

AFFECT-MODULATED POSTAURICULAR REFLEXES OF CHILDREN WITH  
AUTISM SPECTRUM DISORDER

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## **ABSTRACT**

MEGAN L. KOVAC: Affect-modulated Postauricular Reflexes of Children with ASD  
(Under the direction of Rune J. Simeonsson and Gabriel S. Dichter)

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impaired functioning in two domains: (1) social communication and interaction, and (2) restricted interests, repetitive behaviors, and sensory sensitivities. The present study examined affect-related postauricular responses to social and nonsocial pictures in children with ASD using a protocol that integrated psychophysiology, caregiver ratings of symptom severity, and Ecological Momentary Assessments (EMA). Results were suggestive of greater postauricular responses among children with ASD while viewing nonsocial images related to circumscribed interests but not other nonsocial images or social images, indicative of greater positive affective responses to images related to circumscribed interests compared to their typically developing peers. Correlations between psychophysiological responses and symptom severity in both core autism domains (i.e., social deficits and restricted interests) were examined, as were correlations with self-reported affect obtained via EMA. The results of this study suggest that postauricular reflex responses may be a useful tool for studying affective responses in children with ASD.

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## **LIST OF ABBREVIATIONS**

PAR	Postauricular reflex
ASD	Autism spectrum disorder
TD	Typically developing
CI	Circumscribed interests
PI	Primary Interests
HAI	High Autism Interest
NNI	Nonsocial Neutral Interest
ERP	Event-related potential
CDC	Center for Disease Control
EEG	Electroencephalography
EMA	Ecological momentary assessment
PA	Positive affect

## **CHAPTER 1: INTRODUCTION**

### **Autism Spectrum Disorder**

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impaired functioning in two domains: (1) social communication and interaction, and (2) restricted interests, repetitive behaviors, and sensory sensitivities. (American Psychiatric Association, 2013). Although ASD was once considered extremely rare, prevalence rates have spiked in the last two decades, increasing 78% from 2002 to 2008, prompting public awareness campaigns and invigorating research efforts to identify causes and potential treatments. Recent epidemiological studies indicate that ASD now affects approximately 1 in 68 children in the United States (Baio, 2014). ASD is more common among males (i.e., 1 in 42 males compared to 1 in 189 females) (Baio, 2014). It is associated with a number of genetic disorders (e.g., Fragile X syndrome, Prader-Willi syndrome) but a specific genetic cause has not yet been identified. Indeed, relatively little is known about what causes ASD, but recent research has identified the following as risk factors: genetic factors (King et al., 2013), advanced parental age (Hultman, Sandin, Levine, Lichtenstein, & Reichenberg, 2011; Lampi et al., 2013), family history (Lauritsen, Pedersen, & Mortensen, 2005), and the presence of other medical conditions (e.g., Fragile X syndrome).

The second domain of impairment encompasses a broad range of repetitive behaviors, including circumscribed interests. Circumscribed interests (CIs) are intense and encompassing preoccupations or interests often exhibited by individuals with ASD

(American Psychiatric Association, 2000). CIs are considered relatively common in ASD; one study found that approximately 88% of individuals with ASD experience CIs (Klin, Danovitch, Merz, & Volkmar, 2007).

## Study Goal

The goal of the present study was to use psychophysiology to examine affective responses to social and nonsocial stimuli in children with ASD. The study focused exclusively on positive affect, an area that has received little attention in ASD research to date, in order to better understand how affective functioning may contribute to approach motivation for social and nonsocial behavior in ASD. Specifically, this study examined affect-modulation of the postauricular reflex (PAR) in children with and without ASD while they viewed three categories of images: social images, non-social images that tend to be of high interest to children with ASD (“High Autism Interest” or HAI), and non-social images that do not tend to be of high interest to children with ASD (“Nonsocial Neutral Interest” or NNI). The HAI images represented the most commonly reported categories of circumscribed interests for individuals with ASD (Sasson, Dichter, & Bodfish, 2012; Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011). Postauricular reflex responses were then correlated with caregiver reports of restricted interests and social impairments to determine the extent to which PAR response magnitudes corresponded to symptomatic impairments. Finally, the PAR response magnitudes were correlated with EMA data to determine whether PAR magnitudes corresponded to subjective reports of affect and behavior in a real-world context.

The specific research questions were: (1) Do children with ASD exhibit different affective responses measured by the PAR to social, “High Autism Interest,” and “Nonsocial

Neutral Interest” stimuli, compared to children without ASD? (2) Is there a significant association between affective responses measured by the PAR and clinical severity of core ASD symptoms? (3) Is there a significant association between affective responses to the different categories of stimuli and subjective reports of affect in a real-world context.

## Background

### *ASD and Affect*

In 1943, Leo Kanner published the first clinical report of children with ASD, *Autistic Disturbances of Affective Contact*. He described 11 children who exhibited a rare “inability to relate themselves in the ordinary way to people and situations from the beginning of life” (Kanner, 1943). For most people, affect may vary somewhat based on different factors (e.g., environmental context) (Kuppens, Oravecz, & Tuerlinckx, 2010). For example, an individual may exhibit positive affect (e.g., happy, interested) if he or she is around friends or engaged in a pleasing activity. That same individual may exhibit negative affect (e.g., tense, worried) in more threatening circumstances. Although affect varies among individuals and across situations, that variability generally stays within a normal range and follows a predictable pattern. When affect is excessively labile, the likelihood of psychological maladjustment increases (Kuppens, Van Mechelen, Nezlek, Dossche, & Timmermans, 2007).

A multitude of complex cognitive, physiological, and psychological processes contribute to the emotional experiences of human beings. Affect can be thought of as the basic biological system underlying those processes and it can be reduced to positive (i.e., appetitive) and negative (i.e., defensive) responses. Psychophysiology researcher Peter Lang has articulated a cohesive hypothesis about the relation between affective state and motivational priming, which provides a helpful perspective for examining affective responses in ASD. The motivational priming hypothesis posits that an individual’s response to unconditioned stimuli will be modulated by the nature of the stimuli (i.e., threatening or appetitive) and the affective state of the individual at the time the response is elicited (Lang et al., 1998). These affect-modulated responses represent a basic survival circuit that recruits

autonomic physiological reflexes and influences appetitive responses (i.e., approach) or defensive responses (i.e., avoidance).

Typical patterns of affective response can be well understood in an evolutionary context (i.e., threatening stimuli elicit negative affective responses which compel people to flee, while desirable stimuli elicit positive affect and compel people to approach); however, affective functioning plays an important role in more immediate, real-world contexts. Psychophysiological research suggests that this basic system underlies most affective experiences, so it makes sense to examine affect-modulated psychophysiology in a population with deficits in affective functioning (Lang & Bradley, 2010).

ASD has been conceptualized as a disorder of affect because children with ASD often exhibit an unusually restricted range or an atypical pattern of affective responses. Typically developing children often exhibit positive affective responses toward their peers. Children with ASD, though, tend to exhibit odd or unusual affective responses during social interactions. For example, a child with ASD may exhibit minimal affective response when he or she enters the preschool classroom or playgroup, but he or she may become exuberantly excited (e.g., laughing, smiling, waving hands) when presented with a preferred object or routine.

### *Affect and Psychophysiology*

Affect can be measured by observing explicit physical or verbal cues (e.g., posture, facial expressions, words). More subtle indicators of affect can be measured using psychophysiology. Psychophysiology is a method of measuring physiologic responses to stimuli that are associated with psychological responses. It involves placing electrical



sensors, or electrodes, on precise points typically along the scalp and facial muscles (Cacioppo, Tassinary, & Berntson, 2007) to record task-related physiologic activity. Psychophysiology is an excellent tool for measuring physiological responses that cannot be seen with the naked eye. Furthermore, psychophysiology typically has excellent temporal resolution, which makes it ideal for addressing the temporal chronometry of affective responses.

There are certain reflexes that are modulated by affective state. That is, the magnitude of those reflexes covaries (i.e., attenuates or potentiates) with the affective state of the individual. Measuring the magnitude of those responses provides a highly reliable index of affective state. In the laboratory setting, affective state is elicited by showing individuals pictures of things that are positive (e.g., appetizing food), neutral (e.g., a pair of socks), or negative (e.g., mutilation). A startle probe, which is a quick and unexpected acoustic (e.g., burst of white noise) or tactile (e.g., puff of air) stimulus, evokes the reflex of interest and the magnitude of the reflexive response provides an index of affective state. For example, the startle eyeblink reflex is larger when individuals are in a negative state (e.g., viewing negative stimuli) and smaller when they are in a positive state (e.g., viewing positive stimuli) (Lang, Bradley, & Cuthbert, 1990). This method of studying affect-modulated psychophysiological reflexes is a valuable tool when investigating affective disorders.

### *The Postauricular Reflex*

The focus of the present study was the postauricular reflex (PAR), a psychophysiological response that is also sensitive to affective state (Benning, Patrick, & Lang, 2004). The postauricular muscle is a vestigial muscle located behind the ear. In lower

order mammals, the postauricular muscle helps draw the ears up and back to orient to sound. It also helps mammals pull their ears closer to the head to facilitate nursing (Johnson, Valle-Inclán, Geary, & Hackley, 2012). The location of the postauricular muscle makes even the largest responses difficult to observe with the naked eye. Consequently, psychophysiology is an excellent technique for observing and recording the PAR. Figure 1 illustrates how the PAR is measured using psychophysiological techniques.

Figure 1: Sensor placement for postauricular reflex recording

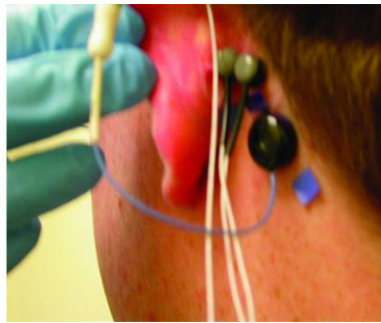


Image from [www.youngscientistjournal.org](http://www.youngscientistjournal.org)

There is a wealth of evidence showing that the magnitude of the PAR varies with the affective state of an individual. That is, when individuals are in a positive, or “approach” oriented, affective state, they exhibit a larger PAR (Benning, 2011). This makes the PAR an excellent index of positive affect. The PAR is suitable for measuring negative affect as well as positive affect in that negative stimuli have been shown to elicit smaller PARs (Benning, 2011), but it has been consistently identified as a uniquely reliable index of positive affect.

The first study to demonstrate a correlation between the PAR and affective response was published in 2004 (Benning et al., 2004). In that study, undergraduate college students viewed pleasant, neutral, and negative images while participating in psychophysiology recording sessions. Researchers found a significant effect of image valence on PAR response

magnitudes, indicating that PAR was greater when subjects were viewing positive pictures (e.g., women smiling) and smaller when viewing negative images (e.g., snakes, mutilation). A subsequent study yielded similar findings; PAR magnitudes were greater when subjects were viewing pleasant images than when they were viewing neutral or negative (e.g., people frowning) images. This pattern has been replicated in non-patient samples numerous times (Benning, 2011; Gable & Harmon-Jones, 2009; Hess, Sabourin, & Kleck, 2007; Sandt, Sloan, & Johnson, 2009).

