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Attention Regulation and Social Competence in Younger Siblings of Children with Autism

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ATTENTION REGULATION AND SOCIAL COMPETENCE IN YOUNGER SIBLINGS OF CHILDREN WITH AUTISM

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Younger siblings of children with autism (Sibs-ASD) are at risk for the development of an Autism Spectrum Disorder (ASD) or subclinical social and cognitive deficits better known as the Broader Autism Phenotype (BAP).The current study utilized a multi-level approach to examine executive attention and social competence in preschool-aged Sibs-ASD and a comparison group of age-, sex-, and Verbal IQ-matched younger siblings of children without autism (Sibs-COM). Forty-two participants (24 Sibs-ASD, 18 Sibs-COM) completed a modified version of the Children's Attention Network Task (ANT), with electroencephalograph (EEG) collected simultaneously, and a peer interaction paradigm with an unfamiliar peer. Overall, Sibs-ASD and Sibs-COM displayed comparable performance on behavioral indices of the Children's ANT, P3 amplitude and latency, and measures of observed social functioning. Surprisingly, Sibs-ASD displayed a reduced (less negative) N2 amplitude and shorter N2 latency, most evident at Fz compared to FCz, a finding not observed in Sibs-COM. Furthermore, on a parent-report index of social functioning, Sibs-ASD reportedly displayed greater social impairments than Sibs-COM. Interestingly, post-hoc analyses indicated that differences in N2 amplitude and social functioning were most apparent between affected Sibs-ASD and Sibs-COM. Therefore, results of this study provide support for social and cognitive deficits consistent with theories of the BAP.

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CHAPTER 1: INTRODUCTION

Executive attention develops rapidly in early childhood, underlies several self-regulatory processes, and is an important predictor of social competence. It is hypothesized that early deficits in executive attention prevent children from flexibly attending to social information(Riggs et al., 2003; Riggs et al., 2006) and contribute to social deficits characteristic of several developmental psychopathologies (e.g., Pennington & Ozonoff, 1996) including autism (Mundy, 2003; Kenworthy et al., 2009).Interestingly, subclinical social deficits and executive dysfunction are also noted in some first-degree relatives of children with autism, which suggests that subtle deficits in executive attention may contribute to the presentation of subclinical social deficits. However, this relation in first-degree relatives of children with autism has not been examined.

In the proposed study, a multi-level analysis was conducted to examine how behavioral and neurophysiological (Electroencephalograph [EEG]/ Event Related Potentials [ERPs]) indices of executive attention could explain the relation between sibling group status and individual differences in social interaction. These associations were measured in a sample of children considered at-risk for the development of autism, the younger siblings of children with autism (Sibs-ASD), as well as in a matched sample of younger siblings of typically developing children (Sibs-COM). Specifically, it was hypothesized that differences in executive attention skills may partially mediate the association between sibling status and social interaction skills, thereby providing a mechanism accounting for the subtle social deficits seen in Sibs-ASD.

BROADER AUTISM PHENOTYPE AND SOCIAL COMPETENCE

Rubin and Rose-Krasnor (1992) defined social competence as a person's ability to achieve personal goals while simultaneously maintaining positive relationships with others over time and across situations. Based upon this definition, Yeates and colleagues (2007) proposed a heuristic model of how social competence develops through the dynamic interaction of three integral factors (information processing, social interaction, and social adjustment). Additionally, this model states that neurological insult, as observed in neurodevelopmental disorders, can lead to deficits in any or all of the three factors, thus impacting the development of social competence.

Yeates and colleagues' model is specifically applicable to the study of neurodevelopmental disorders such as autism, which is characterized by deficits in social skills in the areas of social communication, social interaction, and restricted and stereotyped behaviors (American Psychological Association, 2000).Although social deficits are common to the diagnosis of Autism Spectrum Disorders (ASDs), it has long been noted that there is great variability in the presentation of these deficits (e.g., Wing & Gould, 1979).Some children with ASDs are characterized by deficits in social approach, as evidenced by low levels of social initiation (e.g., Sigman & Ruskin, 1999). On the other hand, some children with ASDs show an interest in interacting with others, but show deficits in social reciprocity as noted by an inability to take the perspective of others or effectively continue conversations. These deficits in reciprocity may be due in part to poor metacognitive awareness and difficulties accurately monitoring one's own behavior and the reactions of others (Travis & Sigman, 1998).

Similar deficits in social approach and reciprocity are also observed among unaffected first-degree relatives of those with autism and these subclinical deficits characterize the broader autism phenotype (BAP; Bailey et al., 1998; Pickles et al., 2000). For example, parents with BAP characteristics often display personality traits that are characteristic of low levels of social approach, such as being aloof or shy, compared to parents who do not display these features (Murphy et al., 2000; Piven et al., 1994). In addition, they demonstrate poorer social reciprocity as seen on performance on the Eyes Task, a social-cognitive task assessing one's ability to decipher emotional states based on cues from only the eyes (Losh & Piven, 2007).

Similarly, there is some evidence that siblings of children with autism display comparable deficits in social approach and reciprocity. For example, 4- to 18-year-old siblings of children with autism are rated by their parents as displaying greater social deficits compared to same-aged siblings of children without an ASD diagnosis(Constantino et al.,2006).In addition, the younger infant siblings of children with autism display social deficits such as poor social communication skills (e.g., expressive language; Toth et al., 2007), low levels of affective expression (Cassel et al., 2007), and less spontaneous use of social communicative behaviors, such as gestures, compared to siblings of typically-developing children (Stone et al., 2007).In contrast, Verté and colleagues(2003) did not find differences on parent- and self-report measures of broadly defined social competence in a sample of 6- to 16-year-old siblings of children with autism relative to a sample of siblings of children without autism. One reason for this discrepancy might be that Verté and colleagues used general measures of social functioning (the social competence scale on the CBCL and perceived social skills on the

MESSY),which may be less sensitive to the specific social deficits related to social approach/initiation and reciprocity expected in the siblings of children with autism.

In the current study, the range of social deficits that can be expected in children at risk for an ASD was captured in a peer interaction paradigm with an unfamiliar peer. This allowed for conditions that tapped both social approach/initiations and social reciprocity. In addition, parent-report questionnaires of autism symptomatology (i.e., the Social Responsiveness Scale and the Autism Quotient) were used to assess social interaction behaviors. In assessing social interaction skills using these two methodologies, a more thorough understanding of social interactions occurred in the current study.

BROADER AUTISM PHENOTYPE AND EXECUTIVE ATTENTION

Executive attention is best conceptualized as a collection of executive function skills such as planning, cognitive flexibility, and inhibition. Executive attention is formally defined as the ability to monitor and resolve conflict between brain networks and processes (Botwinick et al., 2001) and relates to self-regulatory skills, such as effortful control, which is necessary for effective social interactions (Rueda et al., 2005). In addition to deficits in social interaction, first-degree relatives of those with autism display deficits in information processing abilities such as executive attention.

For example, both parents and siblings of children with autism show deficits related to poor executive attention including deficits in verbal and non-verbal fluency, set-shifting, and planning (Delrome et al., 2007; Hughes et al., 1999; Wong et al., 2006) compared to parents and siblings of children with typical development. In addition, Zwaigenbaum and colleagues (2005) found that younger siblings of children with ASD who themselves were later diagnosed with an ASD showed “sticky attention,” or

particular difficulty disengaging from a computerized visual stimulus, at 12- and 24-months compared to younger ASD siblings who did not go on to receive a diagnosis. Although it is feasible that greater executive dysfunction is found in younger siblings who eventually receive a diagnosis of autism, it appears that a range of executive dysfunction exists among affected and unaffected first-degree relatives. The variability in executive dysfunction potentially serves as a predictor of the relative magnitude of social deficits observed in first-degree relatives; therefore, Sibs-ASD with a diagnosis of an ASD were included in this study. In doing so, the greater range of variability in executive attention aided in the understanding of the range of social interaction skills observed in Sibs-ASD.

Neurophysiology of Executive Attention

Behavioral and neurophysiological (EEG/ERP) indices of executive attention, although assessing the same construct, might measure different aspects of executive attention. One particular study highlights the importance of assessing both neurobiological processes and behavioral processes on the same task. Schmitz et al. (2006) gave both adults with autism and those without autism several tests of executive attention (GO/NO-GO, STROOP, and SWITCH) while simultaneously obtaining fMRI data. No group differences in behavioral performance were noted on these tasks; however, those with autism demonstrated greater activation of frontal and parietal structures, the insula, and the AC during executive attention tasks compared to adults without an autism diagnosis. These finding suggest that differences in neural functions related to information processing can differentiate groups and may predict variability in social behaviors that behavioral measures alone cannot recognize.

Executive attention is governed by a network of frontal brain structures, specifically the anterior cingulate (AC) and the lateral prefrontal cortex. Cognitive tasks that require effort due to conflict between stimuli lead to greater activation of the AC. As children and adults become better able to resolve conflict between stimuli, these processes become more automatic and structures such as the insula become activated more than the AC. The anterior cingulate (AC) is important in social and cognitive processes in typical development and in those with an autism diagnosis. Structurally, smaller volume and hypometabolism of the AC (Haznedar et al., 2000) and decreased blood flow to the AC is associated with autism (Ohinishi et al., 2000).Neurobiological measures associated with AC activity are important to observe not only because of its role in executive attention, but also due to the deficits in AC functioning noted in autism.

A non-invasive method of assessing neurobiological processes of executive attention is through the use of neurophysiological indices (EEG/ERP). EEG/ERP paradigms allow for the measurement of time-sensitive cognitive processes that begin well before a person's behavioral response. Two ERPs elicited during executive attention tasks that have been localized to the AC are the N2 and the P3 (Lamm et al., 2006; Liotti et al., 2005; Nieuwenhuis et al., 2003). The N2 is a negative deflection, occurring 200-450 ms after the onset of a stimulus, with a fronto-central maximum, and is thought to measure executive control, or he *effortful* decision-making process that appears on tasks where there is *conflict* experienced with what one *excepts* to do and what one *needs* to do in order respond correctly(Folstein & Van Petten, 2008; Jonkman, 2006;Kopp et al., 1996; Lamm et al., 2006).A prominent N2 is typically observed on incongruent or NoGo trials where there is greater conflict; however, recent work by Nieuwenhuis et al. (2003)

show that an N2 is also observed on Go conditions when this condition is infrequently presented. The P3 follows the N2, is a positive deflection occurring 300-600 ms after stimulus onset, and is observed at medial electrode sites. The P3 is a measure of *attention allocation* when a task is presented (Kirmizi-Alsan et al., 2006). The N2 and the P3, together, measure how one is able to detect and allocate attention in order to resolve conflict when measured on correct responses.

Group differences are observable on the N2 and the P3 in typical and atypical populations. Typically developing children with more developed conflict monitoring skills demonstrate reduced (more positive) N2 amplitude and shorter N2 latencies (Lamm et al., 2006; Rueda et al., 2005; Todd et al., 2007). In children (5- to 7-years-old) with greater attention difficulties, such as those observed in Attention Deficit Hyperactivity Disorder, the P3 is reduced (more negative) compared to typically developing children (Jonkman, 2006; Spronk et al., 2008). Recent research examining the N2 and the P3 in children with higher functioning autism indicates that the N2 is negatively correlated with autism symptomatology, such that greater deficits in social interaction and social reciprocity are characterized by a more enhanced (more negative) N2. In addition, a reduced P3 (less positive) is related to less efficient reciprocal social monitoring as displayed during an interaction with an unfamiliar peer (Mohapatra et al., 2009). Based on the above literature, it was hypothesized that children with better executive attention skills will display reduced (more positive) N2 amplitudes and enhanced (more positive) P3 amplitude compared to children with poorer executive attention. However, the relation between neurophysiological indices of information processing and social interaction has

been observed in only a handful of studies in both typical (Henderson et al., 2004) and atypical (Schwartz, 2007) populations and therefore required further investigation.

METHODOLICAL CONSIDERATIONS AND BROADER AUTISM PHENOTYPE

Two methodologies are typically used in characterizing the BAP. The first type of research design observes infant younger siblings of children with autism who are thought to be at-risk for the later development of an ASD. Typically, comparisons are made within this at-risk group to understand predictors of ASDs. The second methodology typically assesses group differences later in development (e.g., adolescents) and typically comparisons are made between affected and unaffected at-risk siblings or unaffected siblings compared to a comparison (no family history of autism) group.

Although the above methodologies have provided invaluable information regarding potential BAP features, two-group comparisons (i.e., affected vs unaffected Sibs-ASD) may not capture the range of social and cognitive behaviors within the BAP. Furthermore, it may not help in understanding which BAP characteristics are most similar to comparison groups and which are most similar to individuals affected with autism. Since social and cognitive traits are hypothesized to belong along a continuum (ranging from least to most impaired), BAP traits may range anywhere within that continuum (Constantino, 2011). As a result, it may be difficult to accurately capture BAP traits in a two group analysis because variability within the BAP may mask group differences. Therefore, utilizing a three group comparison (affected Sibs-ASD vs unaffected Sibs-ASD vs Sibs-COM) is essential to begin fully characterizing the BAP as an intermediate phenotype between affected children and typically-developing children with no family history or risk of autism.

As stated in previous sections, there is a high likelihood that many Sibs-ASD will have a diagnosis of an ASD themselves. Therefore, both affected and unaffected Sibs-ASD will be included in subsequent analyses, when necessary, not only help explain variability amongst younger siblings of a child with autism, but to further discern profiles of social and cognitive functioning within the BAP. In doing so, this study will significantly contribute to the current literature base since these analyses are typically not conducted.

EXECUTIVE ATTENTION AND SOCIAL COMPETENCE

The relation between sibling group status and individual differences in social interaction may be explained by executive attention skills. Between four and six years of age, a rapid development in executive function skills aid in the development of socially competent behaviors (e.g. review by Zelazo& Muller, 2002). Executive functions are important information processing abilities that provide the building blocks necessary for effective and efficient social interactions. Deficits in executive functions are hypothesized to contribute to the social deficits present in autism (Kenworthy et al., 2009; Mundy, 2003) and other developmental psychopathologies (e.g., Pennington & Ozonoff, 1996). Furthermore, executive dysfunction can lead to subclinical, yet maladaptive, social-emotional outcomes such as greater aggressive and antisocial behaviors (Hughes et al., 2000) that impact a child's social competence.

Specific skills which facilitate social interaction, such as theory of mind and delay of gratification, are related to executive attention. Theory of mind requires efficiency in inhibitory systems (Carlson & Moses, 2001) in order for children to be aware of and understand the mental states of others (Wellman, 2000). Delay of gratification, or a

child's ability to inhibit immediate gratification for a potentially more valued outcome later on (Mischel et al., 1989), requires executive attention in order to meet social demands (Peake et al., 2002). Children who are better able to delay gratification are able to flexibly shift attention away from a desired stimulus and utilize various techniques to control their attention (i.e., self-distraction). Effective delay of gratification in preschool predicts long-term social skills such as greater frustration tolerance and self-control (Mischel et al., 1988), greater interpersonal competence (Mischel et al., 1989), and general inhibitory skills (Eigsti et al., 2006) in adolescence and adulthood. Both theory of mind and delay of gratification, which rely on executive attention skills and consistently predict effective social interaction abilities, demonstrate that there are probable pathways through which executive attention may impact social interaction. Therefore, it was predicted that executive attention will predict individual differences in social interaction, and partially mediate the relation between sibling status and social interaction.

SUMMARY

In summary, Sibs-ASD are at heightened risk for displaying subtle deficits in both social interaction and executive functions related to attention regulation. However, the relations between these constructs are less well understood. Based on Yeates and colleagues' conceptualization of the development of social competence, an understanding of how information processing (i.e., executive attention) relates to social interaction skills (e.g.., social approach/initiation and social reciprocity) may help to better bridge these two literatures. In order to bring these literatures together and examine a more comprehensive model of social competence in young children at risk for autism, the

current study directly tested the mediating effects of executive attention on the relations between sibling status and social outcomes.

STUDY AIMS AND HYPOTHESES

Aim 1: To compare a sample of younger siblings of children with autism (Sibs-ASD) to an age-, IQ-, and gender-matched comparison sample of younger siblings of typically developing children (Sibs-COM) on behavioral and neurophysiological (N2 and P3) indices of executive attention using the children's ANT.

Hypothesis 1-A:It was hypothesized that Sibs-ASD would show a greater difference in reaction time (RT) and error rates between incongruent and congruent trials (conflict RT and conflict Accuracy) compared to Sibs-COM.

Hypothesis 1-B:It was hypothesized that Sibs-ASD would demonstrate enhanced N2(more negative)and reduced P3(less positive) amplitudes compared to Sibs-COM on correct incompatible trials of the children's ANT. Differences in N2 and P3 latency were no hypothesized.

