a standardized Stroop paradigm (Chevallier et al., 2012). Reports indicate that Stroop interference increases with social distracters in typical development; whereas, the opposite pattern is observed in ASD. This research indicates that when stimulus type (social or non-social) is irrelevant to completing cognitively demanding tasks, the reduced distractibility of social information coupled with the increased distractibility of non-social information in ASD represent that altered a-priori weight of faces and other social information.

Though Experiments 1 and 2 stated separate research questions and employed different tasks, taken together these results provided support for impairments in disengaging and shifting attention in ASD as well as the impact of social and non-social competition for perceptual resources. Posner and colleagues have conceptualized attention as an organ system, divided into interrelated neural systems (alerting, orienting, and executive). The orienting network is responsible for "moving" attention and the selection of information from sensory input. Disengaging, shifting, and reengaging attention are key operations of the orienting system that serve spatial selectivity and aid in making automatic and quick responses. Reports on attention within ASD generally focus more heavily on the dysfunction of disengagement and shifting attention (Posner and Dehaene, 1994); however, few studies to date directly address the differential patterns of attention in response to varying social and non-social stimuli. The preferential looking paradigm implemented in Experiment 1 demonstrates anomalies and impairments in the alerting and orienting networks of attention in ASD. Children and adolescents with ASD displayed disproportionate patterns of attention to non-social objects over images of faces in comparison to both typically developing children and those with pediatric OCD. The aim of Experiment 2 was to investigate impairments in orienting attention and executive control over attention in response to social and non-social stimuli; however, task design may have reduced the ability to tap into this executive network and its control over orienting attention to different classes of stimuli. At the very least, previous research was replicated and impairments in inhibiting reflexive saccades were reported in children with ASD.

Across both experiments, relations were reported between task performance and symptom measures of social impairment and restricted and repetitive behaviors of ASD. Patterns of attention to non-social objects were found to be related to measures of global repetitive behavior severity and impairment in social communication (see results in Experiment 1). In addition, performance during the antisaccade task was directly related to measures of restricted and repetitive behaviors (see results in Experiment 2). These results are in line with previous research and provide further evidence that oculomotor measures and performance on cognitive tasks are related to the severity of repetitive behaviors within ASD (Agam et al., 2010), in particular tasks that require response to social and non-social information, stimulus conditions that not surprisingly tap into behavioral and cognitive deficits in ASD (Ozonoff, 1995).

Despite limitations of both experiments that have been mentioned and discussed throughout this dissertation, the present study has extended and replicated previous lines of research regarding impairments in attention in ASD as well as the aberrant processing of social and non-social information in comparison to typical development. A novel contribution of the current investigation was to begin to explore attentional impairments specific to ASD in comparison to children with OCD, another developmental disorder with a similar behavioral phenotype of restricted and repetitive behaviors. Patterns of reflexive attention in ASD in response to concurrently displayed social and non-social images suggests differences in comparison to the OCD group. During a task requiring volitional control over attention, the ASD group made a significantly greater number of directional errors and these errors were directly related to measures of repetitive behaviors. These findings support models of altered saliency of social and non-social informationin ASD though specific hypotheses regarding the effects of non-social images related to circumscribed interests were not upheld. In addition, the assessment of visual attention and oculomotor behavior may be used to quantify impairments in ASD as well as discrete aspects of the repetitive behavior phenotype in ASD.

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