### *The Postauricular Reflex and ASD*

Examining the PAR in children with ASD is novel and promising for a number of reasons. Affect-modulated psychophysiology has been rigorously examined in non-patient populations, but it has been largely overlooked in ASD research. Initial psychophysiological investigations have identified anomalous affective response patterns in adults with ASD (Bölte, Feineis-Matthews, & Poustka, 2008; Dichter, Benning, Holtzclaw, & Bodfish, 2010; Wilbarger, McIntosh, & Winkielman, 2009). The present study furthered this line of research by focusing on an appetitive or “approach” oriented reflex and image categories that were particularly relevant to core symptoms of ASD (i.e., social and nonsocial images) (Lang & Bradley, 2010).

Finally, a great deal of research has focused on symptoms of social impairment in children with ASD. In contrast, relatively little research has focused on what motivates children with ASD or why they tend to engage in certain behaviors. Since the PAR is an excellent index of appetitive responses, it is uniquely suited to addressing these questions.

### *Ecological Momentary Assessment (EMA)*

The link between the PAR and positive affect has been well established in the psychophysiology literature; however, few studies have examined the relation between affect-modulated psychophysiology, as measured in the laboratory, and affective functioning in the real-world context. To examine whether findings about the relation between PAR and positive affect in ASD were consistent across settings, an Ecological Momentary Assessment was used in the present study to assess self-reported affect outside of the laboratory setting.

EMA is a method of obtaining subjective information from respondents in a natural setting (Shiffman & Stone, 1998). It is a valuable tool for overcoming common roadblocks to accurate information gathering in laboratory settings and it has been increasingly used in research on substance abuse and mood disorders (Shiffman, Stone, & Hufford, 2008). It is particularly useful for gathering information about feelings or experiences that may be context-dependent. The ubiquity and accessibility of technology has made EMA a more viable option for researchers in recent years. EMA has been implemented successfully with different populations, including adolescents, severely mentally ill individuals, and individuals from disadvantaged backgrounds (aan, Hogenelst, & Schoevers, 2012; Forbes et al., 2012; Granholm, Ben-Zeev, Fulford, & Swendsen, 2013; Marhe, Waters, van, & Franken, 2013). EMA was employed in the current study to gather subjective reports of affect and behavior in real-world contexts as potential correlates of laboratory-based PAR measures of affective responses.

## Significance of Present Study

Atypical affective functioning is a salient feature of ASD, yet the physiological underpinnings of affect in ASD are not well understood. Through the use of psychophysiological methods in the laboratory and behavioral assessments across contexts, the present study sought to address this gap. Few studies have examined affect-modulated psychophysiology in children, and there have been no studies focused on the postauricular reflex in children with ASD. Other psychophysiological research in ASD has focused on event-related potentials (ERPs). These studies advance understanding of aberrant neural circuitry in children with ASD, but ERPs have been primarily discussed as correlates of cognitive processes (e.g., social cognition), social impairments (e.g., averted gazes), and aversion to change (Gomot et al., 2011; Kohls et al., 2011). These studies have focused on the mechanisms that underlie social cognition, while almost no research has focused on the mechanisms that underlie affective responses.

The present study was the first to examine affect-modulated PAR in children with ASD, which is significant for a number of reasons. First, a study published in 2010 found that adults with ASD did not exhibit the typical pattern of PAR responses while viewing unpleasant images (Dichter et al., 2010). The present study extended that line of research to children with ASD and is the first study to utilize stimuli specifically selected for individuals with ASD. Second, the PAR is an excellent index of positive affect and positive affect has been greatly understudied in ASD. Although common features of ASD include flat or overly negative affect (Snow, Hertzog, & Shapiro, 1987; Yirmiya, Kasari, Sigman, & Mundy, 1989), positive affect in response to circumscribed interests is an equally salient feature of ASD (Turner-Brown, Lam, Holtzclaw, Dichter, & Bodfish, 2011).

Finally, the addition of an EMA protocol furthered the potential impact of the present study. Only two studies have implemented an EMA protocol with children who have ASD, and only one study has attempted to correlate data obtained through EMA with physiological data (i.e., imaging or EEG) recorded in the laboratory (Forbes et al., 2012; Khor, Gray, Reid, & Melvin, 2014). The incorporation of EMA in the present study affirmed the feasibility of using this method with adolescents who have ASD and established a foundation for improving the links between clinical research and real-world experiences of families affected by ASD.

## **CHAPTER 2: METHODS**

### **Sample**

All procedures were approved by the UNC Institutional Review Board to ensure compliance with ethical guidelines in human subjects research. A total of 81 children (41 with ASD, 40 typically developing), ages 9-18 years, were recruited for a parent study at UNC-Chapel Hill. Children with ASD were recruited using the UNC Autism Research Registry, and typically developing children were recruited using the UNC listserve.

Inclusion criteria for the ASD group were:

- Previous diagnosis of ASD confirmed by a score above threshold for ASD on the Autism Diagnostic Observation Schedule (ADOS-G) (Lord, Rutter, DiLavore, & Risi, 2002), administered as part of the study procedure
- Average cognitive functioning, using a threshold of SS=70 on the Kaufman Brief Intelligence Test, Second Edition (KBIT-2), administered as part of the study procedure (Bain & Jaspers, 2010)

Inclusion criteria for the typically developing (TD) group were:

- No past or present diagnosis of developmental delay, psychopathology, or neurological disorders
- Average cognitive functioning, as described above, confirmed with the KBIT-2

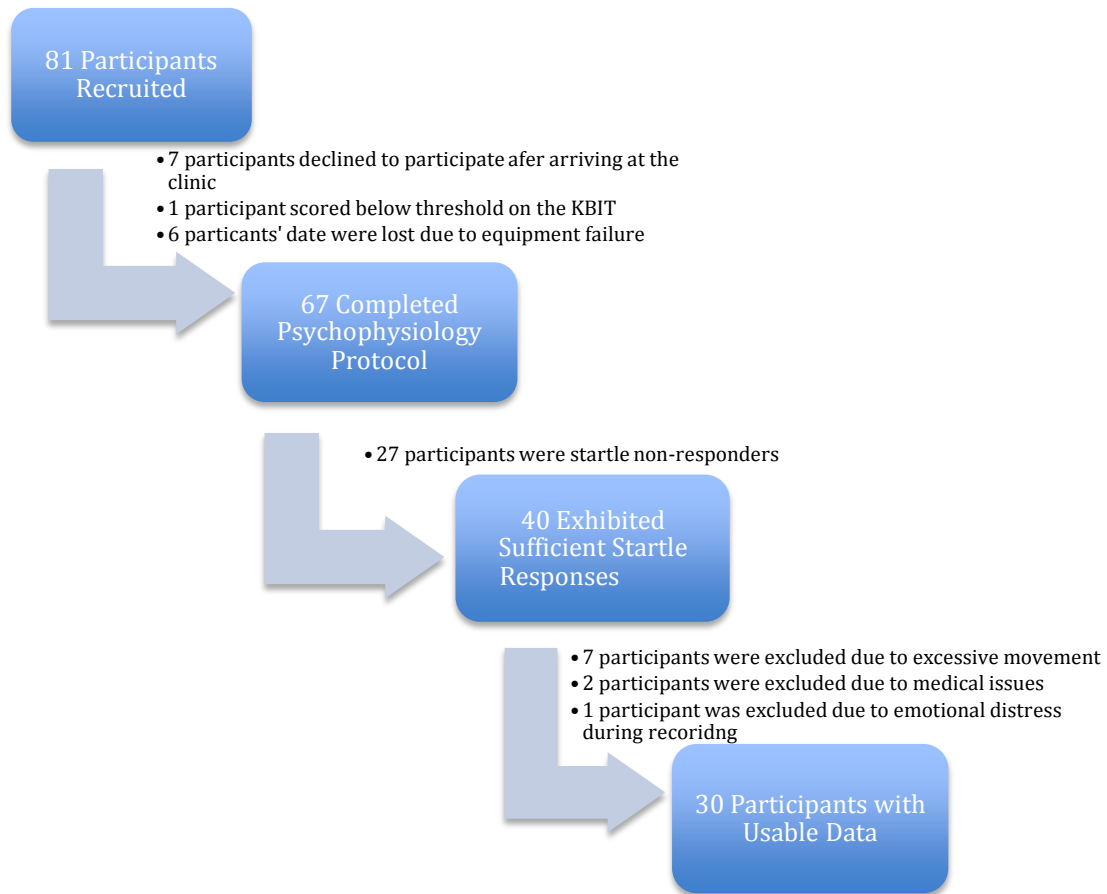
### *Psychophysiology Participants*

Of the 81 children enrolled in the study, 67 (35 with ASD, 32 typically developing) completed the psychophysiology protocol for the present study; however, usable psychophysiology data was obtained only for thirty participants. Seven participants chose not to complete the psychophysiology protocol because of discomfort with the procedure or the tasks (e.g., application of sensors, images, startle probe), and one participant obtained a score below the threshold for inclusion on the cognitive assessment. Data were lost for six participants due to technical problems with the recording equipment.

Twenty-seven participants (14 TD, 13ASD) who exhibited minimal responses across all three viewing conditions (i.e., mean response less than 2 microvolts) were considered startle non-responders and were excluded from analysis (Quevedo, Benning, Gunnar, & Dahl, 2009). Data from 10 additional participants (4 TD, 6ASD) were excluded for the following reasons: excessive movement (e.g., constantly tensing facial muscles, tapping fingers on desk, active facial tics), medical issues (e.g., neurocardiogenic syncope and hypoplastic left heart syndrome), and emotional distress during the recording session (e.g., one participant became frightened and upset in response to certain images). The attrition of subjects is illustrated in Figure 2.



Figure 2: Attrition of Psychophysiology Participants



The final sample of psychophysiology participants contained 30 children (16 ASD, 14 TD) and is described in Table 1. The ASD and TD groups did not differ with regard to age ( $F(1,28)=.003$ ,  $p=.96$ ), gender ( $\chi^2 = .238$ ,  $p=.626$ ), or IQ ( $F(1,28)=2.87$ ,  $p=.102$ ). Sixty-three percent of the sample was Caucasian, 27% was African American, 3% were Asian, and 7% endorsed Other Race on the demographic questionnaire.

#### *EMA Participants*

Participants could choose to participate in the EMA protocol regardless of whether or not they successfully completed the psychophysiology portion of the study, so although there

was some overlap between participants with usable psychophysiology data and usable EMA data, there were also participants who had only completed one portion of the study. A total of 42 participants (out of the 81 initially recruited for the parent study) agreed to participate in the EMA protocol. Three of those individuals withdrew before completing any surveys, citing conflicts with their schedule in two cases and unspecified reasons in the third case. The final EMA sample was comprised of 19 children with ASD and 20 typically developing children. Participants in the EMA sample were older than participants in the psychophysiology sample ( $t=2.83$ ,  $p=.006$ ), but they did not differ with regard to IQ ( $t=.35$ ,  $p=.73$ ) or gender ( $\chi^2 = 2.02$ ,  $p=.16$ ). Characteristics of the participants who were included in the EMA analyses are provided in Table 2. As with the psychophysiology sample, participants in the EMA sample were primarily Caucasian (77%). Fifteen percent of the sample self-identified as African American, 3% identified as Asian, and 5% identified as Other.