Aim 2: To compare the Sibs-ASD to the Sibs-COM on parent-report and observational measures of social interaction behaviors.

Hypothesis2:Sibs-ASD would demonstrate lower levels of social approach and fewer reciprocal social interactions as assessed during an interaction with an unfamiliar peer in the laboratory compared to Sibs-COM. On parent report of social behaviors (e.g., SRS and AQ), Sibs-ASD would demonstrate greater social deficits compared to Sibs-COM.

Aim 3: To examine the mediating role of attention regulation (assessed behaviorally and via N2/P3 amplitudes) in the association between ASD sibling status and social competence.

Hypothesis 3-A: The relation between sibling group (Sib-ASD vs. Sib-COM) and social competence would be partially *mediated* by behavioral indices of executive attention (conflict accuracy, conflict RT). Specifically, poorer social interactive skills in Sibs-ASD would be partially explained by greater conflict RT and conflict accuracy on incompatible trials.

Hypothesis 3-B:The relation between sibling group (Sib-ASD vs. Sib-COM) and social competence would be partially *mediated* by electrophysiological indices of executive attention. Specifically, poorer social interactive skills in Sibs-ASD would be partially explained by an enhanced N2 (more negative) and reduced (less positive)P3 amplitude.

CHAPTER 2: METHODS

PARTICIPANTS

Target participants were recruited from an ongoing NICHD and Autism Speaks funded longitudinal study of younger siblings of children with autism. They were recruited for two separate sessions. During the first session, target participants completed the Wechsler Preschool and Primary Scale of Intelligence-Third Edition (WPSSI-III) and diagnostic measures (i.e., the Autism Diagnostic Observation Schedule [ADOS] and the Social Communication Questionnaire [SCQ]). Results of the first session were used to determine eligibility for the second session which involved the Children's Attention Network Task (ANT) and peer interaction with an unfamiliar peer. The inclusion criteria for the Sib-ASD group were: 1) older sibling had a community diagnosis of an ASD, 2) participant was between 4 and 6 years-old, 3) a parent spoke English 4) participant was born full term, and 5) participant's Verbal IQ was greater than 70. For the Sibs-COM group, the inclusion criteria were: 1) must have an older sibling that does not have a community ASD diagnosis, 2) participant was between 4 and 6 years-old, 3) a parent spoke English 4) participant was born full term 5) participant's Verbal IQ was greater than 70, 6) participant's ADOS social communication and interaction score was less than 7, and 8) participant's SCQ total score was less than 11.

A total of 52 target participants (30 Sibs-ASD, 23 Sibs-COM) completed the first session. Ten participants did not complete the second session due to the following reasons: they were older than 7-years-old when they completed the first session (1 Sibs-ASD and 1 Sibs-COM), their Verbal IQ was less than 70 (3 Sibs-ASD), they had missing diagnostic information (1 Sib-COM), or they were unable to be scheduled for the second

session (2 Sibs-ASD and 2 Sibs-COM). The final sample of 42 participants (24 Sibs-ASD, 18 Sibs-COM) completed the peer interaction assessment, the Children's ANT, or both.

Among the 42 participants in the final sample, sibling group status was unrelated to age, $t(40)= -.22$, $p=.83$, Verbal IQ, $t(40)= -.14$, $p=.89$, or sex, $\chi^2= (1, N=42)=.05$, $p=.82$. Five families did not report family income; however, of those that did report family income, Sibs-ASD and Sibs-COM did not differ in household income, $\chi^2(4, N=37)= 2.73$, $p=.44$. Most families reported a household income greater than $50,000 which is slightly above the median household income for individuals in Miami-Dade County. In addition, there was no group difference between Sibs-ASD and Sibs-COM with regard to ethnicity, $\chi^2(3, N=39)=1.34$, $p=.72$. The ethnic distribution of the entire sample was 48% White/Non-Hispanic, 33% White/Hispanic, 10% Black/African-American, 2% Other, and 7% did not report their ethnicity. This distribution closely represented the ethnic make-up of Miami-Dade County according to the 2010 US Census report. Refer to Table 1 for more detailed demographic information.

To capture spontaneous social behaviors during the peer interaction task, an independent sample of typically-developing children was recruited from the community (non-target participants) to provide play partners for all 42 target participants. Inclusion criteria for this sample of non-target participants included: 1) no family history of an ASD diagnosis, 2) the non-target participant was not diagnosed with an ASD, 3) the non-target participant was between 4-and 6-years-old, 4) a parent spoke English, and 5) the participant's Verbal IQ was greater than 70.The following guidelines were used when matching target and non-target participants: 1) the target and non-target participant were

the same sex 2) the target and non-target participant were within approximately 15 Verbal IQ points of each other and 3) the target and non-target participants were within approximately 6 months of age. Non-target participants were matched as a group to the target participants on age, $t(40)=1.24$, $p=.22$, verbal IQ, $t(40)=-.86$, $p=.39$, and ethnicity, $\chi^2(3, N=77)=4.76$, $p=.19$. Although nine participants did not indicate their household income, target and non-target participants had similar household incomes, $\chi^2(4, N=67)=3.72$, $p=.45$.

PROCEDURE

All recruitment and study procedures were approved by the University of Miami Institutional Review Board (UM IRB). Target and non-target participants completed two separate visits in the Department of Psychology at the University of Miami. Participants completed a number of tasks across both visits; however, only the tasks pertinent for the current study are described below. Table 2 lists the tasks completed by participants across the two sessions.

During the first visit, target participants completed the Wechsler Preschool and Primary Scale of Intelligence - Third Edition (WPPSI-III) to assess cognitive functioning and the Autism Diagnostic Observation Scale (ADOS) to assess autism symptoms. Non-target participants were also administered the WPPSI-III to assess verbal IQ. Instead of the ADOS, the parents of non-target participants completed the Social Communication Questionnaire (SCQ) to screen for autism symptoms.

During the second visit, target participants (Sib-ASD or Sib-COM) completed the Children's Attention Network Task (ANT) while EEG was continuously recorded and a peer interaction protocol with an age-, sex-, and verbal IQ-matched non-target

participant. The order of the EEG and peer interaction tasks was randomized in order to minimize any consistent effects of order on performance.

The peer interaction protocol took place in a laboratory room with two wall-mounted cameras and a microphone attached to the ceiling. Recording of peer interaction tasks occurred in an adjoining room where the parents and examiners sat. Examiners maneuvered cameras from the adjoining room to ensure that the participants were within the camera frame at all times. Peer interaction tasks were recorded on DVD and coded at a later time by the author and a trained undergraduate assistant. In order to differentiate between target and non-target participants while coding the data, participants wore a letter on their backs to identify them at a later date.

The peer interaction tasks pertinent to the current study were the Free Play and Puzzle tasks. The Free Play task was a 10-minute interaction where participants played together with a set of age-appropriate toys selected to support both solitary and social play. In the Puzzle task participants decided and completed a two-sided puzzle together. The task ended when participants completed the puzzle or after 10 minutes, whichever came first.

Target participants also completed a modified version of the Children's Attention Network Task (ANT) while EEG was continuously recorded. Participants were seated approximately 50 cm away from a computer screen, where stimuli were presented. Participants responded using a response pad that was placed on top of a table in front of them, to minimize upper body movements. In addition, an undergraduate assistant sat to the right of the participant to monitor the participant's physical movements, minimize talking or oral motor movements (e.g., chewing), and provide reinforcement between blocks.

Participants first completed a practice block. Following the practice block, participants were capped with a 128-channel Geodesic Sensor Net where each sensor was evenly spaced from left ear to right ear and from inion to nasion. The Geodesic Sensor Net contained sponge-like electrodes that were dipped in a solution of potassium chloride and baby shampoo prior to application. Impedances were kept under 40 kΩ and EEG was continuously recorded. Following capping, participants completed four test blocks. After each block, participants were asked to rest and were provided a small reward (e.g., stickers). To ensure consistency, a fixed reinforcement schedule was implemented so that each participant received one sticker after each block. After completion of the task, the examiners removed the EEG Net.

During the first and second sessions, parents of the participants completed parent report questionnaires. At the end of each session, participants were monetarily compensated for their time.

MEASURES

Measures and Screeners Used for Participant Selection

Autism Diagnostic Observation Schedule-Generic(ADOS-G; Lord et al., 1999): The ADOS-G is a semi-structured observational assessment that assesses language and communication, reciprocal social interaction, imagination and creativity, and restricted and repetitive behaviors and interests in order to assess symptoms of pervasive developmental disorders. There are four, 30-minute modules and a participant is administered one based upon verbal abilities. Module 1 is intended for children without spontaneous speech, module 2 is intended for children with some flexible speech, module 3 is intended for verbally fluent children, and module 4 is intended for verbally fluent

adults and adolescents. The ADOS was used for diagnostic clarification and as part of exclusion criteria for Sibs-COM.

Social Communication Questionnaire (SCQ: Berument et al., 2003): The SCQ is a 40-item parent-report screener of autism symptoms based upon the Autism Diagnostic Interview-Revised (ADI-R: Lord et al., 1994). Parents are required to respond 'yes' or 'no' to each question and either 0 or 1 points is given based upon the responses. Along with a total score, three subscale scores are created: social interaction, language/communication, and repetition and stereotyped behaviors. A score of 15 is typically used as a cut-off score for differentiating between an ASD vs. a non-ASD diagnosis; however, when validity data was collected for preschool-aged children, a total score of 11 provided the greatest specificity/sensitivity (100/62) for preschool-aged children (Allen et al., 2007). Therefore, the SCQ was used to exclude Sibs-COM and non-target participants with scores greater than 11.

Wechsler Preschool and Primary Intelligence Test- Third Edition (WPPSI-III; Wechsler, 2002):The WPPSI-III is a measure of cognitive abilities used for children between 2 years, 6 months to 7 years, 3 months of age. There are 14 subtests and 4 main factors: Full Scale IQ, Perceptual Reasoning Index, Verbal Comprehension Index, Processing Speed Index, and General Language Comprehension. For the current study, participants were administered the 10 subtests used to calculate a Verbal IQ, Performance IQ, Full Scale IQ, and the General Language Composite (GLC).

Parent-Report Measures Used to Measure Social Interaction

Social Responsiveness Scale (SRS; Constantino, 2004): The SRS is a 65-item parent and teacher report questionnaire that assesses a child's ability to engage in appropriate

social interaction behaviors. The SRS asks about observed behaviors that are rated on a scale from 0 (never true) to 3 (almost always true). The SRS provides a total symptom score that has a test-retest reliability of 0.88 in clinical subjects. The SRS measures five areas of social functioning, which include: social awareness, social information processing, capacity for reciprocal social responsiveness, social use of language, and stereotypic/repetitive behaviors/preoccupations. The total score is comprised of the five areas of social functioning and higher scores indicate greater social deficits. The following subscales from the SRS were used as a continuous measure of parent-reported social behaviors to assess for social interaction skills: social awareness, social cognition, and social motivation.

Autism Quotient-Child (AQ-Child; Auyeung et al., 2008): The AQ-Child is a 50-item parent-report questionnaire designed to measure autistic symptoms in children 4 to 11 years of age. Parents respond to each question using a 4-point Likert scale where parents rated how descriptive each statement was of their child. Scores ranged from definitely agree (0 points) to definitely disagree (3 points) for each question. The AQ-Child identifies four areas of social functioning which include: Mind-Reading, Attention to Detail, Social Skills, and Imagination. The Mind Reading and Social Skills subscales from the AQ-child were used as continuous measures of parent-reported social interaction skills.

Coding of Peer Interaction Task

As noted earlier, two tasks were coded to assess social interaction skills with an unfamiliar peer, the Free Play and Puzzle task. During each task, only the target participant's behaviors were coded. To assess inter-rater reliability, intraclass

correlations (ICC) were calculated for continuous data and Cohen's Kappas were calculated for nominal and ordinal data. Coders overlapped on at least 20% of the videos coded and the corresponding videos were used to determine inter-rater reliabilities.

Free Play Coding: The Free Play task was a 10-minute interaction where participants were asked to play with age-appropriate toys, which included: a ball, dinosaur figurines, plastic food, a Polly Pocket playhouse with figurines, and a Magna Doodle. The 10-minute play session was divided into 5, two-minute coding epochs. For each epoch, 7-point Likert scales were used to quantify (1) Positive Affect, (2) Negative Affect, and (3) Wariness and 5-point Likert scales were used to quantify (4) Social Initiation and (5) Social Responsiveness. For data analysis, scores for each scale were averaged across the five epochs.

Positive Affect: The coding of Positive Affect involved observing the intensity and frequency of positive affect displayed by the participant. Lower end scores (1/2) indicated the absence or few low intensity expressions (e.g., giggles and smiles). Mid-range scores (3-5) involved more frequent and intense displays of positive affect (e.g., smiling for longer durations). High scores (6/7) indicated frequent and intense expressions of positive affect (e.g., singing, excited shrieking). Inter-rater reliability for this code (ICC) was .85.

Negative Affect: The coding of Negative Affect involved the intensity and frequency of negative affect displayed by the participant. Lower end scores (1/2) indicated the absence or few low intensity expressions (e.g., frowns and pouts). Scores within the mid-range (3-5) involved more frequent and intense displays of negative affect (e.g., whiny).

Higher scores (6/7) indicated frequent and intense expressions of negative affect (e.g., tantrums). Inter-rater reliability (ICC) for this code was .65.

Wariness: Wariness was a measure of a child's hesitance to engage with the toys or a peer during the free play task. Higher scores indicated greater hesitance to engage. Within the current sample, wariness was infrequently observed and therefore dropped from further analyses.

Social Initiation: Social Initiation was a measure of the target participant's tendency to initiate a social bid with the unfamiliar peer using verbal comments, questions, and nonverbal directives. Lower scores (1/2) indicated a few, if any, attempts to initiate a social interaction with an unfamiliar peer. These attempts, if made, were predominantly nonverbal gestures (e.g., showing a toy to peer). A mid-range score (3) indicated greater frequency and a combination of nonverbal and verbal social bids. Higher scores (4/5) indicated frequent and more verbal social bids (e.g., questions). Inter-rater reliability for this code (ICC) was .95.

Social Responsiveness: Social Responsiveness was a measure of the target participant's ability to appropriately respond to bids initiated by the non-target participant using verbal and nonverbal cues. If non-target participants did not provide an opportunity for the target participant to respond, the epoch was not scored. Lower scores (1/2) indicated few if any attempts to respond to a non-target participant's social bid. A mid-range score (3) indicated equal attempts at responding compared to not responding to social bids. Higher scores (4/5) indicated that a participant almost always or always responded to a non-target participant's social bids. Inter-rater reliability (ICC) for this code was .68.

Proportion of Social Play: In addition to the Likert-scale scores, the predominant play style of each target child was coded in 30-second epochs. There were 5 mutually exclusive play style codes: (1) non-engaged, (2) onlooker/hovering, (3) solitary, (4) parallel, and (5) social play. Average inter-rater reliability for these codes (average Kappa) was .68.

Non-engaged play referred to when target participants did not engage in play behaviors (e.g., with the toys or pretend play) with the non-target participant, but may have engaged in conversation. Inter-rater reliability (Kappa) for this code was .67.

Onlooker/hovering behaviors were coded when the target participant watched or hovered around the non-target participant without engaging in play. The inter-rater reliability (Kappa) for this code was .78.

Solitary play occurred when the target participant played with the toys, alone, away from the non-target participant. The inter-rater reliability (Kappa) for this code was .79.

Parallel play was observed when the child played independently of, but in close proximity to, the non-target participant. Typically, participants engaged in play with similar toys. Reliability was difficult to obtain for this task with a resulting kappa of only .23. This was a result of coders having difficulty differentiating parallel from social play due to how quickly and easily participants shifted between these play styles. However, this code was not used in subsequent analyses.

Social play was observed when the participant played with the non-target participant toward a common play goal. Inter-rater reliability (Kappa) for this code was .97. Of interest in the current study was the proportion of time spent in social play (# of epochs of social play/total # of epochs).

Puzzle Task Coding: During the Puzzle task, target and non-target participant were asked to decide and complete a two-sided, 20-piecepuzzle. On one side, was a fish scene and on the other side was an animal scene. Participants were provided 10-minutes to complete the task before examiners asked if participants required help. Because participant completed the puzzle at different times within the 10-minute segment, behaviors that occurred over the entire time interval were coded. Two scales were used for this study, Quality of Negotiation and Quality of Cooperation, and were coded on a 5-point Likert scale.

Quality of Negotiation referred to the target participant's ability to decide on which side of the puzzle to complete. Target participants who received lower scores (1/2) often started the task without asking or checking with the non-target participant. A mid-range score (3) indicated agreeing with the non-target participant immediately after a suggestion was made. Higher scores (4/5) indicated a verbal decision-making process where the target participant stated which side they wanted to complete and negotiated with their peer, if necessary. Inter-rater reliability (ICC) for this code was .78.

Quality of Cooperation: were behaviors coded after participant's made a decision on which side of the puzzle to complete and referred to the target participant's ability to work on the puzzle with the non-target participant. Lower scores (1/2) indicated that the participant did not participate in completing the puzzle or was more aggressive (e.g., grabbing pieces from non-target participant). A mid-range score (3) indicated that the participant helped to complete the puzzle but was demanding or was aggressive. Higher scores (4/5) indicated that the participant engaged in putting puzzle pieces together to help complete the puzzle. Inter-rater reliability (ICC) for this code was.88.

Behavioral and Electrophysiological Indices of Executive Attention

Children's Attention Network Task (Children's ANT: Rueda et al., 2004): The Children's ANT was originally designed to provide measures of alerting, orienting, and inhibition/conflict monitoring. Because inhibition/conflict monitoring was the executive function of interest in the current study, the task was modified to exclusively assess inhibition/conflict monitoring. Furthermore, to obtain more data and provide a sufficient number of trials to reliably assess ERP indices of interest, more trials were added to each block.

The stimuli for the Children's ANT were presented on the computer screen and stimulus presentation timing was controlled using EPrime software. First a cue appeared (*) and remained on the screen for 450 ms signaling the start of a new trial. Then, a small fixation point (+) remained in the center of the screen for 1000 ms to orient the participant to the stimuli on the screen. The fixation point remained on the screen while the stimulus appeared. The stimulus and fixation point remained on the screen for 2400 ms. This timing parameter was determined through pilot testing of four participants which revealed that 2400 ms allowed for children to respond correctly, on average, to 40% of incongruent trials. Refer to Figure 1 for modified Children's ANT stimuli and timing parameters.

First, participants completed a practice block consisting of 24 trials which included: 11 congruent trials, 11 incongruent trials, and 2 neutral trials. After the EEG cap was placed on their head, participants were asked to complete four additional blocks, each consisting of 48 trials (22 congruent, 22 incongruent, and 4 neutral trials) with an equal likelihood of the target stimulus being on the right and left side. On incongruent and

congruent trials, five fish were presented in a horizontal row and the participant was asked to respond by pressing a button corresponding to the direction the central fish's mouth. On congruent trials, the central fish's mouth was in the same direction as the flanking fishes. On incongruent trials, the central fish was in the opposite direction of the flanking fish. Neutral trials were interspersed to ensure that participants were attending to the information. Children used a response box with four buttons in sequence. In order to indicate their responses, participants pressed "1" if the center stimulus was oriented towards the left and they pressed "4" if the center stimulus was oriented towards the right. The participant's first response was only calculated. If they continued to press the response pad, these responses were not recognized by the EPrime system. To indicate that the participant made a correct response, bubbles emerged from the central fish and remained on the screen for 2000 ms until the start of the next trial. If they did not make a correct response, the fish remained on the screen without bubbles emerging from the central fish.

Behavioral Performance on the Children's Attention Network Task: Behavioral data from the children's ANT was analyzed based upon the methods outlined in Rueda et al. (2004).Accuracy was computed as the proportion of errors averaged across the number of blocks completed on incongruent and congruent trials, separately. In order to assess the degree to which participant's experienced conflict on this task, or relative difficulty on incongruent compared to congruent tasks, a Conflict Accuracy score was computed. This was measured as the difference between the number of errors on incongruent compared to congruent trials. Higher scores indicated that participants had greater difficulty on incongruent trials compared to congruent trials.

Reaction time (RT) was calculated on correct, congruent and incongruent trials, separately and averaged across all trial blocks. To assess the degree of difficulty on incongruent compared to congruent trials, a Conflict RT score was calculated for each participant. This was noted as the difference between average RT on incongruent versus congruent trials. Higher Conflict RT scores indicated greater difficulty on incongruent, relative to congruent trials and were related to more difficulty on the task.

Electroencephalograph (EEG) during the Children's Attention Network Task: During EEG data collection, the EEG signal was amplified by a factor of 10,000 and filtered with a low-pass band filter of 100 Hz and a high-pass band filter of 0.1 Hz. The EEG signal was digitized at 250 Hz. EEG data was analyzed offline, using Net Station software, after participants had completed the study. Data were re-filtered with a low pass setting of 30 Hz. Then data were segmented to 100 ms prior to and 900 ms after stimulus presentation. Trials were removed if the response time was less than 100 ms and included times when participants did not respond. Artifact detection tools were set to automatically correct for ocular movement and blinks and then manual artifact detection occurred to remove additional eye blinks not detected using ocular movement tools. Data was re-referenced to the average reference and baseline corrected to 100 ms prior to stimulus onset. Data were then grand average for each participant across trial type and N2 and P3 peaks were identified and peak amplitude, mean peak amplitude, and latencies were calculated for each participant.

The N2 and the P3 were measured on correct incongruent and correct congruent trials. After visual inspection of approximately 10 participants, it was determined that the N2 was present and maximal, between 250 and 500 ms. The P3 was identified as the

positive deflection immediately following the N2 and observed to be present and maximal between 500 and 700 ms. Mean N2 and P3 amplitude were computed as the mean amplitude ± 50 ms of the most negative or positive peak within the time ranges specified above. Based on previous research, the N2 was analyzed at Fz (electrode 11) and FCz (electrode 6) whereas the P3 was analyzed at Cz (electrode 55) and Pz (electrode 62).

CHAPTER 3: RESULTS

PRELIMINARY ANALYSES

Data Reduction

Peer Interaction Task: Correlations between peer interaction variables were conducted and are presented in Table 3. In order to reduce the data prior to analysis, a principal components analysis (PCA) was conducted with the following variables: Positive Affect, Negative Affect, Social Initiation, Social Responsiveness, Proportion of Social Play, Quality of Negotiation, and Quality of Cooperation. A principal axis method was used to extract the components and was followed by a varimax (orthogonal) rotation.

A two component solution was supported by eigenvalues greater than one on the rotated matrix and results of the scree test. This solution was retained and accounted for 65% of the variance. Variables were included in a component if the loading was .4 or greater for a given component and less than .4 for the other component (see Table 4 for variables and associated loadings). For data analysis, factor scores were computed using the regression method (M= 0, SD=1).

The first component was labeled *Social Engagement* and included the following variables that function to maintain or enhance social interactions: Positive Affect, Social Initiation, Social Responsiveness, and Proportion of Social Play. The second component was labeled *Social Dysregulation* and included the following variables that interfere with social interactions: Negative Affect and Quality of Cooperation (negative loading).

Parent-Report Measures of Social Functioning: Correlations between parent-report measures of social functioning (SRS Social Awareness, SRS Social Cognition, SRS Social Motivation, AQ Mind Reading, AQ Social Skills) are presented in Table 5. In

order to reduce parent-report data prior to analysis, a PCA was conducted. A principal axis method was used to extract the components. Since only one component was produced a varimax rotation was not conducted. This single component solution accounted for 66% of the total variance. Each parent-reported variable had a positive loading greater than .4 and the component was labeled *Social Deficits* with higher scores indicating greater social impairments in the basic social and motivational skills necessary for effective social interactions (e.g., theory of mind).Variable loadings are presented in Table 6. For data analysis, factor scores were created for each participant using the regression method (M=0, SD=1).

Some participants were excluded from the PCA analysis (10 Sibs-ASD, 5 Sibs-COM) due to missing data on either the SRS or AQ. In order to obtain a composite that maximized use of participants' data, a second composite score was created by averaging z-scores. First, z-score transformations were conducted for each subscale from the SRS and AQ used in the above PCA analysis. Then, a composite score was created by averaging each participant's z-scores on all available data. Therefore, if participants had data from three subscales, their total z-score was divided by three. This new composite score was named *Z-Social Deficits*.

The composite parent-report scores derived from the PCA and z-score methods were highly correlated, $r(28)=.96$, $p<.001$. In order to maximize the sample size and statistical power, the *Z-Social Deficits* score was used in subsequent analyses and is simply referred to as *Social Deficits* in subsequent analyses.

OUTLIER ANALYSES

Box plot analyses were conducted using SPSS to assess for outliers on key variables. Participants with data more than 3 standard deviations from the total sample mean were excluded from the corresponding analyses. There were no outliers on behavioral or electrophysiological measures from the Children's ANT task, observed *Social Engagement*, or parent-reported *Social Deficits*. One participant was 3 standard deviations above the mean on observed *Social Dysregulation* and was therefore removed from relevant analyses.

INCLUSION/EXCLUSION OF SIBS-ASD DIAGNOSED WITH AN ASD

Since the likelihood of a Sib-ASD having a diagnosis of an ASD is estimated at 10-20% (e.g., Ozonoff et al., 2011), significantly higher than the likelihood in the general population, it was expected that several Sibs-ASD would have an ASD diagnosis at the time of the current assessments. In order to ensure that any group differences detected in the analyses reflected traits characteristic of the broader autism phenotype (rather than an ASD diagnosis per se), Sibs-ASD with a diagnosis (Affected Sibs-ASD) and Sibs-ASD without a diagnosis (Unaffected Sibs-ASD) were compared on demographic measures as well as the primary study variables [e.g., electrophysiological (i.e., mean N2 amplitude) and behavioral (i.e., error rates on incongruent trials) indices of the Children's ANT, *Social Engagement*, *Social Dysregulation*, and *Social Deficits*].

Of the 24 Sibs-ASD, 4 (4 male) met criteria for a diagnosis of Autism, and 7 (3 male, 4 female) met criteria for a Pervasive Developmental Disorder (PDD) and were labeled Affected Sibs-ASD. The remaining 13 participants (10 male, 3 female) did not meet criteria for a diagnosis of an ASD and were referred to as Unaffected Sibs-ASD.

Affected and Unaffected Sibs-ASD were of comparable age, $t(15.76) = .86$, $p = .41$, Verbal IQ, $t(22) = -.61$, $p = .55$, and sex, $\chi^2 = (1, N = 24) = .08$, $p = .77$. Furthermore, they displayed similar behavioral performance on the Children's ANT. The groups also did not differ on N2 amplitude, P3 amplitude, or P3 latency during the Children's ANT. However, some differences and trends suggesting possible group differences were noted on N2 latency, observed *Social Engagement,* and parent-reported *Social Deficits*.

Specifically, Affected and Unaffected Sibs-ASD differed on N2 latency $F(1,9) = 12.68$, $p = .01$, $\eta_p^2 = .59$, such that Affected Sibs-ASD displayed shorter N2 latencies compared to Unaffected Sibs-ASD. In addition, Affected and Unaffected Sibs-ASD tended (p-values < .15 with medium effect sizes) to differ on observed *Social Engagement*, $F(1,21) = 2.85$, $p = .11$, $\eta_p^2 = .13$, and parent-report of *Social Deficits,* $F(1,22) = 2.46$, $p = .13$, $\eta_p^2 = .11$. Specifically, Affected Sibs-ASD displayed less *Social Engagement* during peer play and had higher scores on parent-reported *Social Deficits*.

Therefore, when group differences between Sibs-ASD and Sibs-COM were observed on any of the above noted variables, or in the results of any of the primary variables, follow-up three-group (Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM) comparisons were conducted.

HYPOTHESIS TESTING:

Aim 1: Differences in Behavioral and Electrophysiological Indices on the Children's ANT.

Relations Between Electrophysiological and Behavioral Indices of Children's ANT: A full summary of correlations among behavioral and electrophysiological measures from the Children's ANT across the full sample and separately by sibling group

are reported in Tables 7.1 and 7.2, respectively. Based on the entire sample, participants' reaction times on correct congruent and incongruent trials were related to ERP latencies. Specifically, longer reaction times on both congruent and incongruent trials were related to longer ERP latencies (i.e., N2 at Fz and FCz and P3 at Cz and Pz). In addition, there were positive relations between N2 amplitudes at Fz and FCz, N2 latencies at Fz and FCz, P3 amplitude at Cz and Pz, and P3 latencies at Cz and Pz. Similar patterns existed within each sibling group, except for correlations among N2 amplitude at Fz and FCz. Interestingly, N2 amplitude between Fz and FCz was correlated only for Sibs-ASD and not for Sibs-COM.

Accuracy and Reaction Time

Participants: Of the 42 participants who completed the second visit, 8 participants (6 Sibs-ASD, 2 Sibs-COM) did not complete the behavioral portion of the Children's ANT. There was no significant difference in age, $t(16.62) = -1.40$, $p = .18$, Verbal IQ, $t(40) = -.17$, $p = .87$, sex, $\chi^2(1, N=42) = .7$, $p = .40$, and diagnostic group $\chi^2(1, N=42) = .34$, $p = .56$ between participants who did and did not complete the behavioral portion of the Children's ANT.

Consistent with past studies (e.g., Liotti et al, 2005) participants with less than 40% accuracy on incongruent trials (n= 6; 4 Sibs-ASD, 2 Sibs-COM) were excluded from analyses. Those participants did not differ from those retained in the analyses on age, $t(32) = 1.59$, $p = .12$, verbal IQ, $t(32) = 1.65$, $p = .11$, sex, $\chi^2(1, N=34) = .57$, $p = .45$, and diagnostic group $\chi^2(1, N=34) = .55$, $p = .46$. The final sample included 28 participants (14 Sibs-ASD, 14 Sibs-COM).

Behavioral Performance: Sibling groups were compared on the effects of stimulus incongruency on accuracy using a 2(Group: Sibs-ASD vs Sibs-COM) X 2(Congruency: Congruent vs Incongruent) repeated measures analysis of variance (ANOVA) with proportion of errors as the dependent variable. Although siblings groups did not differ on accuracy, there was a main effect of congruency, $F(1,26)=11.68$, $p<.01$, $\eta_p^2= .31$, where participants, regardless of diagnostic group, made more errors on incongruent compared to congruent trials (Figure 2).

In addition, sibling groups were compared on the effects of stimulus in congruency on reaction time using a 2(Groups: Sibs-ASD vs Sibs-COM) X 2(Congruency: Congruent vs Incongruent) repeated measures ANOVA with reaction time on correct trials as the dependent variable. Regardless of diagnostic group, all participants were slower to respond on correct incongruent trials compared to correct congruent trials, $F(1,26)= 9.71$, $p<.01$, $\eta_p^2= .27$ (Figure 3).

Overall, as expected, all participants made more errors and were slower to respond on incongruent trials compared to congruent trials. However, contrary to the proposed hypothesis, Sibs-ASD did not experience more difficulty (i.e., longer reactions or more errors) with incongruent stimuli compared to Sibs-COM.

Electrophysiological Indices of the Children's ANT

Participants: Of the 42 participants that attended the second visit, 13 participants did not complete the EEG task due to scheduling or technical errors (n=8; 6 Sibs-ASD, 2 Sibs-COM) or refusal to be capped for the EEG task (n=5; 4 Sibs-ASD, 1 Sibs-COM). The participants who did not complete the EEG portion of the Children's ANT did not significantly differ from those who did complete the task on age, $t(40)= -1.54$, $p= .13$,

Verbal IQ, $t(40)= -.65$, $p= .52$, or sex, $\chi^2(1, N=42)=.89$, $p=.35$. However, there was a marginal difference on diagnostic group $\chi^2(1, N=42)= 3.01$, $p=.08$, such that Sibs-ASD were slightly more likely to not complete the EEG protocol. To be consistent with behavioral data, participants with less than 40% accuracy on incongruent trials were also excluded from EEG analysis. The following analyses included 11 Sibs-ASD and 13 Sibs-COM.

Grand average waveforms separated by trial type (congruent vs. incongruent) and scalp site (Fz, FCz, Cz, and Pz) are presented for Sibs-ASD and Sibs-COM in Figure 4. Because three group analyses were conducted for Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM, separate grand average waveform graphs are presented in Figure 5.

Analysis of Mean N2 Amplitude:A 2(Group: Sibs-ASD vs. Sibs-COM) X 2(Congruency: Congruent vs Incongruent) X 2(Scalp Site: Fz vs FCz) repeated measures ANOVA was conducted with mean N2 amplitude as the dependent variable. The mean N2 amplitude did not differ based on congruency, $F(1,22)= 2.87$, $p=.10$, $\eta_p^2= .16$, but a trend (large effect size and $p<.15$) was observed such that N2 amplitude was more negative on incongruent compared to congruent trials. There was a main effect of Group, such that the mean N2 amplitude was reduced (less negative) for Sibs-ASD compared to Sibs-COM, $F(1,22)= 5.79$, $p=.03$, $\eta_p^2= .21$. This effect of Group was qualified by an interaction with Scalp Site, $F(1,22)= 10.92$, $p<.01$, $\eta_p^2= .33$.