#### *Participants with Both Psychophysiology and EMA Data*

To pursue the third research question regarding associations between PAR responses and self-reported affect, participants had to complete the psychophysiology protocol and the EMA protocol. Since not all participants completed both protocols, and since a substantial portion of the psychophysiology data were not usable, the PAR-EMA correlations were examined in a very restricted sample. The characteristics of those participants are reported in Table 3.

Table 1: Sample Characteristics for Participants with Usable Psychophysiology Data

	<b>N</b>	<b>Mean Age</b>	<b>% Male</b>	<b>Mean IQ</b>	<b>RBSR- RI Scale</b>	<b>SRS-T Score</b>
<b>ASD</b>	16	12.38 (SD=3.28)	88%	104.31 (SD=17.32)	3.38 (SD=2.09)	75.31(SD=8.32)
<b>TD</b>	14	12.43 (SD=2.17)	93%	114.71 (SD=16.16)	0 (0)	57.93 (SD=3.67)

Table 2: Sample Characteristics for Participants with EMA Data

	<b>N</b>	<b>Mean Age</b>	<b>%Male</b>	<b>Mean IQ</b>	<b>RBSR- RI Scale</b>	<b>SRS-T Score</b>
<b>ASD</b>	19	14.11 (SD=3.33)	74%	102.2 (SD=16.9)	2.61 (SD=2.06)	76.3 (SD=7.48)
<b>TD</b>	20	14.5 (SD=1.96)	80%	113.1 (SD=10.6)	.1 (SD=.3)	57.7 (SD=3.66)

Table 3: Sample Characteristics for Participants with Usable Psychophysiology and EMA Data

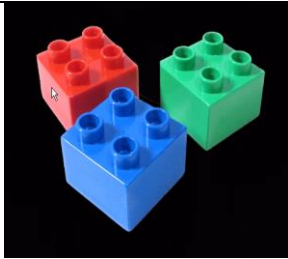


	<b>N</b>	<b>Mean Age</b>	<b>%Male</b>	<b>Mean IQ</b>	<b>RBSR- RI Scale</b>	<b>SRS-T Score</b>
<b>ASD</b>	6	13.17 (SD=3.65)	83%	117.17 (SD=12.58)	4 (SD=2.45)	78.5 (SD=4.04)
<b>TD</b>	6	12.83 (SD=2.40)	100%	110.83 (SD=7.08)	0 (SD=0)	57.67 (SD=2.50)

## Measures and Materials

### *Psychophysiology*

Psychophysiology data were collected using E-prime to present visual stimuli, Neuroscan hardware and SCAN software to record PAR responses, and MATLAB to reduce and analyze the PAR data. Psychophysiological responses were collected using Discount Disposables (St. Albans, Vermont) 4mm Ag-AgCl electrodes filled with electrolyte paste. The visual stimuli for the psychophysiology data came from two sources. The social stimuli were selected from the NimStim image set (Tottenham et al., 2009). The HAI, or “High Autism Interest,” images consisted of non-social images that were previously determined to be of high interest to children with ASD (e.g., trucks, clocks, mechanical devices) based on research using subjective ratings and visual exploration tasks (Sasson et al., 2012; Sasson et al., 2011). The NNI, or “Nonsocial Neutral Interest” images, consisted of non-social images that have been shown *not* to be the common focus of circumscribed interests in ASD and which have been shown to have equivalent subjective ratings by individuals with and without ASD (Sasson et al., 2012). Figure 3 provides examples of each image type described above.

Figure 3: Examples of High ASD Interest, Non-social Neutral ASD, and Social Images

High Autism Interest (HAI)	Nonsocial Neutral Interest (NNI)	Social
		

#### *Behavioral Measures for Inclusion Criteria and Symptom Severity*

Clinical assessments with well-validated psychometric properties were used to confirm diagnostic status (i.e., group membership) and capture symptom severity. The ADOS-G, which is recognized as a gold-standard assessment for ASD spectrum disorders, was administered to all participants in the clinical group (i.e., participants with ASD) (Lord et al., 2002). The Kaufman Brief Intelligence Test, Second Edition (KBIT-2), a brief psychometrically-sound cognitive screener with good psychometric properties, was administered to all participants to confirm intact cognitive functioning (i.e., Composite Intelligence Quotient greater than 70) (Bain & Jaspers, 2010).

Caregivers of all participants were administered an abbreviated version of the Autism Diagnostic Interview, Revised (ADI-R), as well as the Repetitive Behavior Scale, Revised (RBS-R). The RBS-R characterizes the frequency and severity of repetitive behaviors in six domains, including restricted interests (i.e., Restricted Behavior Subscale) (Bodfish, Symons, & Lewis, 1999). Caregivers also completed the Social Responsiveness Scale (SRS) to describe their child's competence and interest in social communication and social

interactions (Constantino et al., 2003), and the Interest Scale (IS) to provide information about their child's interests (Turner-Brown, Lam, Holtzclaw, Dichter, & Bodfish, 2011).

### *EMA Measures*

To gather data about participants' affect in naturalistic settings, an Ecological Momentary Assessment protocol using the Positive and Negative Affect Scale for Children (PANAS-C) (Laurent et al., 1999) was implemented. The PANAS-C measures the two core dimensions of affective functioning, positive and negative affect. It requires respondents to rate how much they feel like each of 30 different emotion words (e.g., *interested*, *sad*, *frightened*) using a likert-style scale. Scored responses yield overall Positive Affect (PA) and Negative Affect (NA) scores. Given the present study's focus on positive affect, only the PA scores were used in analysis. The PANAS-C has been validated with adolescent populations and has been successfully used in previous studies incorporating EMA protocols with children who have ASD (Forbes et al., 2012).

The PANAS-C was modified slightly to facilitate understanding and accessibility among participants in the present study. The response labels were modified to decrease language complexity (e.g., *moderately* was changed to *some*) and visual supports were added to facilitate comprehension for the participants with ASD. The paper-and-pencil format of the PANAS-C was translated to an online version using Qualtrics (see Figure 4). Online administrations was selected to maximize response rates by eliminating the need to mail surveys back to study personnel or interact with an interviewer over the telephone. Additionally, three questions were added to the beginning of the questionnaire to obtain

information about where participants were when they were contacted, what they were doing, and whom they were with.

Figure 4: Sample Item from the Modified Version of the PANAS-C

How much do you feel this way?

**INTERESTED**

Not at all      A little      Some      Quite a bit      A lot

○      ○      ○      ○      ○

Two measures were used to categorize the activities that participants were engaged in during the EMA as Circumscribed Interest/Primary Interest or not. The Autism Diagnostic Interview- Revised contains one item that focuses on circumscribed interests, so that measure was referenced when reviewing the EMA data and categorizing activity types as CIs or not. The Interest Scale (IS) requires caregivers to identify their child's Primary Interest (PI). This measure was used to identify typically developing participants' Primary Interests (PI) for categorization purposes. Categorizing PIs for the typically developing group provided a point of comparison between the ASD and TD groups when examining self-reported positive affect in highly preferred (i.e., CI or PI) activities.

The information that participants provided about whom they were with when they were contacted was used to categorize activities as either Social or Nonsocial. Activities

were categorized as Social if the participants reported being with friends, family, or two parents. Activities were categorized as Nonsocial if participants reported being alone or with one parent. The presence of more than one parent was required to qualify as a Social activity because the age range of the participants made it likely that they would be accompanied by one parent for supervision or transportation purposes, rather than social interaction.

## Procedures

### *Psychophysiology and Behavioral Assessments*

The psychophysiology recording session and the behavioral assessments took place at the Carolina Institute for Developmental Disabilities (CIDD). In order to reduce anxiety associated with psychophysiology procedures, a video illustrating the process was shared with participants prior to their arrival at the CIDD (<http://youtu.be/4a3qmDNaeuA>). On the day of the visit to the CIDD, participants were greeted, given a tour of the facility, and shown a schedule of activities for the day. Visual schedules were used for some participants to alleviate anxiety and facilitate understanding.

Postauricular reflex magnitudes were collected as part of a psychophysiology session conducted as part of a parent study that included measurement of other facial psychophysiological components as well as the application of an EEG cap. That session consisted of a brief orientation (30 min), sensor placement (30 min), and recording (30 min). Sensors were applied according to standard recommendations (Cacioppo et al., 2007). Recording locations were cleaned with mild cleansing swabs and scrubbed with gel that facilitates conductance of the electrical activity to the sensors. Next, sensors were affixed with adhesive collars. Recording sessions took place in a comfortable and well-controlled

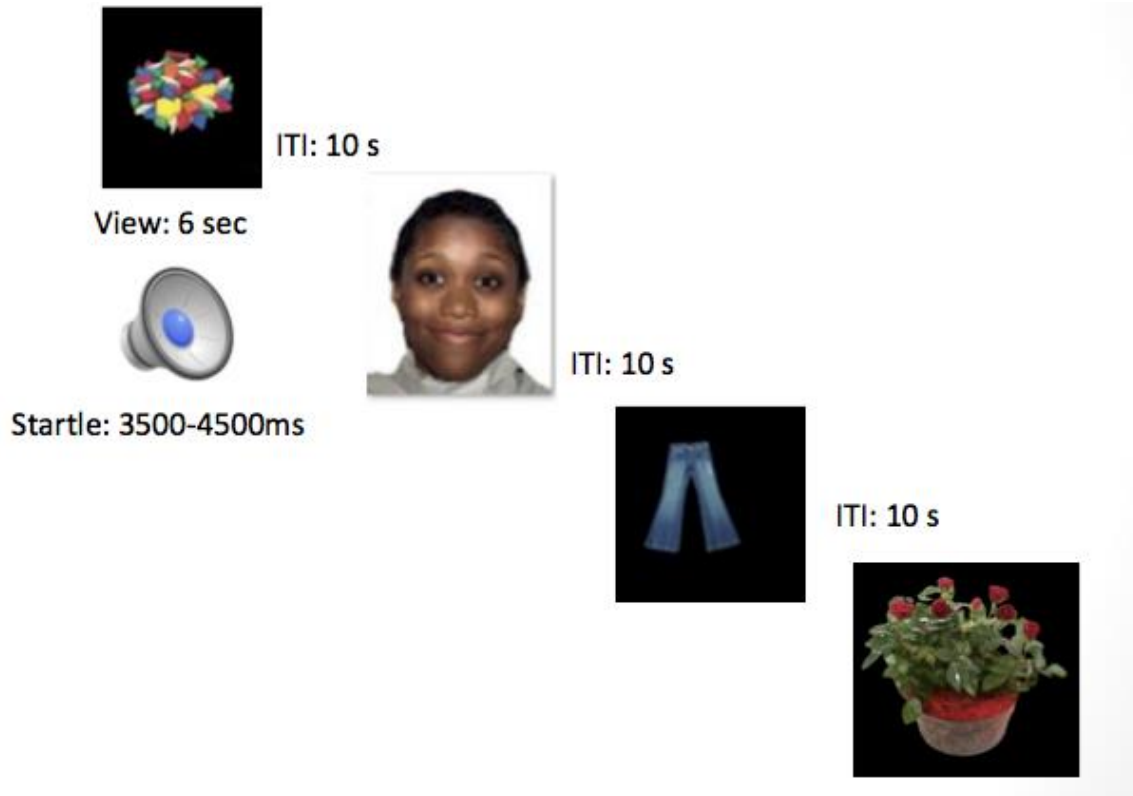


room, and stimuli were presented to subjects on a 24-inch computer monitor. The recording room was equipped with a camera and speaker so that the participant could be observed and communicate with the experimenter throughout the recording session.

The recording session for measuring PAR responses to the HAI, NNI, and Social images took approximately 12 minutes. Each participant viewed 10 images from each of three image categories, resulting in a total of 30 images viewed by each participant. The order of the images was counterbalanced across participants to control for order effects. There were 34 HAI, 40 NNI, and 19 Social images in the total image pool. An acoustic startle probe (i.e., a burst of white noise with instantaneous onset) was presented to elicit the PAR while participants viewed static images from each category. After viewing all images, participants completed valence and arousal ratings for each image. Subjective valence ratings reflected how positive or negative participants found each image and subjective arousal ratings reflected how exciting or calm they felt after viewing each image.

The specific presentation procedure is illustrated in Figure 5. First, an image from one of the three image categories appeared on the screen and remained there for 6 seconds. Approximately 3500 milliseconds after the image appeared on the screen participants heard the startle probe (i.e., a brief burst of white noise) to elicit the PAR response while viewing that image. There was a 10 second inter-trial interval between each image presentation to allow time for the effect of each image to dissipate.

Figure 5: Illustration of Psychophysiology Viewing Task Procedure



#### *Ecological Momentary Assessment of Affect*

The EMA protocol consisted of six automated prompts to complete the Mood Check over the course of four days: one Friday afternoon, two on Saturday, two on Sunday, and one on Monday afternoon. In most cases, the EMA protocol was explained during the visit to the CIDD. Participants and their caregivers provided contact information (i.e., email addresses and phone numbers) and the windows of acceptable contact times (e.g., Friday between 3:00 and 6:00 p.m.) were confirmed. Contact windows did not interfere with school or academic tasks. Participants were told that the goal was to “catch” them doing things that they typically do when they have free time. Caregivers were asked to confirm whether it was likely that their child would be engaged in a primary interest (e.g., circumscribed interests for

participants with ASD) during the set contact times to increase the likelihood of obtaining affect ratings from participants while they engaged in circumscribed interests.

The prompts were delivered via email and text message to ensure that they reached participants in a variety of settings. Each prompt contained the Mood Check number (1-6), the participant ID, and a link to the online survey. Participants were shown screenshots of what the email/text message prompts would look like, as well as screenshots of the Mood Check. The Mood Check was reviewed with the participants and caregivers to ensure complete understanding of the vocabulary and instructions.

Three participants (two with ASD and one without ASD) were unable to receive the administration overview during their visit to the CIDD but indicated a strong desire to participate. For those subjects, the administration procedure was explained via telephone. Additionally, for two participants who did not have text messaging enabled on their cell phones prompts were delivered via telephone calls to their cell phones and the surveys were completed online.

After the six mood checks were administered, the data were reviewed. In two cases, follow up was required to clarify what the participants were doing during when they were texted because their initial responses were too ambiguous to categorize.

## Data Analysis

### *Data Acquisition and Preparation*

The psychophysiology data were recorded using a SynAmp2 64-channel system. Data were sampled at 2000 Hz with alternating current (AC) and 500 Hz low-pass filter. The postauricular muscle responses were acquired as streams of continuous waveforms using

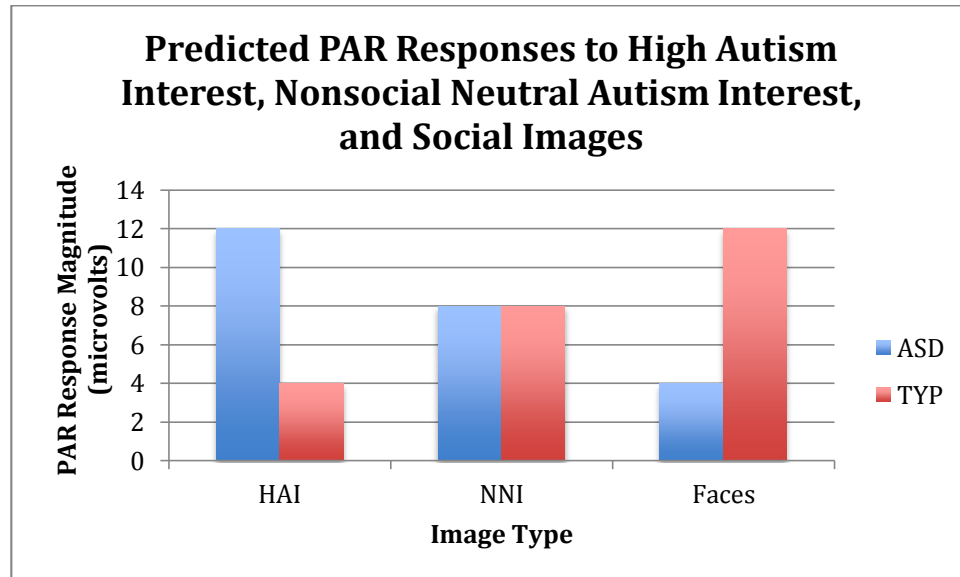
Neuroscan SCAN v.4.3.1 software, with condition markers (i.e., stimulus presentation, startle probes) digitally denoted in the files. The condition markers were used to identify specific windows of time for extracting PAR response magnitudes based on trigger onset and stimulus type (i.e., image category). Data were then processed in MATLAB, to extract PAR responses within the specified windows and calculate within-subject baseline and peak magnitude responses. PAR responses were assessed by averaging aggregate waveforms across all pictures within a single category (i.e., HAI, NNI, Social). Baseline averages were determined based on the 50ms prior to stimulus onset and peak averages were determined by the maximum activity during the 8-30 ms post image onset. The PAR magnitude was then calculated using the difference between baseline and peak response magnitudes. Data were visually inspected for artifact or systematic error. Automated correction (ARTCOR) was employed to correct for data artifacts (e.g., sneezes, stretches, yawns). Corrected data files were further processed in SAS to generate mean PAR response magnitudes in microvolts for each image category for each subject. The resulting data were then analyzed using SAS. The level of significance for all analyses was set at  $p < .05$ .

*Research Question 1: Do children with ASD exhibit different affective responses measured by the PAR to social, “High Autism Interest,” and “Nonsocial Neutral Interest” stimuli, compared to children without ASD?*

The first research question was addressed using a Group (ASD, TD) x Category (HAI, NNI, social) repeated measures ANOVA with group as the between-subjects factor and the three image categories as the within-subjects factor. Follow up t-tests were used to examine group differences in PAR responses to specific image categories. Given the reduced sample

size due to attrition, effect sizes were calculated using Cohen's  $d$  to further explore the magnitude of differences between PAR responses of children with ASD and typically developing children. It was predicted that, within the ASD group, PAR magnitudes while viewing HAI images would be greater than PAR magnitudes while viewing NNI images, which in turn would be greater than PAR magnitudes while viewing social images. For the TD group, it was predicted that PAR magnitudes while viewing social images would be greater than PAR magnitudes while viewing NNI images, which in turn would be greater than PAR magnitudes while viewing HAI images. This predicted trend is illustrated in Figure 6, and it would suggest that children with ASD exhibit significantly greater positive affect when viewing HAI images relative to the other two image categories. Finally, *post-hoc* analyses explored the role of age and gender on PAR response magnitudes in the three viewing conditions.

Figure 6: Predicted trend in PAR response to High Autism Interest, Nonsocial Neutral Autism Interest, and Social Images



Valence and arousal ratings data were analyzed using similar Group (ASD, TD) x Category (HAI, NNI, Social) repeated measures ANOVAs. Follow-up t-tests were conducted to examine group differences in subjective ratings for each image category.

*Research Question 2: Is there a significant association between affective responses measured by the PAR and clinical severity of core ASD symptoms?*

The second research question was examined using Pearson correlation tests. The PAR response magnitudes exhibited by children with ASD were correlated with scores from the Social Responsiveness Scale (SRS) and the Restricted Interest subscale of the Repetitive Behavior Scale (RBS-R RI). It was predicted that children with ASD who exhibited relatively greater PAR potentiation to HAI images would have higher scores on the RBS-R (RI), indicating increased severity with regard to restricted interests. It was further predicted that children with ASD who exhibited smaller PAR responses to images of faces would have

higher scores on the SRS, indicating increased levels of social impairment. Data from the typically developing group were correlated with symptom severity measures as well, in case there were any signals that sub-clinical symptom severity may be correlated with relative elevations in PAR responses to HAI images or relative decreases in PAR response to Social images. It was expected that no correlation would be observed in the Typically Developing group.

*Research Question 3: Is there a significant association between affective responses to the different categories of stimuli and subjective reports of affect in a real-world context?*

The final research question was addressed in an exploratory fashion due to the limited number of participants that completed both the psychophysiology and the EMA portions of the study. Data were examined using scatterplots, for descriptive purposes only, to determine whether PAR responses correlated with subjective reports of positive affect in real-world settings. The primary correlation of interest for Question 3 was between PAR potentiation to HAI images and mean positive affect during CI activities. It was predicted there would be a positive correlation between PAR responses to HAI images and mean Positive Affect when engaged in CI activities, for the ASD group. A positive association was also predicted between the PAR responses to HAI images and positive affect while engaged in PI, for the TD group. Descriptive statistics were generated to examine behavior patterns related to social and nonsocial activities for both groups. Correlations between PAR responses to HAI and Social images and EMA-reported frequencies of social and nonsocial behavior were also examined.

### **CHAPTER 3: RESULTS**

To thoroughly examine affect-modulated PAR responses to HAI, NNI, and Social images, mean PAR response magnitudes were used in analysis. To examine relations between affective responses and caregiver reports of restricted interests and social impairment, individual PAR response magnitudes were correlated with symptom severity scores on the RBS-R Restricted Interest Scale and the SRS. Finally, to explore relations between affective responses and self-reported positive affect, individual PAR responses were correlated with EMA data. Additional correlations were examined between PAR responses and time spent in Circumscribed Interest/Primary Interest activities and Social activities. The variables used in these analyses are summarized in Table 4.