Post-hoc independent samples t-tests were conducted to compare Sibs-ASD and Sibs-COM on N2 amplitude at Fz and FCz. At Fz, Sibs-ASD had a reduced mean N2 amplitude ($M=-.82$, $SD= 3.82$) compared to Sibs-COM ($M= -5.15$, $SD= 2.84$), $t(22)=3.28$, $p<.01$. However, the groups did not differ in N2 amplitude at FCz (Sibs-ASD: $M= -3.78$,

SD= 3.82; Sibs-COM: *M*= -4.35, *SD*=1.94),*t*(22)= .58, *p*=.57. Post-hoc paired t-tests revealed that within the Sibs-ASD group, the N2 amplitude was significantly reduced at Fz (*M*= -.82, *SD*= 3.82) compared to FCz (*M*=-3.78, *SD*= 3.82), *t*(10)= 3.96, *p*<.01. In contrast, there were no site differences in N2 amplitude for the Sibs-COM sample (Fz: *M*= -5.15, *SD*= 2.84 and FCz: *M*= -4.35, *SD*=1.94), *t*(12)= -.96, *p*=.36. Refer to Figure 6 for further illustration of differences in N2 amplitude between Sibs-ASD and Sibs-COM.

*Follow-Up Analyses of N2 Amplitude, Parsing Apart Differences Among Affected and Unaffected Sibs-ASD:*A follow-up analysis was conducted using the three sibling subgroups (Affected Sibs-ASD n=6, Unaffected Sibs-ASD n=5, and Sibs-COM n=13). A 3(Group: Affected Sibs-ASD, Unaffected Sibs-ASD, Sibs-COM) X 2 (Congruency: Incongruent vs Congruent) X 2(Scalp Site: Fz vs FCz) repeated measures ANOVA was conducted. Once again, a main effect of group was observed, $F(2,21)= 4.15$, $p<.05$, $\eta_p^2= .28$. Post-hoc Tukey HSD analyses revealed that mean N2 amplitude for Affected Sibs-ASD (*M*= -1.31, *SD*= 3.18), regardless of congruency and site, was less negative that mean N2 amplitude for Sibs-COM (*M*= -4.75, *S*D= 1.76). The Unaffected Siblings (*M*= -3.48, *S*D=1.76) did not significantly differ from Sibs-COM or Affected Siblings on mean N2 amplitude (see Figure 7).

Again, the difference between Groups was qualified by an interaction with Scalp Site, $F(2,22)= 5.21$, $p<.05$, $\eta_p^2= .33$. Post-hoc univariate ANOVAs with Scalp Site (Fz and FCz) as the dependent variable were conducted. At Fz, the three groups differed significantly on N2 amplitude, $F(2, 24)= 6.07$, $p<.05$, $\eta_p^2= .37$. Consistent with the pattern above, Tukey HSD post-hoc analyses revealed that Affected Sibs-ASD (*M*= .19,

SD= 4.27) displayed a significantly reduced mean N2 amplitude compared to Sibs-COM (*M*=-5.15, *SD*= 2.63). However, Unaffected Sibs-ASD (*M*=-1.72, *SD*=2.98) did not significantly differ in mean N2 amplitude compared to either Sibs-COM or Affected Sibs-ASD. At FCz, the three groups did not significantly differ on N2 amplitude, $F(2,24)= 1.33$, $p= .27$, $\eta_p^2= .11$.

Post-hoc paired t-test analyses were conducted for each group, separately, between Fz and FCz. Affected Sibs-ASD displayed a reduced mean N2 amplitude at Fz compared to FCz, $t(5)= 2.74$, $p<.05$ as did Unaffected Sibs-ASD, $t(5)=2.59$, $p<.05$. However, Sibs-COM did not display a similar pattern of results, $t(12)=-.96$, $p=.36$.

N2 Amplitude Summary: While sibling group differences were hypothesized, it was expected that Sibs-ASD would show larger amplitude N2 responses and that these effects would not be frontal site specific. However, Sibs-ASD, as a group, showed reduced amplitude N2 and this was predominantly due to smaller amplitude N2 responses at Fz. Post hoc analysis revealed a comparable pattern of reduced amplitude N2 at Fz relative to FCz for both Affected and Unaffected Siblings but not for the Sibs-Com. Although, these differences were observed with relatively small sample sizes for the Unaffected and Affected Sibs-ASD groups, it is notable that these significant differences were qualified with medium ($.06<\eta_p^2 \leq .14$) and large ($\eta_p^2 > .14$) effect sizes and likely represented true group differences.

Analysis of N2 Latency: A 2 (Group: Sibs-ASD vs. Sibs-COM) X 2 (Congruency: Congruent vs. Incongruent) X 2 (Scalp Site: Fz vs FCz) repeated measures ANOVA was conducted with N2 latency as the dependent variable. Overall, Sibs-ASD did not differ from Sibs-COM on N2 latency, $F(1,22)= .08$, $p=.78$, $\eta^2= .004$. However, there were

significant interactions between Group and Scalp Site, $F(1,22)= 5.44$, $p< .05$, $\eta^2= .20$, and Group and Congruency, $F(1,22)= 5.51$, $p<.05$, $\eta^2= .20$.

To examine the Group by Scalp Site interaction, post-hoc independent samples t-tests were used to compare Sibs-ASD and Sibs-COM on N2 latency, averaged across incongruent and congruent trials at Fz and FCz. N2 latency did not significantly differ between Sibs-ASD ($M= 368.18$, $SD= 46.68$) and Sibs-COM ($M=389.39$, $SD= 34.45$) at Fz, $t(22)=-1.28$, $p=.21$. In addition, Sibs-ASD ($M=390.00$, $SD= 38.14$) did not significantly differ from Sibs-COM ($M=376.31$, $SD= 30.25$) at FCz, $t(22)=.98$, $p=.34$.

Post-hoc paired samples t-tests were used to compare N2 latency at Fz and FCz for Sibs-ASD and Sibs-COM, independently. Sibs-ASD did not demonstrate a significant difference in latency at Fz compared to FCz, $t(10)=-1.63$, $p=.14$. In addition, Sibs-COM did not demonstrate a significant difference in latency at Fz compared to FCz, $t(12)=1.67$, $p=.12$. Although post-hoc tests did not reveal significant associations, marginal results for both Sibs-ASD and Sibs-COM, in opposite directions, may account for the Group by Site relation observed. That is Sibs-ASD tended to display shorter N2 latencies at Fz relative to FCz, whereas Sibs-COM tended to display longer N2 latencies at Fz relative to FCz (see Figure 8).

To interpret the Group by Congruency interaction on N2 latency, post-hoc independent samples t-tests were used to compare N2 latency between Sibs-ASD and Sibs-COM on congruent and incongruent trials. Sibs-ASD ($M=359.45$, $SD= 55.14$) and Sibs-COM ($M= 382.77$, $SD= 30.90$) did not significantly differ on N2 latency on congruent trials, $t(22)= -1.31$, $p=.21$. In addition, Sibs-ASD ($M= 398.72$, $SD= 35.68$) did

not significantly differ from Sibs-COM (*M*=382.92, *SD*= 29.76) on N2 latency on incongruent trials, *t*(22)= 1.18, *p*= .25.

Paired samples t-tests were conducted to compare the N2 latency for incongruent and congruent trials for Sibs-ASD and Sibs-COM, independently. Sibs-ASD had a longer N2 latency on incongruent compared to congruent trials, *t*(10)= -2.26, *p*= .05. However, Sibs-COM did not significantly differ on N2 latency between incongruent and congruent trials, *t*(12)= -.03, *p*=.97.

Follow-Up Analyses of N2 Latency, Parsing Apart Differences Between Affected and Unaffected Sibs-ASD: Preliminary analyses indicated significant differences in N2 latency between Affected and Unaffected Sibs-ASD. Therefore, follow-up comparisons were conducted with a 3(Group: Affected Sibs-ASD, Unaffected Sibs-ASD,vs. Sibs-COM) X 2(Congruency: Congruent vs. Incongruent) X 2(Scalp Site: Fz vs. FCz) repeated measures ANOVA. Contrary to previous N2 latency analyses, there was a main effect of Group, $F(2,21)= 5.24$, $p<.05$, $\eta_p^{2=} .33$ and post-hoc Tukey HSD analyses revealed that Affected Sibs-ASD (*M*= 354.83, *SD*= 16.79) displayed shorter N2 latencies compared to Unaffected Sibs-ASD (*M*= 408.2, *SD*= 32.03). Neither of the Sibs-ASD groups significantly differed from Sibs-COM (*M*= 382.85, *SD*= 29.19), whose mean latency was intermediate between the two sibling group values. This group difference was qualified with an interaction with Congruency, $F(2,21)=8.42$, $p<.05$, $\eta_p^{2=} .45$.

Post-hoc univariate ANOVAs with N2 latency as the dependent variable, collapsed across scalp sites, were conducted for congruent and incongruent trials separately. Overall, the three groups did not differ on N2 latency on incongruent trials, $F(2,25)=1.36$, $p=.28$, $\eta_p^{2=} .11$. However, Affected Sibs-ASD (*M*= 320.67, *SD*= 34.98) displayed

significantly shorter N2 latencies on congruent trials compared to Unaffected Sibs-ASD (M= 406.00, SD= 33.26) and Sibs-COM (M= 382.77, SD= 30.90), $F(2,25)=11.40$, $p<.001$, $\eta_p^{2=}$ .51. Yet Unaffected Sibs-ASD and Sibs-COM did not significantly differ from each other on N2 latency on congruent trials. Post-hoc paired t-test analyses were conducted to assess if the groups differed in N2 latencies on incongruent and congruent trials, separately. Only Affected Sibs-ASD displayed significantly shorter N2 latencies on congruent compared to incongruent trials, $t(5)=-2.55$, $p=.05$.

A marginal interaction of Group and Scalp Site was also observed, $F(2,22)= 2.84$, $p=.08$, $\eta_p^{2=}$ .21. Post-hoc univariate ANOVAs with N2 latency as the dependent variable, collapsed across congruency, were conducted for Fz and FCz separately. At Fz, Affected Sibs-ASD (M= 340.67, SD= 34.45) displayed a significantly shorter N2 latency compared to Unaffected Sibs-ASD (M= 401.2, SD= 38.28) and Sibs-COM (M= 389.38, SD= 34.45), $F(2,24)= 5.11$, $p<.05$, $\eta_p^{2=}$ .33. However, at FCz, Unaffected Sibs-ASD (M= 415.2, SD= 36.02) displayed a longer N2 latency compared to Affected Sibs-ASD (M= 369.00, SD= 27.09) and Sibs-COM (M= 376.31, SD=30.25), $F(2,24)= 3.67$, $p<.05$, $\eta_p^{2=}$ .26 (Figure 9).

Post-hoc paired t-test analyses were also conducted for each group, separately, comparing N2 latencies at Fz and FCz; however, none of the groups displayed significant differences in N2 latencies between Fz and FCz.

N2 Latency Summary: Primary analyses examining differences in N2 latency between Sibs-ASD, as a whole, and Sibs- COM revealed significant interactions between Group and Congruency and Group and Scalp Site. Overall, Sibs-ASD, but not Sibs-COM, displayed significantly longer N2 latencies on incongruent compared to congruent

trials. In addition, Sibs-ASD tended to display shorter N2 latencies at Fz compared to FCz, whereas the opposite pattern of results was obtained for Sibs-COM.

Separating Affected from Unaffected Sibs-ASD revealed that Unaffected Sibs-ASD displayed significantly longer N2 latencies compared to Affected Sibs-ASD. Interactions between Group and Congruency revealed that Affected Sibs-ASD displayed the shortest latencies on congruent trials, compared to the other groups, and significantly differed between congruent and incongruent trials. There was also a Group and Scalp Site interaction that revealed Unaffected Sibs-ASD and Sibs-COM displayed the longest N2 latencies at Fz and only Unaffected Sibs-ASD displayed longer N2 latencies at FCz.

P3 Amplitude: A 2(Group: Sibs-ASD vs. Sibs-COM) X 2(Congruency: Congruent vs Incongruent) X 2(Scalp Site: Cz vs Pz) repeated measures ANOVA was conducted for P3 amplitude. Contrary to the hypothesis, Sibs-ASD did not significantly differ from Sibs-COM on P3 mean amplitude, $F(1,22)= .21$, $p=.66$, $\eta_p^2= .01$. There was a main effect of Scalp Site, $F(1,22)= 7.33$, $p<.05$, $\eta_p^2= .25$ such that the P3 mean amplitude was greater at Pz compared to Cz. There was not a main effect of congruency, $F(1,22)= .44$, $p= .52$, $\eta_p^2= .02$ (Figure 10).

P3 Latency: A 2(Group: Sibs-ASD vs Sibs-COM) X 2 (Congruency: Congruent vs Incongruent) X 2 (Scalp Site: Cz vs Pz) was conducted for P3 latency. Sibs-ASD did not significantly differ from Sibs-COM on P3 latency, $F(1,22)= .58$, $p=.45$, $\eta_p^2= .03$. There were no main effects of Scalp Site, $F(1,22)= 3.31$, $p=.08$, $\eta_p^2= .13$, or Congruency, $F(1,22)= .30$, $p=.59$, $\eta_p^2= .01$, nor were there any significant interactions (Figure11).

ERP Summary: Contrary to hypothesis, Sibs-ASD displayed reduced (less negative) N2 amplitude, which was primarily observed at Fz. This localization of the N2 was also

observed with N2 latency, where Sibs-ASD displayed shorter N2 latencies at Fz. Furthermore, Sibs-ASD displayed differences on N2 latency on congruent trials, which was not observed for Sibs-COM.

Post-hoc analyses were conducted to parse apart the impact of Affected Sibs-ASD on overall group differences. Specifically Affected Sibs-ASD displayed reduced N2 amplitude that was localized to Fz. However, differences in N2 amplitude were only observed between Affected Sibs-ASD and Sibs-COM. Although Unaffected Sibs-ASD did not significantly differ from Affected Sibs-ASD or Sibs-COM, they displayed a similar pattern of N2 localization in that they displayed reduced amplitude at Fz compared to FCz. Yet, results of N2 latency revealed that Affected and Unaffected Sibs-ASD displayed significant differences on N2 latency and Sibs-COM displayed an overall mean, intermediate to the other two groups. Shorter N2 latencies that were observed on congruent trials among Sibs-ASD were primarily due to Affected Sibs-ASD who displayed the shortest N2 latencies at Fz and on congruent trials. Although differences in N2 amplitude and latency occurred, the groups did not differ on P3 amplitude or latency.

AIM 2: DIFFERNCES IN OBSERVED AND REPORTED SOCIAL FUNCTIONING

Peer Interaction with an Unfamiliar Peer

Participants: Of the 42 participants that attended the second visit, three participants (2 Sibs-ASD, 1 Sibs-COM) were unable to complete the peer interaction paradigm because their non-target match did not attend the second session and one (Sibs-COM) participant was excluded from coding and analysis due to errors recording the peer

interaction onto a DVD. The final sample included 38 participants (21 Sibs-ASD and 17 Sibs-COM).

Relation Between Observed and Parent-Reported Social Functioning: The relations between play behaviors coded during the peer interaction task (*Social Engagement*, *Social Dysregulation*) and parent report of social functioning (*Social Deficits*) were examined using Pearson's correlations across the whole sample as well as separately for Sibs-ASD and Sibs-COM (see Table 8). Across the full sample, parent-reported *Social Deficits* were marginally inversely related to observed *Social Engagement*, $r(36) = -.31$, $p = .07$, and positively related to observed *Social Dysregulation*, $r(35) = .31$, $p = .07$. Patterns of correlations between observed *Social Engagement* and *Social Dysregulation* and parent-reported *Social Deficits* were comparable within each sibling groups.

Group Differences in Observed Social Functioning: A univariate ANOVA comparing sibling groups (Sibs-ASD vs Sibs-COM) on *Social Engagement* was not significant, $F(1,38) = .35$, $p = .56$, $\eta_p^2 = .01$. A post-hoc Multivariate ANOVA was conducted to assess whether Sibs-ASD and Sibs-COM differed on any of the individual variables comprising the *Social Engagement* factor; however, no single factor itself differentiated the two groups. Since Affected and Unaffected Sibs-ASD were marginally different on observed *Social Engagement*, follow-up analyses were conducted. However, the three groups did not significantly differ from each other, $F(2,38) = 1.58$, $p = .22$, $\eta_p^2 = .08$.

Similarly, Sibs-ASD and Sibs-COM did not differ on observed *Social Dysregulation*, $F(1,37) = 2.60$, $p = .12$, $\eta_p^2 = .07$. A post-hoc Multivariate ANOVA was conducted to assess whether Sibs-ASD and Sibs-COM differed on any of the individual variables comprising the *Social Dysregulation* factor.