Table 4: Summary of Variables Used in Analyses

Variable	ASD	TD	t value	p value	d value
<b>PAR Magnitude to High Autism Interest Images</b>	4.65 (SD=3.13)	2.98 (SD=1.16)	1.98	p=.06	.75
<b>PAR Magnitude to Nonsocial Neutral Interest Images</b>	4.31 (SD=2.83)	3.55 (SD=2.22)	-1.74	p>.10	-.64
<b>PAR Magnitude to Social Images</b>	3.77 (SD=1.91)	3.66 (SD=1.97)	.15	p>.80	.05
<b>Repetitive Behavior Scale, Revised (Restricted Interest Scale) Score</b>	3.38 (SD=2.09)	0 (0)	6.45	p<.001**	2.36
<b>Social Responsiveness Score (T-Score)</b>	75.31(SD=8.32)	57.93 (SD=3.67)	7.56	p<.001**	2.77
<b>Overall Positive Affect</b>	34.45 (SD=10.19)	33.72 (SD=7.1)	.26	p>.70	.08
<b>Positive Affect in Social Activities</b>	37.33 (SD=9.95)	34.43 (SD=7.82)	.86	p>.60	.28
<b>Positive Affect in Nonsocial Activities</b>	30.31 (SD=8.09)	32.87 (SD=11.16)	.40	p>.60	.13
<b>Positive Affect in Circumscribed Interest or Primary Interest Activities</b>	40.18 (SD=10.90)	39.87 (SD=8.04)	.09	p>.90	.03
<b>Time Spent in Social Activities</b>	55%	65%	-1.11	p>.20	-3.6
<b>Times Spent in Circumscribed Interest or Primary Interest Activities</b>	44%	21%	2.59	p=.01*	.83

## Research Question 1: PAR Response Magnitudes While Viewing HAI, NNI, and Social Images

### *Postauricular Response Magnitudes*

The first research question regarding PAR response magnitudes to HAI, NNI, and Social images was examined using a repeated measures ANOVA and follow-up t- tests. It was predicted that children with ASD would exhibit different PAR responses to the HAI, NNI, and Social images, relative to typically developing peers. The rationale for this prediction rested, in part, on the appetitive quality of the HAI images for children with ASD. Since PAR is an index of positive affect, it was predicted that the HAI images would be most appealing to the ASD group, followed by the NNI images and then the Social images. That pattern would be reflected in a linear trend of PAR response magnitudes to the three image categories. The HAI images were not expected to be particularly appealing to the TD group, especially compared to Social images. Consequently, a different pattern of PAR responses was predicted in the TD group such that the PAR responses would be greatest while viewing Social images, followed by the NNI images, and then last, by the HAI images.

The omnibus Group (ASD, TD) x Category (HAI, NNI, Social) repeated measures ANOVA revealed no main effect of Category on PAR response magnitudes ( $F(1,28)=1.99$ ,  $p>.15$ ), no main effect of Group on PAR response magnitudes ( $F(2, 27)=.07$ ,  $p>.90$ , and no Category x Group interaction ( $F(2,27)=1.50$ ,  $p>.20$ ). These findings were contrary to the *a priori* hypotheses that the PAR responses of children with ASD would differ from PAR responses of children with typical development. A Group x linear Category trend test approached significance ( $F(1,28)=3.07$ ,  $p<.10$ ), suggesting that the linear pattern of PAR

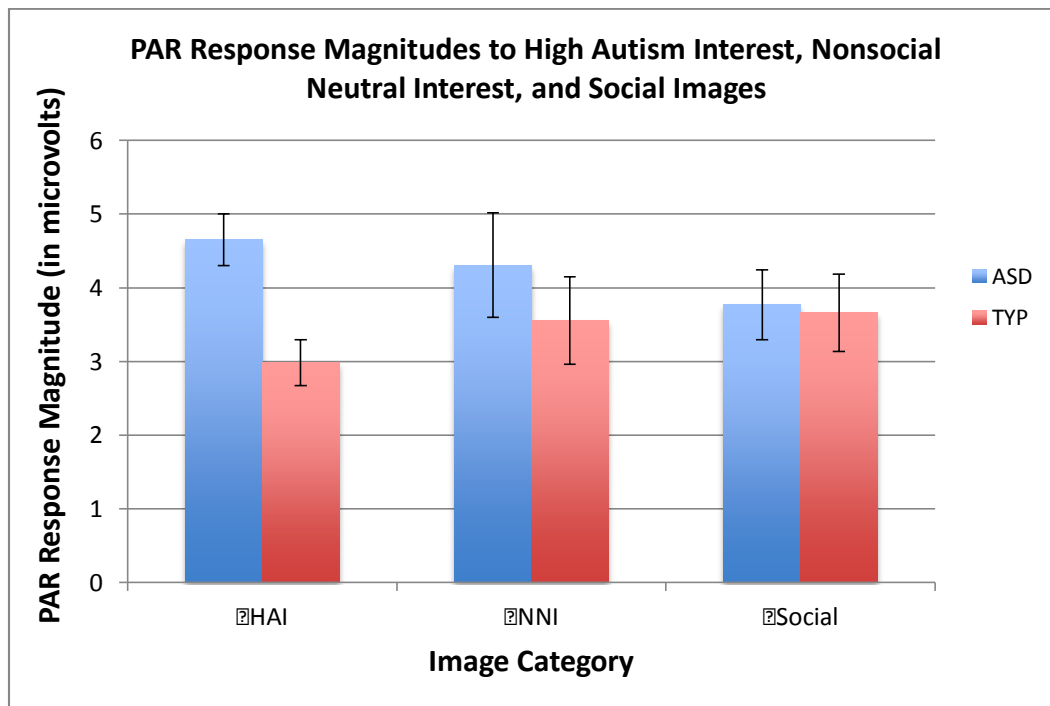
responses to HAI, NNI, and Social images was different between groups. The psychophysiological data is suggestive of a trend in the ASD group of greater PAR responses to HAI images, followed by smaller PAR responses to NNI images, and yet smaller responses to Social images; however, that observation is speculative given the non-significant statistical results.

In follow-up testing, the Satterthwaite t-test was used to compare groups on PAR responses to HAI images because the assumption of equality of variance was not met. The difference between ASD response magnitudes and TD response magnitudes to HAI images approached significance ( $t=1.98$ ,  $p=.06$ ), suggesting relatively greater approach orientation towards the HAI images in the ASD group. Although the difference was not significant, the trend was consistent with the hypothesis that the HAI images would be particularly appealing to the participants with ASD. Due to the small sample size, effect sizes were calculated to further explore the magnitude of differences in PAR responses between groups. The estimate of effect size ( $d=.75$ ) was large, further supporting the trend toward greater appetitive responding (and thus greater approach motivation) to the HAI images among participants with ASD (Cohen, 1988). There was no group difference in PAR responses while viewing NNI images ( $t=-1.74$ ,  $p>.10$ ); however, there was a medium effect size ( $d=-.64$ ), suggesting a trend toward greater PAR responses to NNI images in the ASD group. There was no group difference in PAR responses while viewing Social images ( $t=.15$ ,  $p>.80$ ) and the effect size was very small ( $d=.05$ ). Mean PAR responses are displayed in Figure 7. It was notable that substantial effect sizes were observed for PAR responses to both nonsocial image categories (i.e., HAI and NNI), but not for the social image category. This finding suggests that children with ASD exhibit different patterns of positive affective response to nonsocial

images, but not to social images, relative to their typically developing peers. Considering how positive affect influences approach motivation, it may be that the different appetitive responses to nonsocial images plays an important role in the development of key behaviors in ASD (i.e., circumscribed interests and social impairment).

Potential effects of gender and age were explored by conducting two follow-up ANOVAs, controlling for age in the first analysis and controlling for gender in the second. Including age and gender as covariates did not significantly change the results of any PAR analyses ( $F(2, 27)=1.77, p>.15$ ,  $F(2,27)=1.75, p>.15$ , respectively).

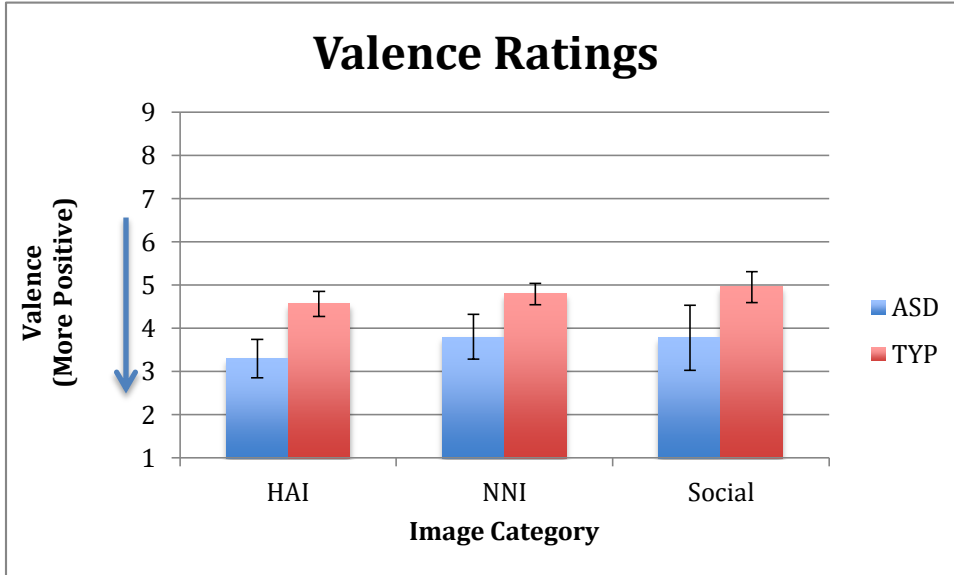
Figure 7: Mean PAR Responses to High Autism Interest, Nonsocial Neutral Autism Interest, and Social Images



### *Valence and Arousal*

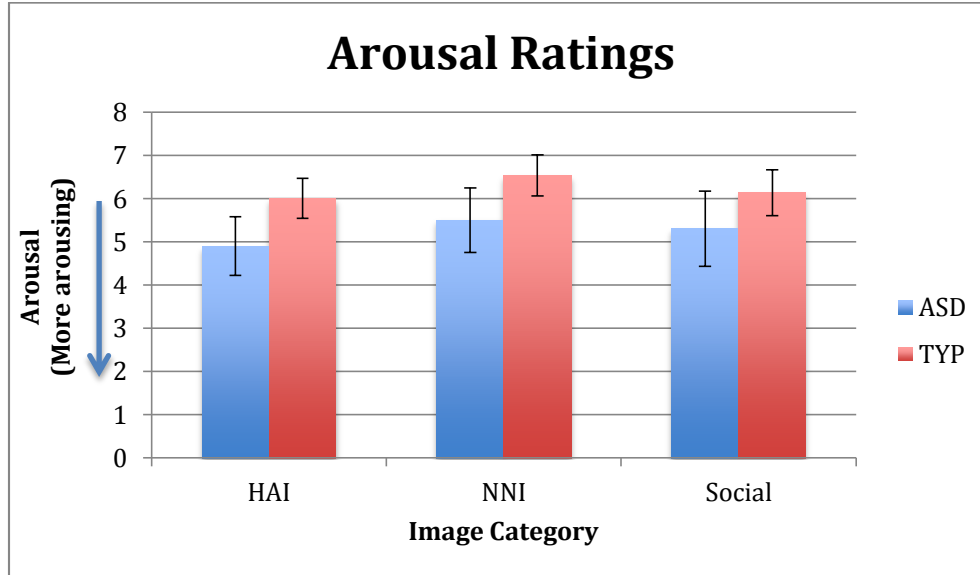
Mean valence and arousal ratings provided by participants in both groups are presented in Figure 8. Ratings data from six participants indicated inadequate comprehension of the task (e.g., same rating endorsed every time) so they were excluded from the analysis. The results of a 2x3 repeated measures ANOVA indicated no main effect of Category ( $F(2,21)=2.44$ ,  $p>.10$ ) and no interaction effect ( $F(2,21)=.40$ ,  $p>.70$ ). The main effect of Group on Valence ratings approached significance ( $F(1,22)=4.22$ ,  $p=.05$ ), suggesting that across all image categories, the ASD group rated images as more pleasing. Valence ratings for the HAI images differed between groups ( $t=-2.45$ ,  $p<.03$ ), with the ASD group rating the HAI images as more pleasing than did the TD group. There were no group differences in valence ratings for the NNI images ( $t=1.74$ ,  $p>.10$ ) or the Social images ( $t=-1.4$ ,  $p>1.8$ ). The group difference in subjective valence ratings of HAI images was consistent with the trend toward group differences observed in PAR responses while viewing HAI images. This pattern suggests that the HAI images were more pleasing to the ASD group than the TD group. The fact that the HAI images were the only images to elicit significantly different valence ratings affirms the unique appeal that HAI images had for children with ASD.