Parent Report of Social Functioning: A univariate ANOVA was conducted to assess whether Sibs-ASD and Sibs-COM differed on parent-reported *Social Deficits*. Overall, Sibs-ASD were rated as having more *Social Deficits*, $F(1,40)= 3.62$, $p<.05$, $\eta_p^2= .13$. Significant differences between Affected and Unaffected Sibs-ASD were observed on parent-reported Social Deficits and therefore follow-up analyses occurred. A univariate ANOVA was used to compared Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM. As would be expected, parents reported the greatest social impairments for Affected Sibs-ASD ($M=.62$, $SD= .83$) compared to Sibs-COM ($M= -.31$, $SD= .66$), $F(2,40)= 4.47$, $p<.05$, $\eta_p^2=.29$. Interestingly, Unaffected Sibs-ASD ($M=.03$, $SD=.92$) were rated as having intermediate levels of social deficits and did not differ significantly from either Affected Sibs-ASD or Sibs-COM. Refer to Figure 12- for group differences between Sibs-ASD and Sibs-COM and Figure 13 for differences between Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM on measures of observed and parent-report of social functioning.

Summary of Sibling Group Differences in Social Functioning: Sibs-ASD and Sibs-COM were observed during interaction with an unfamiliar peer (*Social Engagement* and *Social Dysregulation*) and parents provided ratings of *Social Deficits.* Contrary to hypotheses, Sibs-ASD and Sibs-COM did not significantly differ on measures of observed social functioning. However, Sibs-ASD and Sibs-COM differed on parent-report measures and indicated that Sibs-ASD displayed greater impairments in individual behaviors required for competent social interactions compared to Sibs-COM. Follow-up analyses on parent-reported Social Deficits indicated that Affected Sibs-ASD were rated as significantly more impaired on basic social behaviors compared to Sibs-COM, while

Unaffected Sibs-ASD displayed an intermediate level of parent-reported impairment on the same behaviors.

AIM 3: INDIVIDUAL DIFFERENCE ANALYSES

Originally, it was proposed that executive attention would be examined as a mediator of the association between sibling group and social functioning using regression analyses if differences in social functioning were observed. Therefore, because Sibs-COM and Sibs-ASD differed on *Social Deficits*, mediation analyses were conducted following the steps outlined by Baron and Kenney (1986). Specifically, the following four steps were examined:

Step 1: Sibling status will predict parent-report of social functioning.

Step 2: Sibling status will predict electrophysiological indices (N2 amplitude and N2 latency) of the Children's ANT, a measure of executive attention.

Step 3: Executive attention will predict parent-report of social functioning.

Step 4: In order to establish that executive attention mediates the relation between sibling status and social competence, a Sobel test will be significant.

Because it is necessary for Steps 2 and 3 to be significant and only measures of N2 amplitude and latency demonstrated group differences, only these measures of executive attention were used in subsequent analyses. Furthermore, due to significant correlations between N2 amplitude and Latency at Fz and FCz, scalp sites were averaged and measures of averaged N2 amplitude and Latency were used as the indices of executive attention.

N2 Amplitude as a Mediator of Parent-Reported Social Functioning: The first step involved a simple regression of the direct effect of sibling status on Social Deficits.

Contrary to the prior analysis, sibling status did not predict *Social Deficits*, R^2= .06, $F(1,22)$= .39, p= .27. This difference is likely due to the fact that the regression was conducted on a reduced sample (i.e., children who had ERP and parent report data, n = 23). Because Step 1 was not met, regression analyses were not conducted.

N2 Latency as a Mediator of Parent-Reported Social Functioning: The first step of this analysis involved a simple regression of sibling status on *Social Deficits*. As noted in the above analysis, this relation was not significant and regression analyses were not conducted.

Post hoc Examination of the Relations Between Executive Attention and Social Functioning: Sibs-ASD and Sibs-COM did not differ on all measures of social outcomes and measures of executive attention. However, when Affected and Unaffected Sibs-ASD and Sibs-COM were examined on measures of executive attention and social functioning, in many cases participants appeared to fall along a continuum of functioning in these domains. Therefore, post-hoc correlations of executive attention with social functioning were observed, across the entire sample, to examine the associations between executive attention and social functioning. The correlations among behavioral and electrophysiological measures from the Children's ANT and observed and parent-report measures of social functioning are reported in Table 9.

Social Deficits were inversely related to both N2 latency, averaged across sites and congruency, $r(32)$=-.31, p<.05, and P3 latency, $r(32)$=-.35, p=.09. Specifically, participants who displayed shorter latencies on N2 and P3 were reported by their parents to have more impairment in basic social behaviors. Furthermore, participants who displayed the greatest *Social Dysregulation* during the peer interaction tended to have

smaller amplitude P3 responses, averaged across sites and congruency, during the Children's ANT, $r(28) = -.31$, $p = .09$.

CHAPTER 4: DISCUSSION

The purpose of the current study was to assess the relations between cognitive functioning (i.e., executive attention) and social abilities in preschool-aged, younger siblings of children with and without a diagnosis of an Autism Spectrum Disorder (ASD). The younger siblings of children with autism differed on the amplitude and latency of the N2, an ERP index measured on a task of response inhibition. The N2 is an index of cognitive control, or the effortful decision-making process associated with conflicting cognitive responses. In addition, parents rated the younger siblings of children with autism as having greater deficits in basic social behaviors. Post-hoc analyses separating Unaffected and Affected siblings suggested that in general, social and cognitive impairments fell along a continuum with Affected Sibs-ASD at one end and Sibs-COM at the other, and Unaffected Sib-ASD falling in the middle. This pattern of results suggests that even Unaffected Sibs-ASD display subtle differences in basic cognitive and social functions which lends support to the notion of the Broader Autism Phenotype (BAP).

THE N2: HYPOACTIVITY AND COMPENSATORY MECHANISMS

Sibs-ASD and Sibs-COM differed in the regional specificity, amplitude and latency of the N2 response. Initial correlational analyses revealed that the N2 amplitude was significantly correlated across frontal sites, Fz and FCz, for Sibs-ASD but not for Sibs-COM. This pattern of results might represent more diffuse activation of frontal resources for Sibs-ASD due to structural differences or delayed neural developmental processes (e.g., pruning). Therefore frontal structures may be less developed in both Affected and Unaffected Sibs-ASD compared to typically developing peers. Recent diffuse tensor imaging studies (DTI) lend preliminary support to this hypothesis and

indicate that Affected and Unaffected Sibs-ASD share a similar pattern of white matter abnormalities that is not observed in typically developing children (Barnea-Goraly et al., 2011). Differences in white matter structures may lead to more diffuse activation of frontal sites and may delay development of frontal lobe structures required for effortful control. Therefore, longitudinal analyses of changes in neural structures in combination with electrophysiological indices of executive attention may help in further understanding the neural processes underlying cognitive development among Sibs-ASD.

Results of the current study showed that despite a lack of differences in behavioral performance between Sibs-ASD and Sibs-COM, there were important differences in both the amplitude and latency of the N2. Specifically, younger siblings of children with autism displayed reduced (less negative) N2 amplitude at Fz relative to Sibs-COM. In addition, they demonstrated reduced N2 amplitudes at Fz relative to FCz. Interestingly, when these primary analyses were further examined by assessing the impact of Affected Sibs-ASD on group differences, it was only Affected Sibs-ASD who displayed the significantly reduced N2 amplitudes compared to Sibs-COM. However, both Affected and Unaffected Sibs-ASD displayed significantly reduced N2 amplitudes at Fz relative to FCz, a pattern not observed in Sibs-COM.

A previous study observed similar findings between adults with and without an ASD (Schmitz et al., 2006). Specifically, the two groups did not differ on behavioral performance of response inhibition tasks, but ASD adults did display task-dependent activation of neural structures. As with the Schmitz et al., (2006) study, behavioral performance alone may not capture differences in executive attention, because these differences may be more subtle and related to the mechanisms associated with

information processing. Therefore, indices that measure information processing (e.g., ERP indices or fMRI) may better quantify differences in executive attention.

The direction of sibling group differences in the N2 amplitude (i.e., that the N2 was reduced in Sibs-ASD) was contrary to the original hypothesis. In typically-developing samples of children and adolescents, the N2 amplitude tends be positively associated with age, such that the amplitude gets smaller (less negative) with development (Henderson, 2010; Johnstone et al., 2007; Lamm et al., 2006). In addition, with development, the N2 amplitude has been found to become more frontally-oriented with greater activation at Fz accompanied by age-related decreases in activation at more central and parietal sites (e.g., FCz , Cz, and Pz: Jonkman, 2006). Also, within typically-developing child populations, a more negative N2 has been related to poorer performance on executive function measures (Lamm et al., 2006). Therefore, a more negative N2 amplitude is generally considered less mature and an indicator of the need for greater cognitive effort on tasks. Thus, this was the basis for hypothesizing that Sibs-ASD would display a more negative N2.

For this study, hypothesis for N2 amplitude was rooted in the developmental literature; however, the studies have found that there is a relation between reduced N2 amplitude and executive control in various clinical populations. For example, children with ADHD (Albrecht et al., 2008; Fassbender & Schweitzer 2006), adults with Depression (Richard et al., 2009) and adults with high levels of trait Anxiety (Dennis & Chen, 2009) also display reduced N2 amplitude on tasks of response inhibition. Because the N2 is thought to have neural generators in the Anterior Cingulate (AC) and poorer executive attention is associated with hypoactivation of the AC, it is thought that smaller

N2 amplitudes might be reflective of hypoactivation of the AC. Furthermore, a PET and fMRI study have identified AC hypoactivity in those with a diagnosis of autism (Hazendar et al., 2000) and a PECT study has related hypoactivation to greater social deficits in children with Higher Functioning Autism (Ohnishi et al., 2000). Therefore, in the current study, smaller N2 amplitudes may reflect hypoactivation, or a lag in the development of structures implicated in efficient executive attention in children.

In is important to note that despite physiological differences, Sibs-ASD performed similarly to Sibs-COM on behavioral measures of executive attention. Although a smaller N2 might reflect hypoactivation and inefficient processing, the ability to perform at comparable levels might suggest that Sibs-ASD develop compensatory strategies for performing simple cognitive tasks. For instance, children with ADHD who perform similarly to typically developing peers on behavioral measures of executive attention, display hypoactivation of the AC during various tasks of executive attention. However, this pattern of hypoactivation is counteracted by hyperactivation of other structural areas (Fassbender & Schweitzer, 2009). Similar results are hypothesized in studies of adult patients with a predilection for high levels of anxiety (Dennis & Chen, 2009). Therefore, there is a neural compensatory strategy engaged to help in the completion of this task.

It is also feasible that differences in N2 amplitude are a result of deficits in connectivity between neural structures involved in executive control. This fronto-striatal circuitry includes a number of structures (i.e., frontal cortex, cingulate, basal ganglia, and associated motor areas) that are related to the development of inhibitory functions and cognitive control processes (Booth et al., 2003). Under-connectivity in fronto-striatal

circuitry are observed in adults with high functioning autism (Schafritz et al., 2008) indicating the importance of this network in inhibition of a prepotent response. Furthermore, Diffuse Tensor Imaging (DTI) techniques have identified differences white matter tracts among adults with and without HFA (Langen et al., 2011) that may also contribute to poorer executive attention processes. Therefore, deficits in connectivity among structures may reduce the cognitive efficiency of processing and responding to the task, without impairments in behavioral performance.

Further research is necessary to assess for neural compensatory strategies in the BAP . Regardless of the underlying mechanism, difficulties with structural activation and poor connectivity in associated pathway, may represent an inefficient pattern of neural processing on tasks of inhibition. Consequently, this may lead to behaviorally apparent deficits when these individuals are placed in more cognitively complex and demanding situations (e.g., social interactions). Therefore, future studies can better assess the neural profile of AC and fronto-striatal activation in the BAP to examine patterns of hypo- and hyper-activation of scalp sites and patterns of connectivity to further explain the possibility of compensatory neural mechanisms influencing executive dysfunction in Sibs-ASD.

Unexpectedly, Sibs-ASD also differed from Sibs-COM on patterns of N2 latency based on both stimulus congruency and scalp site. Specifically, Sibs-ASD displayed shorter N2 latencies on congruent relative to incongruent trials and at Fz relative to FCz. Follow-up analyses indicated that Affected Sibs-ASD demonstrated the shortest N2 latency and Unaffected Sibs-ASD displayed the longest latencies with Sibs-COM falling in the middle of the distribution. There were also differences in N2 latency observed at

scalp sites. Therefore, differences in N2 latency observed within Sibs-ASD were unexpected and contrary to hypothesis.

Research suggests that N2 latencies tend to become shorter with age in typically-developing populations (Lamm et al., 2006) and have been interpreted as reflecting general increases in processing speed. Results from this study also indicate that N2latencies were positively related to reaction time which is consistent with the idea that N2 latency partially indexes global processing speed. Interestingly, across the whole sample, longer N2 latencies were associated with fewer parent-reported social deficits. Therefore, in young children, and perhaps in particular among the younger siblings of children with autism, longer N2 latencies may be adaptive in the sense they allow children to take more time to process information. For the Unaffected Sibs-ASD, extended neural and behavioral processing speed may allow for more time to process and integrate complex information.

Overall, results from the current study indicate that electrophysiological indices of executive attention (i.e., the N2) differentiate among Sibs-ASD and Sibs-COM. So, regardless of diagnostic status, Sibs-ASD displayed hypoactivity at Fz and a pattern of increased regional coherence (i.e., greater correlation between sites). This pattern of results may reflect an inefficient style of processing that allows them to perform accurately on relative simple tasks like the Children's ANT, but might make more complex tasks difficult. Unaffected Sibs-ASD may respond more slowly as a way allow more complete information processing. This, in turn, may allow for better developed basic social skills as indicated by the inverse association between N2 latency and parent-reported social deficits. It will be important in future studies to examine the interplay of

neural, cognitive, and behavioral indices of executive attention that may help further explain the variability of behaviors associated with the BAP.

CHARACTERIZING SOCIAL BEHAVIORS

Most often, studies have assessed social behaviors in children with Autism and the BAP by using parent-report questionnaires of autism symptoms. However, the exclusive reliance on parent-report measures of social functioning may be particularly limiting in the study of the BAP because parents of a child with autism, by definition, have a bias in their basis for comparison. In order to reduce biases and provide an assessment of peer interaction skills representative of a child's spontaneous social skills, this study utilized a peer interaction paradigm with an unfamiliar peer. In doing so, a child's spontaneous social behaviors were captured outside the context of the immediate family.

First of all, parent-reported *Social Deficits* were related to both *Social Engagement* and *Social Dysregulation*, and in the expected directions. Although correlations among these measures may indicate that these two measurement approaches tap into the similar behaviors, examining of the specific questions that are included in parent-report measures paints a different story. Specifically, on the SRS and AQ parents reported on specific behaviors important for social competence (e.g., does your child make eye contact), but few items tapped into the actual quality of quantity of children's spontaneous social interactions. Therefore, in the current study parent-report measures tapped into behaviors considered prerequisite for social competence whereas the peer interaction paradigm measured the child's ability to integrate and spontaneously utilize (or not utilize) these basic behaviors.

Interestingly, the Sibs-ASD and Sibs-COM did not differ on observed *Social Engagement* or *Social Dysregulation*, but differed on parent-report of social behaviors. Not surprisingly, Sibs-ASD were rated as having more social deficits than Sibs-COM. Post-hoc comparisons revealed that Affected Sibs-ASD were rated as having significantly more deficits than Sibs-COM, but that Unaffected Sibs-ASD were not significantly different from either of the other groups. These results provide support for a model of continuous social deficits where even those Sibs-ASD, who are not themselves affected, show a distribution of behavior that does not fully overlap with those of the Sibs-COM.

IMPLICATIONS FOR THE BROADER AUTISM PHENOTYPE

The BAP is said to be characterized by subclinical social and cognitive deficits that are representative of an Autism Spectrum Disorder. Overall, Unaffected Sibs-ASD did not significantly differ from either Affected Sibs-ASD or Sibs-COM on N2 amplitude and measures of social functioning. However, they were an intermediary group, in terms of mean N2 amplitude and parent-report of Social Deficit. This provides support for the notion that cognitive and social skills fall along a continuum of functioning from severe to not-severe, instead of belonging to distinct categories of functioning.

A precise understanding of the profiles of social and cognitive functioning in the BAP can provide a further explanation of the mechanisms underlying Autism Spectrum Disorders. Results from this study indicated that Unaffected Sibs-ASD, for the most part, displayed similar patterns of N2 amplitude as Affected Sibs-ASD; however, the two groups differed regarding N2 latency. The interaction between N2 amplitude and latency (i.e., hypoactivation, but longer processing of information) may help in understanding the cognitive mechanisms underlying differences in social functioning between these groups.

Furthermore, from the results of this study, it is difficult to ascertain if the profile of social and cognitive functioning observed in unaffected Sibs-ASD is a result of genetics or environmental factors. Characteristics of the BAP are considered to be a result of genetics which translate into specific phenotypic expressions (e.g., deficits in social behaviors). However, difficulties in social behaviors among Unaffected Sibs-ASD may also be a result of passive observation of social deficits in the sibling with autism. Therefore, it future studies can utilize methodologies that assess if differences in social and cognitive behaviors among Sibs-ASD are mediated by genetic factors or environmental influences.

LIMITATIONS

The sample size in the current study limited the statistical power of the planned analyses. The smaller than expected sample size was largely due to difficulties in recruitment of participants and the ability to accurately match target participants with age-, sex-, and verbal-IQ matched peers. While many of the hypothesized effects were not significant at traditional levels (i.e., $p < .05$), there were several statistical trends and many of the analyses revealed medium to large effect sizes. Effect sizes are increasingly more important in the social sciences because it allows for assessment of the magnitude of an effect, regardless of sample size (Cohen, 1988). Recruitment for this project is ongoing so it is anticipated that the sample size will increase in the near future.

In addition, differences in behavioral performance of the Children's ANT, and possibly differences in P3 amplitude and latency, may be due to task difficulty. Specifically, the task may not have been difficult enough to elicit significant response inhibition. Overall, children made fewer errors even on incongruent trials than would be

expected based on past studies (e.g., Albrecht et al., 2008). Therefore, it will be important to further develop testing paradigms in which timing parameters and therefore difficulty level can be titrated to an individual child's performance.

Finally, this study was impacted by only coding one participant's behaviors (target participant) during the peer interaction task and therefore the full dyadic process was not captured. Although some of the codes sought to assess the non-target participants interaction with the target participant (e.g., social responsiveness), there were few codes that assessed this. It is important to capture the dyadic process because it allows for an examination of both the child's own behaviors and the evocative effects his/her behaviors might have on an unfamiliar peer. Therefore, in the future, the dyadic session could be recoded to fully capture both social partners' behaviors and the dyadic process.

FUTURE DIRECTIONS

Results from the current study provide a foundation for better understanding variability in social and cognitive functioning among Sibs-ASD and even among non-ASD individuals. Specifically, social impairments are not limited to those diagnosed with an ASD and further exploration of these constructs can help provide insight onto the impact of executive attention on social functioning. Following Yeates and colleagues model (2007) an understanding of these deficits is integral in assessing the trajectory of social functioning among individuals with and without CNS insult. Specifically, future studies will benefit from exploration of mediators (e.g., genetics vs environment) and predictors (e.g., development of neural structures) of executive attention and social functioning.

Pertaining to results of the current study, the lack of differences in behavioral performance on the executive functioning task was surprising. Longitudinal studies assessing potential risk factors associated with the development of autism have demonstrated profiles of executive dysfunction as early as infancy (Holmboe et al., 2010; Zwaigenbaum et al., 2005). Therefore it will be important to design longitudinal studies, beginning in infancy, that assess how these skills develop and what moderating factors (e.g., environment) impact the development of these skills. It is likely that unaffected Sibs-ASD may learn better self-regulatory skills over time, thereby allowing them to navigate social situations better. However, this process may be more effortful, based on a genetic predisposition to deficits in cognitive and social functioning, and therefore factors that promote social competence in Sibs-ASD requires further exploration.

In addition to monitoring the trajectory of executive attention skills in Sibs-ASD, utilization of a paradigm that assesses inhibitory skills in a more socially relevant context may help in further understanding how early executive attention skills impact the ability for children to effectively manage social situations. For example, paradigms could be developed that induce social stress during the performance of executive attention tasks (e.g., using socially appropriate versus socially inappropriate stimuli, Dennis & Chen 2009). Other variations would include assessing the processing of stimulus congruency and incongruency in social scenarios.

CONCLUSION

The current study provides a basis for understanding social and cognitive variability among children with autism and the BAP. This study was able to utilize multiple methods to assess executive attention and social functioning. To date, there are

no studies that examine these constructs and relations using similar methodologies. Therefore, results of this study help provide further understanding of the subtle differences among cognitive and social functioning affecting Sibs-ASD and provide a basis for understanding the nature of social variability in individuals with and without a diagnosis of an ASD.

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Table 1: Demographic information on participants who completed the second session. Standard deviations are listed within parentheses.

	Sibs-ASD		Sibs-COM	
	Male	Female	Male	Female
N	16	6	12	6
Age (months)	70.5 (12.92)	63.38 (10.10)	71.42 (14.38)	67.17 (13.83)
Verbal IQ	95.5 (12.61)	110.63 (15.21)	97.92 (10.92)	107.67 (14.75)

Table 2: Tasks and measures completed by participants during the first and second sessions.

TARGET PARTICIPANTS		**NON-TARGET PARTICIPANTS**	
Session 1	Session 2	Session 1	Session 2
WPPSI-III ADOS SCQ SRS	Children's ANT EEG Behavioral Peer Interaction Free Play Puzzle Task AQ CBQ	WPPSI-III SCQ	Peer Interaction Free Play Puzzle Task

Table 3: Correlations among behaviors coded during peer interaction task

	Correlations						
Variables	1	2	3	4	5	6	7
1 Social Initiation	1						
2 Positive Affect	.45**	1					
3 Social Responsiveness	.56**	.40*	1				
4 Proportion of Social Play	.58**	.53**	.39*	1			
5 Reverse Negative Affect	-.14	.27	.22	.09	1		
6 Quality of Cooperation	.31*	-.01	.29*	.21	.31*	1	
7 Quality of Negotiation	.48*	.38*	.48*	.61**	.06	.39*	1

Note: * indicates correlations with p-values <.05

** indicates correlations with p-values <.01

Table 4: Rotated factor pattern from the Principal Component Analysis (PCA) of peer interaction variables

Items	Social Engagement	Positive Social Behaviors
Social Initiation	.81	
Positive Affect	.69	
Social Responsiveness	.74	
Proportion of Social Play	.80	
Reverse Negative Affect		.79
Quality of Cooperation		-.77
Quality of Negotiation	.78	

Table 5: Correlations among behaviors endorsed on the Social Responsiveness Scale (SRS) and Autism Quotient (AQ).

	Correlations				
Variables	1	2	3	4	5
1 SRS Social Awareness	1				
2 SRS Social Cognition	.79**	1			
3 SRS Social Motivation	.32*	.4*	1		
4 AQ Mind Reading	.75**	.75**	.43*	1	
5 AQ Social Skills	.60**	.43*	.48**	.72**	1

Note: * indicates correlations with p-values <.05

** indicates correlations with p-values <.01

Table 6: Factor pattern from the Principal Component Analysis (PCA) of parent-reported variables of social functioning.

Items	Reported Social Functioning
SRS Social Awareness	.87
SRS Social Cognition	.85
SRS Social Motivation	.60
AQ Mind Reading	.92
AQ Social Skills	.79

Table 7.1: Pearson's correlations of behavioral and electrophysiological indices from the Children's Attention Network Task (ANT) for the combined sample (n=24) of Sibs-ASD and Sibs-COM.

	Correlations											
Variables	1	2	3	4	5	6	7	8	9	10	11	12
1 Proportion Incorrect on Congruent												
2 Proportion Incorrect Incongruent	.68**											
3 Congruent RT	.26	.06										
4 Incongruent RT	.21	.06	.93**									
5 Mean N2 amplitude Fz	-.16	-.07	.12	.20								
6 Mean N2 amplitude FCz	-.09	-.23	.11	.24	.52*							
7 Mean P3 amplitude Cz	-.18	-.14	-.15	-.21	-.24	-.04						
8 Mean P3 amplitude Pz	.05	-.03	-.09	-.17	-.43*	-.19	.91*					
9 N2 Latency Fz	.37‡	.40‡	.10	.02	-.11	-.27	-.22	.02				
10 N2 Latency FCz	.32	.24	.48*	.42*	-.002	-.23	-.34‡	-.14	.45*			
11 P3 Latency Cz	.08	.10	.54*	.49*	.07	.28	.22	.09	.-.13	.07		
12 P3 Latency Pz	.26	.28	.58**	.59**	-.003	.22	.04	.05	.06	.35‡	.65**	

Note: ‡ Indicates correlations with a p-value <.10

* Indicates correlations with a p-value<.05

**Indicates correlations with a p-value <.01

Table 7.2: Pearson's correlations among behavioral and electrophysiological performance on the Children's Attention Network Task (ANT) for Sibs-ASD (n=11) and Sibs-COM (n=13), separately.

	Correlations											
Variables	1	2	3	4	5	6	7	8	9	10	11	12
1 Proportion Incorrect on Congruent		.68*	.15	.24	-.13	-.20	-.29	.02	.58*	.64*	.19	.35
2 Proportion Incorrect Incongruent	.65*		-.20	-.09	-.01	-.23	-.15	-.08	.51‡	.39	-.03	.16
3 Congruent RT	.54‡	.46		.93**	.11	.25	-.01	.03	.19	.07	.52‡	.41
4 Incongruent RT	.36	.37	.92**		.05	.20	-.04	.02	.21	.12	.44	.38
5 Mean N2 amplitude Fz	.1	.13	-.07	.11		.17	-.49	-.52‡	.23	.30	.30	.06
6 Mean N2 amplitude FCz	.08	-.22	-.02	.23	.76**		.09	.09	.16	.11	.40	.31
7 Mean P3 amplitude Cz	-.10	-.15	-.35	-.47	.-.04	-.18		.86**	-.58*	-.43	.08	-.32
8 Mean P3 amplitude Pz	.01	-.02	-.19	-.38	-.38	-.52‡	.86**		.42	.07	-.12	-.22
9 N2 Latency Fz	.08	.24	.15	-.01	-.07	-.50	.18	-.26		-.58*	-.21	-.05
10 N2 Latency FCz	.13	.19	.74**	.62*	-.44	-.50	-.25	.07	.47		-.14	.25
11 P3 Latency Cz	.19	.17	.68*	.68*	.21	.27	.08	-.12	-.21	.33		.64*
12 P3 Latency Pz	.35	.46	.86**	.96**	.05	.17	-.32	-.22	-.05	.54‡	.68*	

Note: ‡ Indicates correlations with a p-value <.10
* Indicates correlations with a p-value<.05
**Indicates correlations with a p-value <.01

Table 8: Pearson's correlations between coded behaviors during peer interaction task and parent-report of social functioning for Sibs-ASD and Sibs-COM, separately

	Combined Group Correlations			Separate Group Correlations		
Variables	1	2	3	1	2	3
1 Social Engagement					-.03 (17)	-.21 (18)
2 Social Dysregulation	0			-.16 (19)		.21 (18)
3 z-Social Deficits	-.31ǂ (36)	.31ǂ (35)		-.35 (19)	.25 (18)	

Note 1: Sibs-ASD are represented by shaded area and Sibs-COM are represented by non-shaded area

Note 2: Number of participants for each correlation were listed below values

Table 9: Correlations among measures of executive attention with measures of social functioning for Sibs-ASD and Sibs-COM

	Correlations		
Variables	Social Engagement	Social Dysregulation	Social Deficits
N	29	28	32
Conflict Accuracy	-.13	.22	-.04
Conflict Reaction Time	.11	-.08	-.28
N2 Amplitude	.12	.30	-.04
N2 Latency	.29	-.21	-.31ǂ
P3 Amplitude	.06	-.31ǂ	-.10
P3 Latency	.30	-.09	-.35*

Note: * Indicates correlations with a p-value <.05
**Indicates correlates with a p-value <.01
ǂ Indicates correlates with a p-value <.10

Figure 1: Stimulus and ERP timing parameters of the modified Children's Attention Network Task (ANT) utilized for behavioral and electrophysiological indices of executive attention.

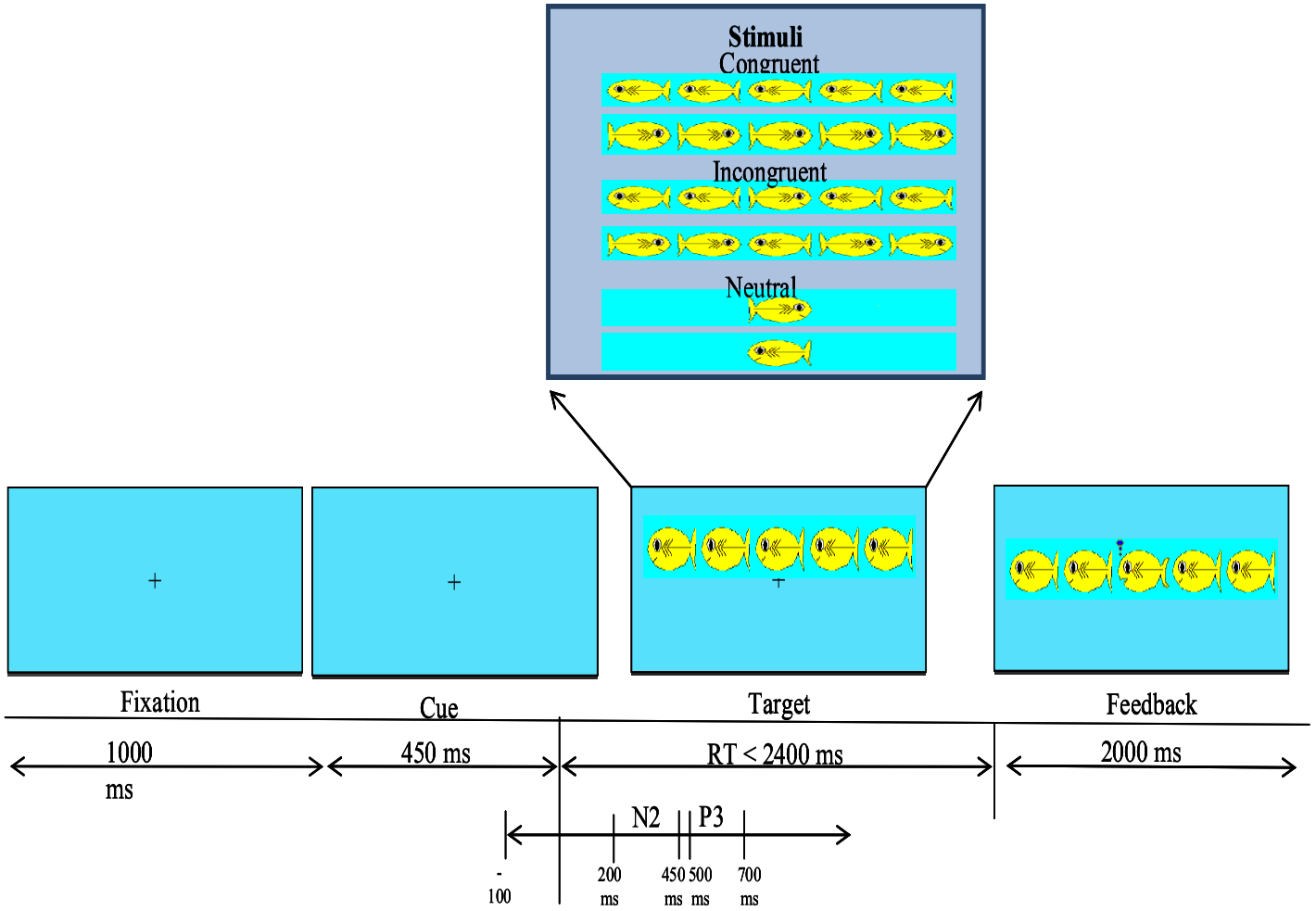
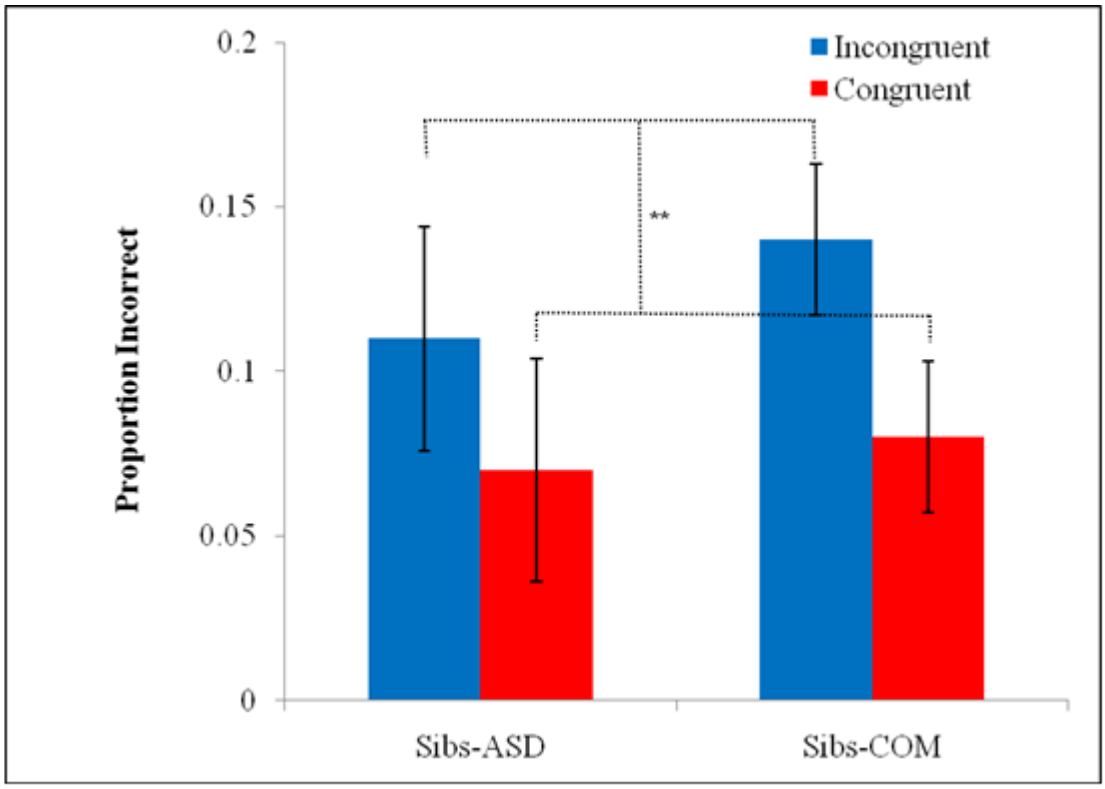
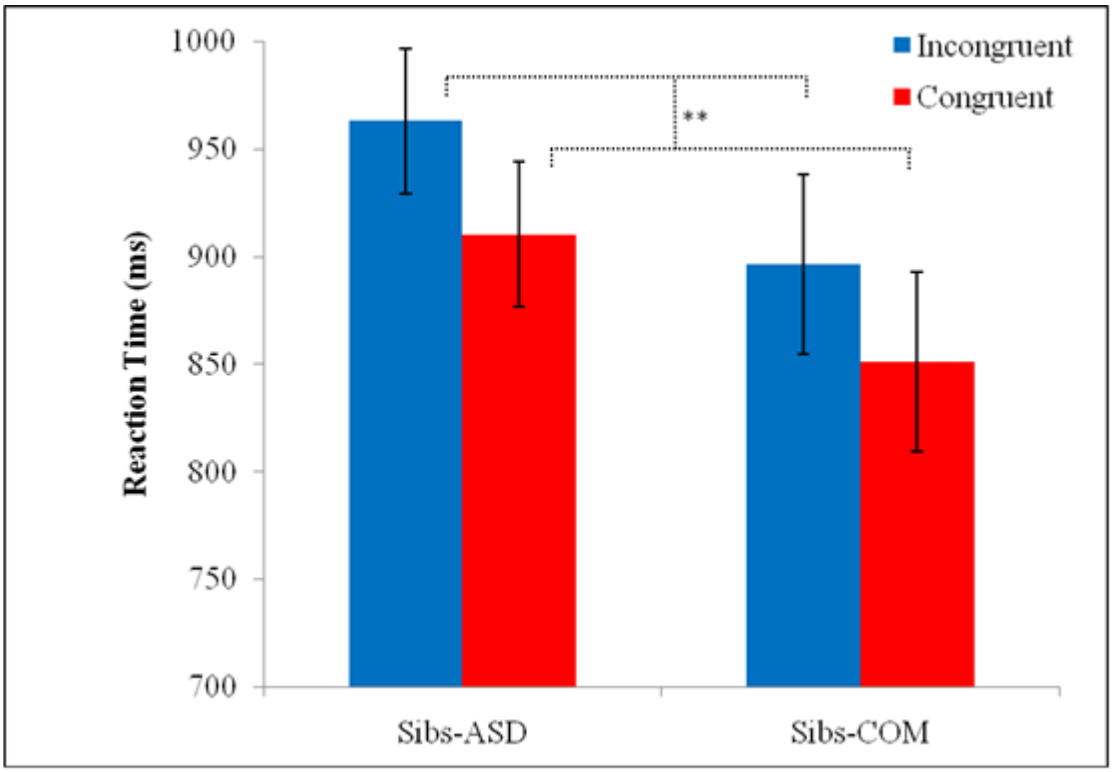