Figure 8: Valence Ratings



Analysis of the arousal ratings revealed a main effect of category ( $F(2,21)=9.65$ ,  $p<.01$ ), suggesting that the three image categories differed in how arousing they were to both groups of participants. There were no interaction ( $F(2,21)=.15$ ,  $p>.85$ ) or group effects ( $F(1,22)=1.35$ ,  $p>.25$ ). Follow-up testing indicated no group differences in arousal ratings for the HAI ( $t=-1.38$ ,  $p>.18$ ), NNI ( $t=-1.21$ ,  $p>.20$ ) images or the Social images ( $t=-.85$ ,  $p>.40$ ). Mean arousal ratings are illustrated in Figure 9.

Figure 9: Arousal Ratings

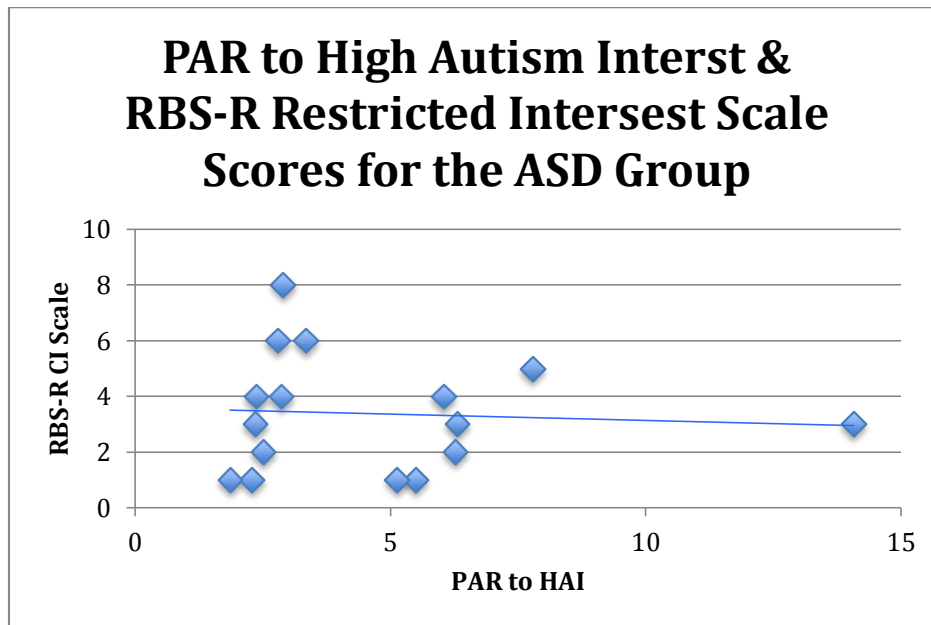


#### Research Question 2: PAR Responses and Symptom Severity

The second research question asked whether PAR responses to different images related to symptom severity for children with ASD. It was predicted that greater PAR responses to HAI images would be positively correlated with caregiver reports of restricted interests, and that smaller PAR responses to Social images would be correlated with greater social deficits. To explore these hypotheses PAR responses to HAI images were correlated with scores from the Restricted Interest subscale of the Repetitive Behavior Scale, Revised and T-scores from the Social Responsiveness Scale (see Figure 10). Contrary to the hypothesis, there was no association between PAR responses to HAI images and symptom severity as reported on the RBS-R Restricted Interest Scale ( $r = -.07, p > .70$ ). This suggests that positive affective responses to HAI images were not related to the intensity or impairment experienced as a result of CIs. Within the TD group, there were no elevations on

the RBS-R Restricted Interest Scale so a correlation between PAR responses to HAI images and RBS-R scores was not examined.

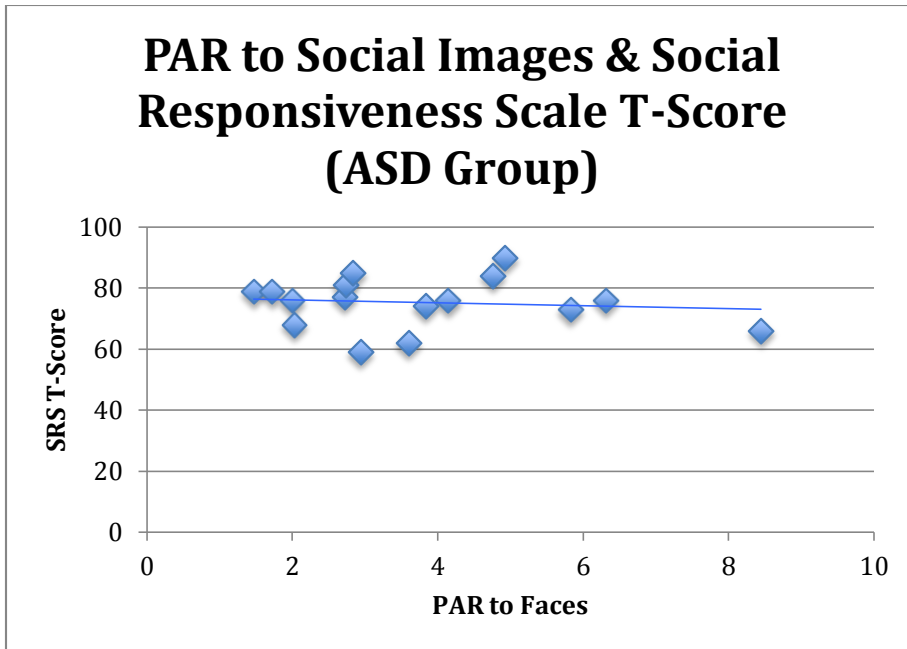
Figure 10: PAR Response to High Autism Interest Images and Repetitive Behavior Scale, Revised Restricted Interest Subscale Scores for the ASD Group



With regard to PAR responses to social images and levels of social impairment as reported on the Social Responsiveness Scale, there were no associations observed in either the ASD ( $r = -.11$ ,  $p > .50$ ) or the TD group ( $r = -.19$ ,  $p > .30$ ). These results were inconsistent with hypotheses and indicated that there was no relation between positive affective responses to social images and levels of social impairment in children with ASD or typically developing children. Overall, results addressing the second research question indicated that there were no associations between PAR responses and severity of symptoms related to restricted interests or social functioning. The correlation between PAR responses to Social images and SRS-T-Scores for the ASD group are shown in Figure 11.



Figure 11: PAR Response to Social Images Correlated with Social Responsiveness Scale T-Scores for the ASD Group



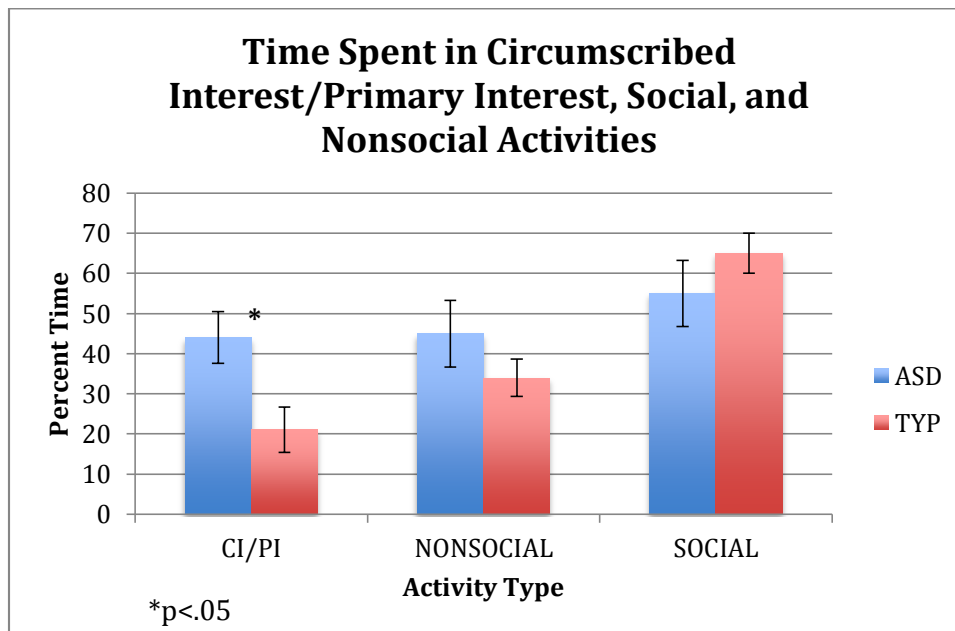
### Research Question 3: Ecological Momentary Assessment

#### *Response Rates and Frequency of Social and Nonsocial Behavior*

The third research question focused on whether PAR responses to HAI or Social images correlated with self-reported affect obtained using an Ecological Momentary Assessment protocol. There were 39 participants in the EMA sample. Each participant was asked to complete six mood check surveys, resulting in a total of 234 surveys sent. Participants completed 210 of those surveys, yielding a 90% response rate (94% among controls, 85% among participants with ASD). One survey was deemed unusable because it had been filled out by a caregiver and was excluded from further analysis. The response rates indicated a high level of compliance among all participants and exceeded average rates of response in other EMA studies (Hufford & Shields, 2002). The number of surveys completed did not differ between the groups. There was no correlation between age and the number of surveys completed ( $r=-.23$ ,  $p>.16$ ) or IQ and the number of surveys completed ( $r=.27$ ,  $p>.05$ ).

Each response was classified as a Circumscribed Interest or Primary Interest activity, based on the criteria described in Chapter 3. Sixteen (84%) of the participants with ASD completed at least one mood check while engaged in a CI; however, only eight (40%) of the participants without ASD completed at least one mood check while engaged in a Primary Interest (PI). Similarly, within the ASD group, participants were engaged in CI activities 44% of the time, while participants without ASD were engaged in PI activities only 21% of the time (see Figure 12). In general, participants with ASD reported being engaged in CI activities significantly more often than their typically developing peers reported being engaged in PI activities ( $t=2.59$ ,  $p=.01$ ).

Figure 12: Percent Time Spent in Circumscribed Interest/Primary Interest, Nonsocial, and Social Activities By Group



#### *PAR and Self-Reported Positive Affect*

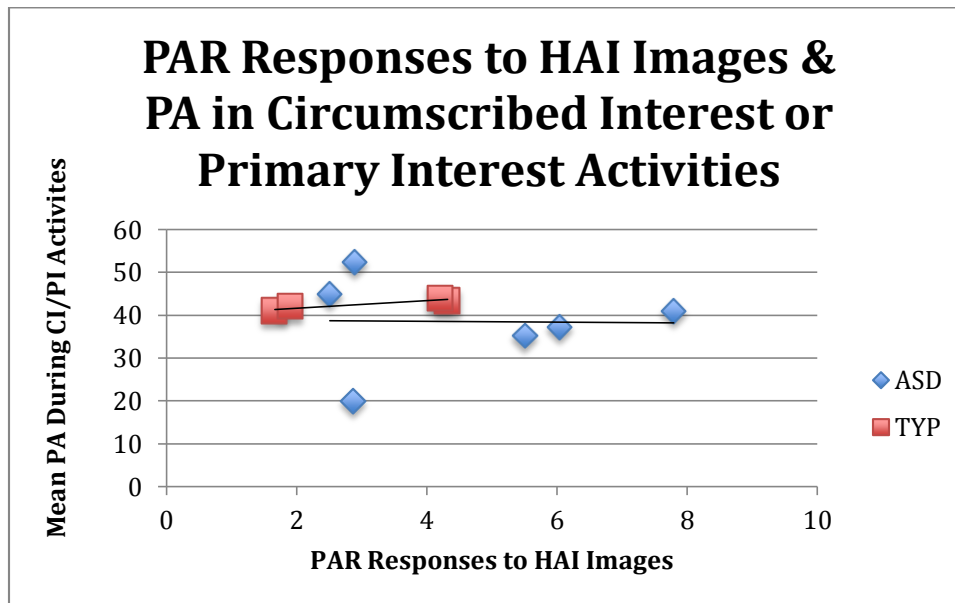
The mean positive affect score was calculated for each subject across all mood checks completed. The mean positive affect for the subjects with ASD was 34.45 (standard deviation=10.19) and the mean positive affect score for the typically developing subjects was 33.5 (standard deviation= 7.11). There was no difference in overall positive affect between the two groups ( $t=.26$ ,  $p=.80$ ). Mean Positive Affect scores for each group are shown in Table 5.

Table 5: Mean Positive Affect

	<b>ASD</b>	<b>TD</b>	<b>t value</b>	<b>p value</b>
<b>Overall PA</b>	34.45 (SD=10.19)	33.72 (SD=7.1)	.26	<i>ns (p&gt;.70)</i>
<b>PA in Social Activities</b>	37.33 (SD=9.95)	34.43 (SD=7.82)	.86	<i>ns (p&gt;.30)</i>
<b>PA in Nonsocial Activities</b>	30.31 (SD=8.09)	32.87 (SD=11.16)	.40	<i>ns (p&gt;.60)</i>
<b>PA in CI/PI Activities</b>	40.18 (SD=10.90)	39.87 (SD=8.04)	.09	<i>ns (p&gt;.90)</i>

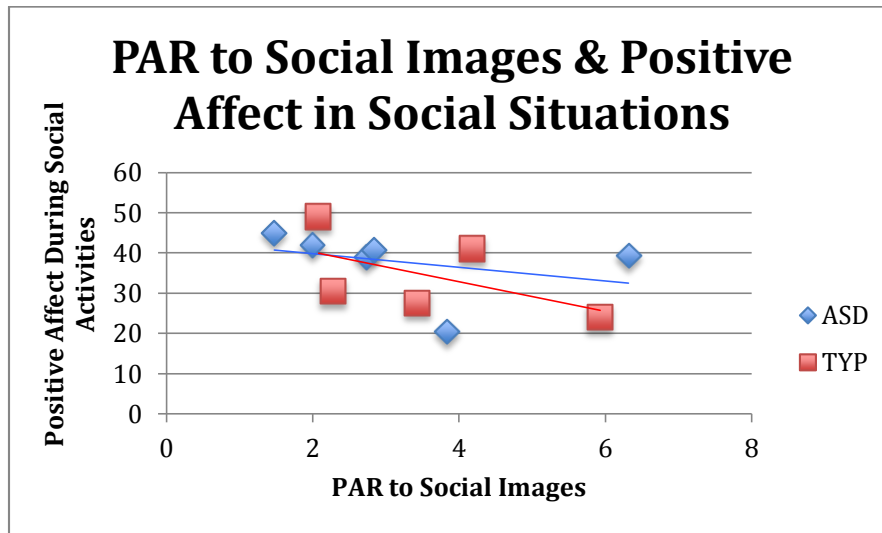
The number of participants who completed both the psychophysiology and the EMA protocol was quite small (6 ASD, 6 TD) and thus analyses were under-powered and must be interpreted with caution. Data are displayed using scatterplots for descriptive purposes only. As illustrated in Figure 13, the predicted relation between PAR responses to HAI images and self-reported positive affect while engaged in CI/PI activities was not observed in the ASD group or in the TD group. In the TD group, there appeared to be a positive association between PAR responses to HAI images and self-reported positive affect while engaged in Primary Interest activities.

Figure 13: PAR to High Autism Interest Images and Positive Affect in Circumscribed Interest/Primary Interest Activities



With regard to PAR response magnitudes to social images and positive affect while engaged in social activities both groups displayed a subtle pattern of negative association between PAR responses to social images and positive affect while in social situations (i.e., greater PAR responses to social images appeared to be associated with lower levels of positive affect while engaged in social situations). These results are displayed in Figure 14. This was a surprising trend, given the prediction that greater PAR responses would be associated with positive affect during engagement in social activities. In general, the social images did not appear to evoke particularly strong PAR responses from participants in either group, so it is possible that the lack of appetitive salience of these images contributed to this finding. An alternative explanation could be that the positive affective responses evoked while viewing images of faces has relatively little to do with the more complex experience of engaging with other socially in real world settings.

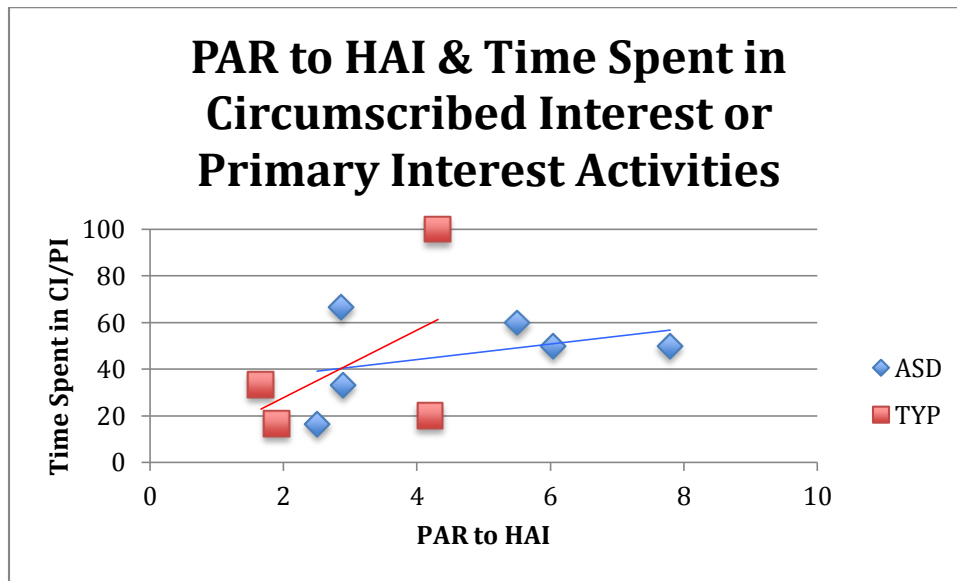
Figure 14: Relation Between PAR to Social Images and Positive Affect in Social Situations



#### *PAR and Frequency of Behavior*

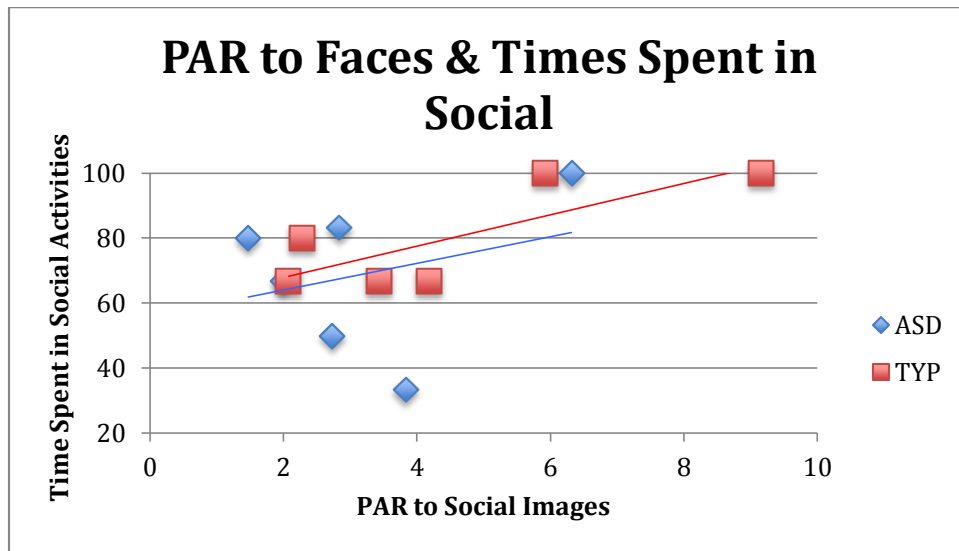
Potential relations between PAR response magnitudes and the amount of time participants spent in different activities were also examined (see Figure 15). Consistent with the study goals of better understanding how positive affect related to restricted interests and social behavior in ASD, these analyses focused on relations between PAR responses and time spent in CI/PI activities and PAR responses and time spent in Social activities. In the ASD group, the relation between PAR responses to HAI images and time spent in CI activities appeared to trend in a positive direction, suggesting that participants with ASD who exhibited greater positive affect while viewing HAI images spent more time engaged in CI activities. The results were similar in the TD group; there appeared to be a positive relation between PAR responses to social images and time spent in PI activities.

Figure 15: Relation Between PAR to High Autism Interest Images and Time Spent in Circumscribed Interest/Primary Interest Activities



There was a strong positive association between PAR responses to Social images and amount of time spent in social situations for the TD group, which suggests that children who found the social images more pleasing spent more time in social situations in natural settings (see Figure 16). The association between PAR responses to Social images and amount of time spent in social activities was more subtle in the ASD group, though the data trended in a similar direction. Overall, the pattern of association between PAR responses to HAI images and Social images and the frequency of different types of behavior (i.e., CI/PI and Social behavior, respectively) suggested that in both groups participants who exhibited greater PAR responses to HAI images spent more time engaging in CI/PI activities and participants who exhibited greater PAR responses to Social images spent more time engaging in social activities.