Figure 2: Error rates for Sibs-ASD and Sibs-COM on behavioral performance of the Children's Attention Network Test (ANT) on incongruent and congruent trials.



** $p<.01$

Figure 3: Reaction time for Sibs-ASD and Sibs-COM on behavioral performance of the Children's ANT on incongruent and congruent trials.



** $p<.01$

Figure 4: Grand average waveforms for Sibs-ASD and Sibs-COM with incongruent and congruent waveforms listed at central medial scalp sites: Fz, FCz, Cz, and Pz.

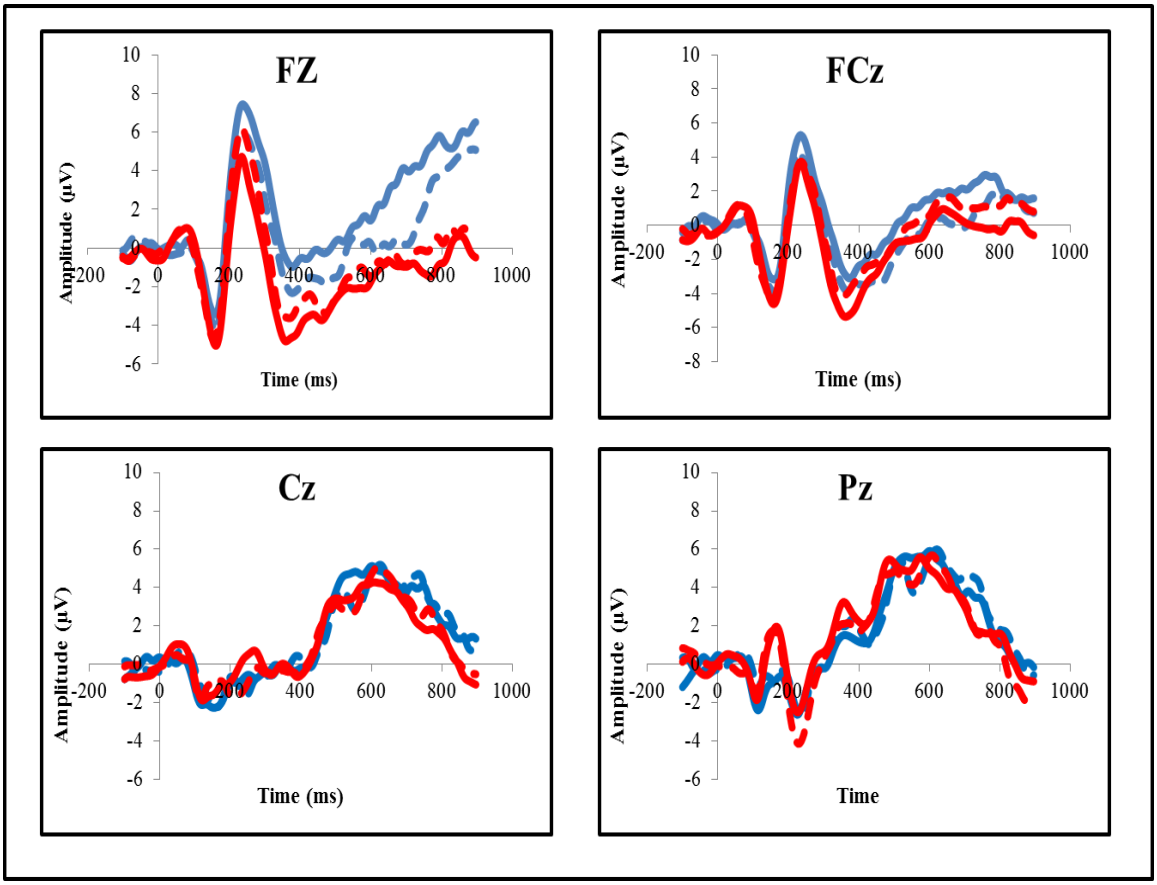


Figure 5: Grand average waveforms for Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM with incongruent and congruent waveforms listed at central medial scalp sites: Fz, FCz, Cz, and Pz.

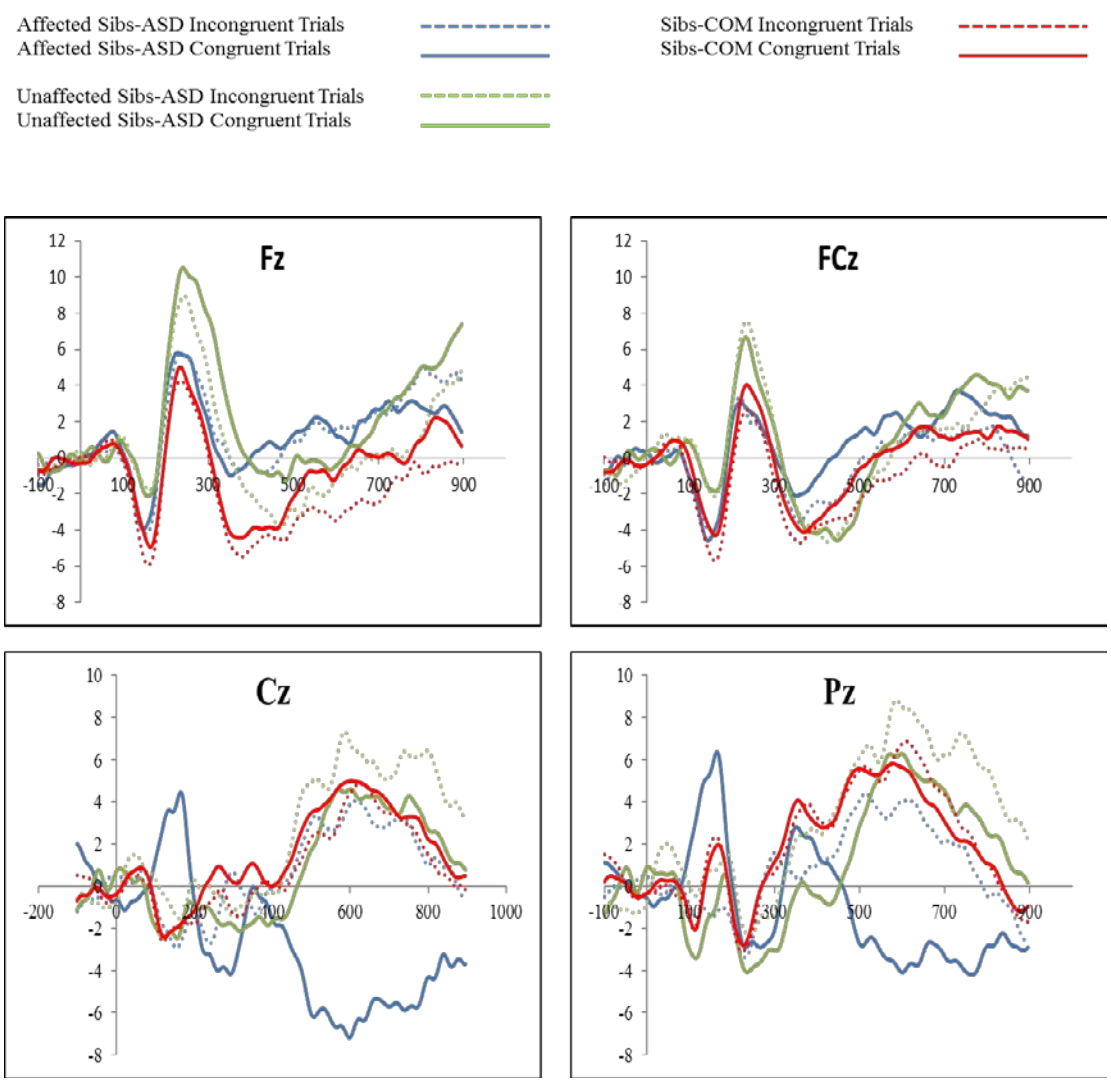
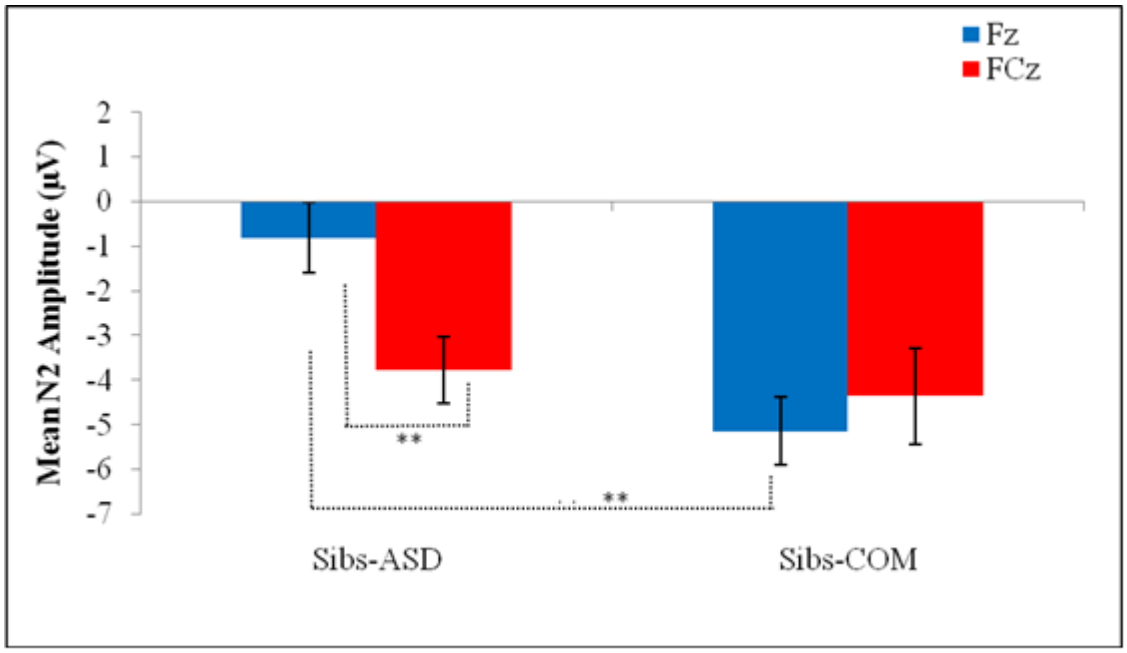
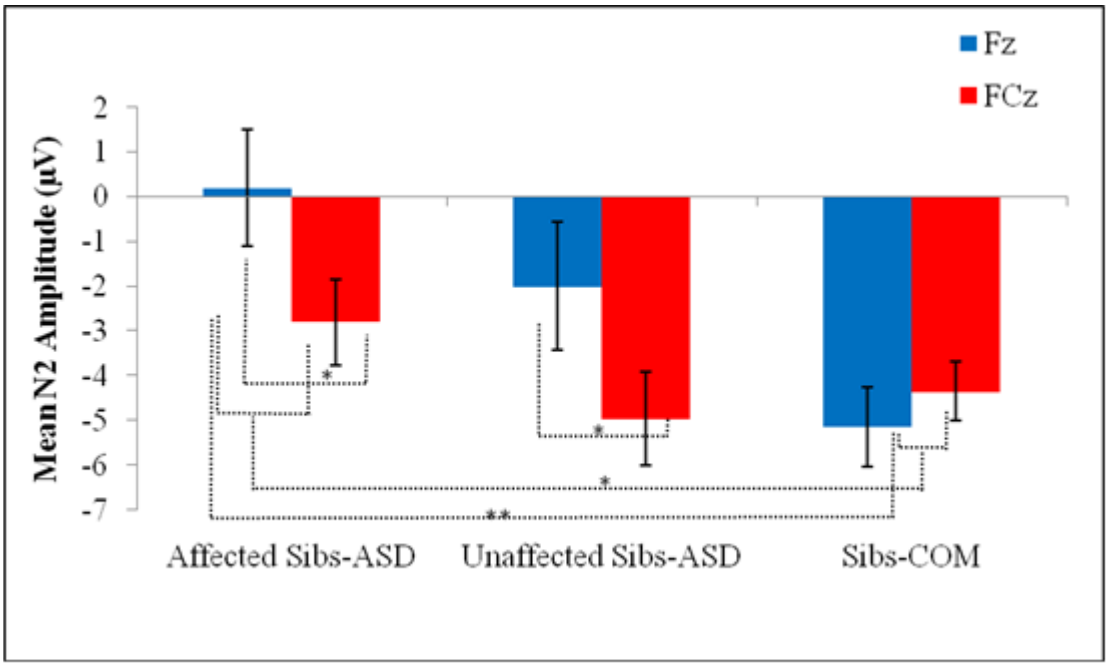


Figure 6: Mean N2 amplitude at frontal scalp sites (Fz and FCz), collapsed across congruent and incongruent trials, for Sibs-ASD and Sibs-COM.



** $p<.01$

Figure 7: Mean N2 amplitude at frontal scalp sites (Fz and FCz), collapsed across congruent and incongruent trials, for Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM.



* $p<.05$
** $p<.01$

Figure 8: N2 latency, in milliseconds, for Sibs-ASD and Sibs-COM at Fz and FCz, collapsed across congruency.

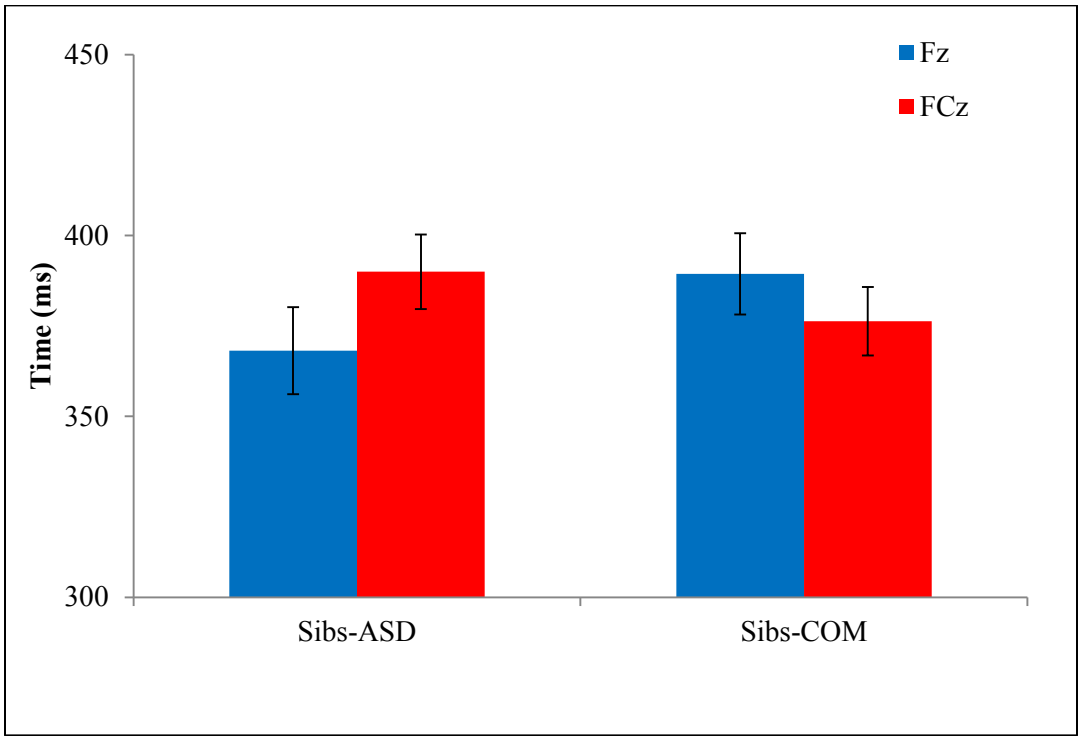
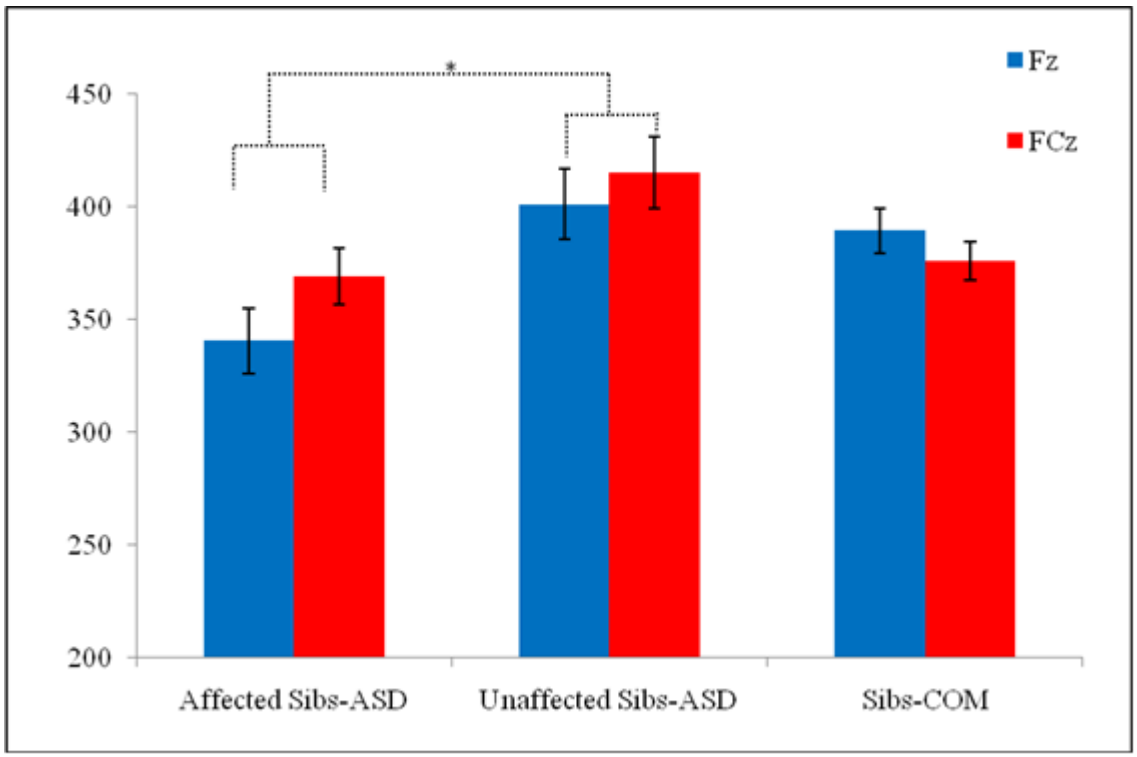


Figure 9: N2 latency, in milliseconds, for Unaffected Sibs-ASD, Affected Sibs-ASD, and Sibs-COM at Fz and FCz, collapsed across incongruent and congruent trials.



* $p<.05$

Figure 10: P3 Amplitude for Sibs-ASD and Sibs-COM at Cz and Pz, collapsed across incongruent and congruent trials.

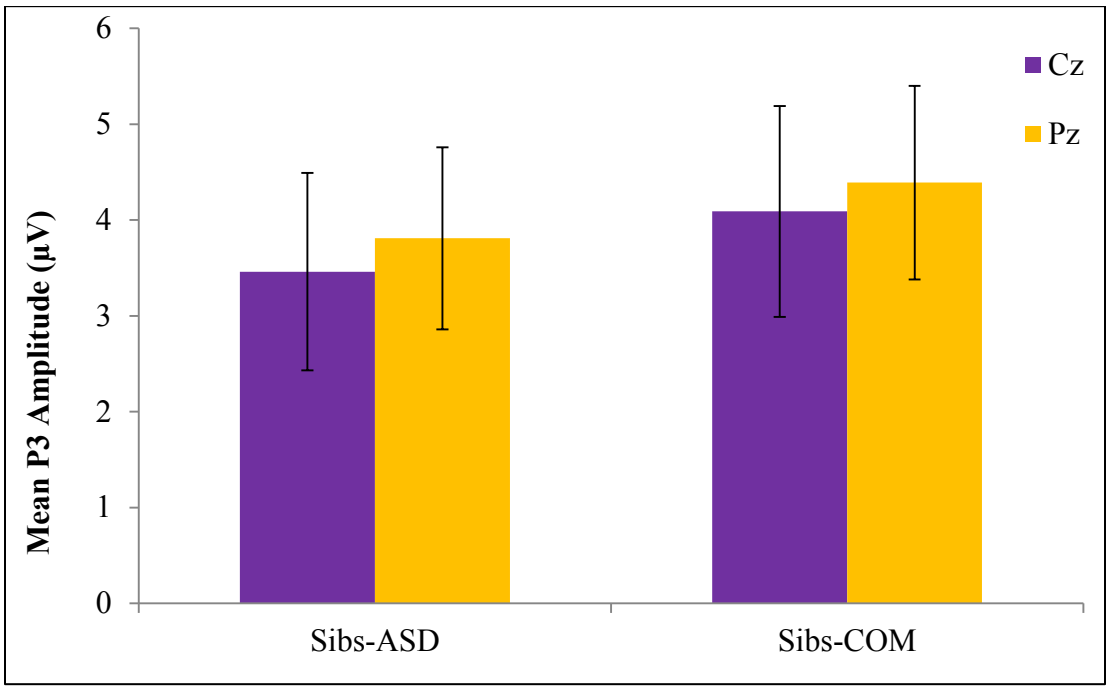


Figure 11: P3 Latency for Sibs-ASD and Sibs-COM at Cz and Pz, collapsed across congruent and incongruent trials.

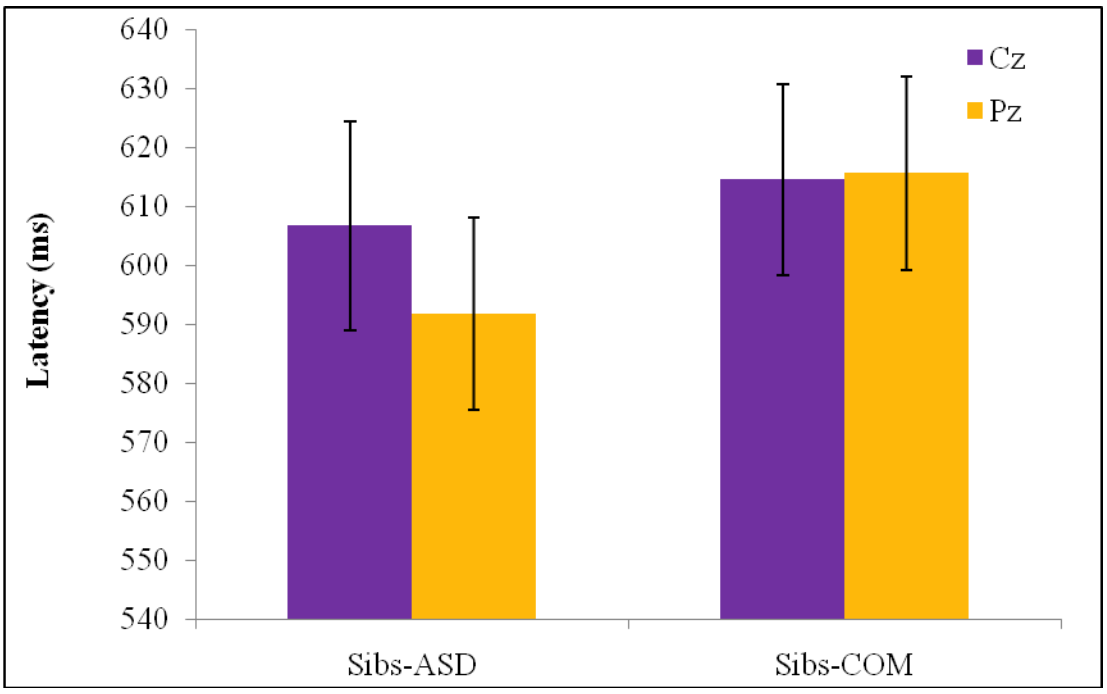
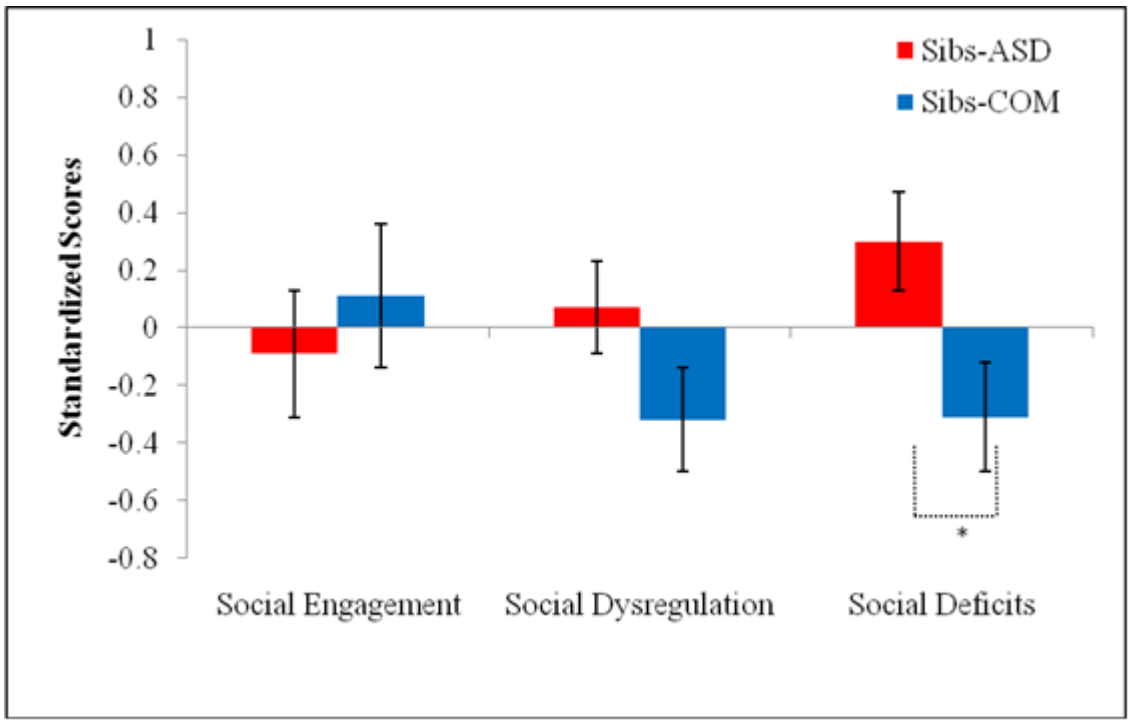
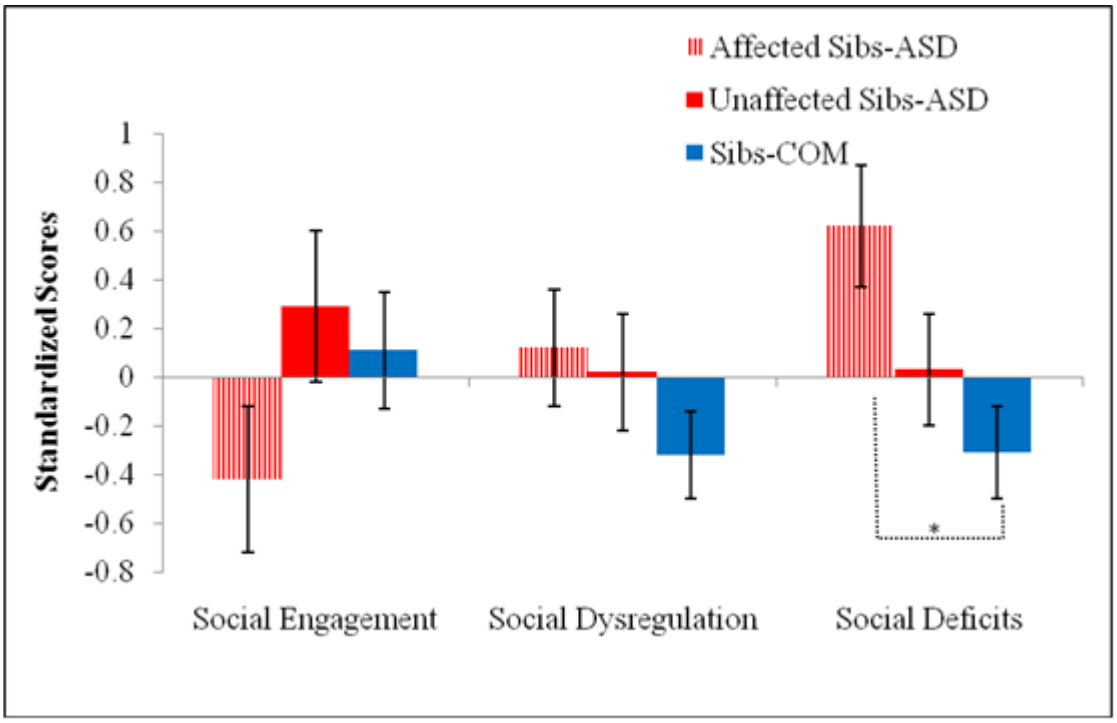


Figure 12: Observed and parent-reported indices of social functioning for Sibs-ASD and Sibs-COM.



*p<.05

Figure 13: Observed and parent-report of social functioning for Affected Sibs-ASD, Unaffected Sibs-ASD, and Sibs-COM.



* $p<.05$