Figure 16: Relation Between PAR to Social Images and Time Spent in Social Activities





## CHAPTER 4: DISCUSSION

### Findings

The present study examined a psychophysiological index of affective response in children with ASD to improve understanding of positive affect and the role it plays in the key domains of impairment in ASD. According to the motivational priming hypothesis, positive affective responses are pre-conscious, physiological responses that prepare individuals to approach or avoid certain situations. By applying the theoretical framework of the motivational priming hypothesis), the present study sought to examine whether children with ASD would exhibit greater approach motivation to images related to circumscribed interests, relative to their typically developing peers. The study further examined whether greater approach motivation to those images would be associated with positive affect and behavior in a real-world context.

The first research question focused on PAR responses to High Autism Interest, Nonsocial Neutral Interest, and Social images in children with and without ASD. Overall, psychophysiological results were suggestive of group differences in PAR responses HAI images. Specifically, the large effect size ( $d = .75$ ) suggested that participants with ASD tended to exhibit larger PAR responses to HAI images than their typically developing peers, which represents a trend toward greater appetitive responding to HAI images in the ASD group. Subjective valence ratings were consistent with this trend. Ratings for the HAI images from the ASD group were significantly more positive than ratings for the HAI images from the TD group. Considering this trend in context of the motivational priming hypothesis,

affective responses to HAI images may contribute to the intense and pervasive Circumscribed Interests that characterize many individuals with ASD.

The Group x Image Category linear trend approached significance, suggesting different patterns of PAR responses among the three image categories between the ASD and the TD group. This is consistent with previous research which has demonstrated atypical modulation of affect-modulated startle responses in individuals with ASD (Dichter et al., 2010; Wilbarger et al., 2009). In light of these findings, further exploration of the potential link between positive affective responses and approach motivation to engage in CIs is warranted.

The only other study that examined PAR responses in individuals with ASD reported notably low levels of PAR modulation to three image categories (Dichter et al., 2010). The image categories in that study were positive, neutral, and negative, and the patterns of modulation exhibited by the ASD group in that study made it difficult to determine whether the atypical pattern of responses exhibited by individuals with ASD reflected a deficit in basic affective reactivity or modulation patterns that differed based on the emotional content of the stimuli. The modulation patterns and valence ratings reported in the present study suggest that this question may best be pursued by continued examination of affective responses to images that are particularly appealing to individuals with ASD.

The relatively surprising finding of a significant main effect of group on valence ratings may also be relevant in designing future research studies. The fact that participants with ASD rated all of the images as more positive, regardless of image category, may suggest that the process of viewing images on a computer screen is a more positive experience for children with ASD than it is for children without ASD. Such a finding may have

implications for the multitude of computer-based interventions being developed to promote academic and social skills among children with ASD.

In seeking to understand why the psychophysiological results did not yield the predicted effects for the NNI and Social conditions, a few points should be considered. The final sample size was reduced due to difficulties with data acquisition, participant compliance with the protocol, and excessive artifact in a substantial portion of the psychophysiology data. Participants in the present study completed a full psychophysiology protocol as part of a larger study, which required the individual application of multiple EEG electrodes and an EEG cap. Although the process is harmless it could be unpleasant to children with sensory sensitivities or low tolerance for unfamiliar experiences. These methodological factors likely contributed to the low percentage of usable psychophysiology data. Since some of the analyses were near significance, it is likely that a larger sample size may have yielded stronger effects. An additional consideration is that the valence and arousal ratings for the Social images were relatively moderate across both groups. That is, neither group identified the Social images as especially appealing or arousing, so they may not have captured the positive or appetitive qualities of social interactions. Previous research has demonstrated the importance of using images that are sufficiently arousing, especially when examining appetitive reflexes. For example, Sandt and colleagues found that PAR response magnitudes were significantly greater when participants viewed appetitive-related stimuli (e.g., food, erotica) compared to non-appetitive pleasant stimuli (adventure) (Sandt et al., 2009). This may have also contributed to the lack of correlation between affective responses and caregiver reports of social impairment.

The second research question pursued in the present study was whether PAR responses correlated with caregiver reports of symptom severity. Contrary to the hypotheses, there was no correlation between PAR response magnitudes to HAI images and restricted interests as reported on the RBSR-Restricted Interest scale in the ASD group. The lack of correlation may suggest that the subscale was too specific to capture the broad range of behaviors that could be associated with potentiated affective responses to HAI images. Similarly, the relation between PAR responses to Social images and levels of social impairment were not significant in either group. Since PAR is a particularly reliable index of positive affective state, it is possible that examining its relation with symptoms characterized by deficit or aversion (e.g., social deficits or active avoidance of social situations) is not ideal.

With regard to the third research question, the present study affirmed that EMA is a feasible measure to use with this population. It is one of only three studies to date to use EMA with participants who have ASD, and the response rates in both groups (85% in the ASD group, 94% in the typically developing group) exceeded average response rates in other EMA studies (50-90%) (Hufford & Shields, 2002). Notably, response rates did not differ between the groups and response rates did not vary as a function of age or IQ. The latter finding differs from results of a recent EMA study with adolescents who had ASD, which found that participants with lower IQs were less compliant (though inclusion criteria for IQ were roughly commensurate with the present study) (Khor et al., 2014). Additionally, the EMA protocol in the present study minimized cost by utilizing participants' own cellular phones. The fact that such impressive response rates were obtained using a cost-effective

protocol may inform how future studies leverage limited resources to incorporate EMA into their study design.

The results from the EMA portion of the present study provide a unique picture of how children with ASD spend their free time and how their “real-world” behavior correlates with a physiological index of positive affect. The finding that children with ASD were more likely to be engaged in CI activities than their typically developing peers were to be engaged in PI activities is consistent with the defining features of CIs (i.e., intense and pervasive). It was interesting, though, that there was no group difference with regard to the frequency of nonsocial behavior. Taken together, these two findings demonstrate the importance of pressing beyond the dichotomy of social versus nonsocial behavior when examining what children with ASD are motivated to spend their time doing.

The planned analyses for examining associations between PAR response magnitudes to HAI images and self-reported positive affect were complicated by drastic reductions in sample size; however, findings suggest it may be more important to examine the frequency of certain behaviors, as opposed to self-reported affect. In the TD group, for example, there seemed to be a strong association between PAR responses to Social images and the amount of time spent in social activities. In the ASD group, there appeared to be a positive association between PAR responses to HAI images and amount of time spent engaging in CIs.

It may be that the key to understanding how positive affect relates to motivation and behavior in ASD is examining what children with ASD do (i.e., activity types and frequencies) rather than relying on self-report of affective state. The measure used in the EMA protocol was relatively simple; however, it still required participants to cease their

current activity, reflect on their internal state, and rate their affective state. Each of those steps may be more complicated or more frustrating for children with ASD and, consequently, the information obtained may be a less reliable measure of affective state.

## Limitations

Several limitations must be noted with regard to the present study. First, the sample size for the psychophysiological analyses was relatively small, and the sample size for the correlational analyses of psychophysiological data and EMA data was extremely small. Consequently, results were considered preliminary with regard to affect-modulation of the postauricular reflex and exploratory with regard to the Ecological Momentary Assessment. Additionally, children with cognitive impairment were excluded from the present study so the results are limited to a subset of children with ASD (i.e., higher functioning children). With regard to the EMA procedure, participants were contacted six times over the course of four days. This was a relatively small number of contacts for an EMA study, though there is no evidence to suggest that increasing the number of prompts would have yielded more compelling results. Finally, the automated prompt system facilitated efficient data collection; however, it made it more difficult to ensure that participants completed the surveys right away or to confirm the method by which they filled out the survey (e.g., mobile device or computer).

## Future Directions

The use of affect-modulated psychophysiology in the present study represents an important step in adapting a traditional experimental protocol to address research questions

unique to ASD. Future studies may improve the percentage of analyzable data by modifying protocols to provide greater accommodations to participants with ASD (e.g., shortened protocols). The finding that participants with ASD exhibited greater PAR responses to High ASD Interest images, relative to their TD peers, is an important contribution to the literature on positive affect in ASD. Future research may expand on this finding by refining the Social image category to increase the appetitive salience of the social images (e.g., adding pictures of social scenes, rather than just faces) to examine whether greater differences may be observed between groups, across image categories. Similarly, the appetitive salience of the HAI category may be increased by “personalizing” the images to an individual’s CI or PI.

Future research should explore new ways to examine positive affect in ASD, with the specific goal of expanding current conceptualizations about what motivates the behavior of children with ASD. Focusing on positive affect is an important component to understanding the physiological underpinnings of key behaviors in ASD and for developing effective interventions and supportive environments.

EMA should be considered an important and viable method for ASD research. It is being increasingly used in a variety of fields and advances in technology promise to expand the breadth and depth of EMA-acquired data in coming years. ASD research stands to benefit from EMA’s ability to gather data from subjects in naturalistic settings, and innovative research designs incorporating multiple approaches (e.g., physiological, behavioral) will magnify the impact that research has on children and families living with ASD. For example, incorporating technology that records physiological data (e.g., heart rate) along with subjective reports of affective state could enhance future studies on affective functioning in ASD. Effective utilization of technology in ASD-focused EMA protocols

may prove an effective way to collect data from individuals across a broad range of real-world settings (e.g., home, school, recreation) and improve understanding and treatment of challenging behaviors. The technology may also prove useful in gathering data from individuals across a broad range of functioning, whether via non-verbal subjective report, caregiver report, or physiological assessments.

## Conclusion

The present study was the first to examine affect-modulation of the postauricular reflex in children with ASD in response to High Autism Interest, Neutral Nonsocial Interest, and Social images. One of the unique contributions of the present study was its emphasis on positive affect and how positive affect relates to the motivation to approach nonsocial, circumscribed interest activities in children with ASD. The trends observed in PAR responses to HAI, NNI, and Social images, considered alongside the substantial effect sizes for PAR responses to HAI and NNI images, provide initial evidence that the core symptoms of ASD may be influenced by greater approach motivation for images associated with circumscribed interests, rather than aversion to social images. These findings suggest that using visual stimuli that are specifically tailored to core deficits in ASD may be a promising approach to studying positive affect, especially as it relates to motivation for children with ASD to engage in certain behaviors. Additionally, the present study successfully implemented a low-cost EMA protocol with a broad age-range of children with and without ASD, affirming the feasibility of this important method in ASD research. Overall, findings from the EMA data indicated no group differences in self-reported positive affect; however, there were promising results when psychophysiological data were correlated with frequency



of behavior spent in social and nonsocial activities. In typically developing adolescents, for example, greater positive affect while viewing social images correlated with increased amounts of time spent in social situations in the real world setting. These findings have important implications for future research, especially with regard to improving understanding of the relation between affect and real-world behavior. Finally, the novel integration of psychophysiology and EMA used in the present study represents an important contribution to the literature on affective functioning in children with ASD.

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