Aspects of Joint Attention in Autism Spectrum Disorder: Links to Sensory Processing, Social Competence, Maternal Attention, and Contextual Factors

Andrew J. Dakopolos

Submitted in partial fulfilment of the
requirements for the degree of
Doctor of Philosophy
under the Executive Committee
of the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2019

ABSTRACT

Aspects of Joint Attention in Autism Spectrum Disorder: Links to Sensory Processing, Social Competence, Maternal Attention, and Contextual Factors

Andrew J. Dakopolos

Background. Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social interaction, communication, and restricted and repetitive behaviors (American Psychiatric Association, 2013). Given the heterogeneity of ASD it is important to understand individual differences within the disorder that are related to cognitive and language development, and how such differences may be related to differences in caregiver behavior or aspects of the social environment. Joint attention is an important component of early social communication and is considered to be a “core deficit” of ASD (Kasari, Freeman, Paparella, Wong, Kwon, & Gulsrud, 2005). Individual differences in joint attention during infancy have been shown to relate to language and cognitive development (Mundy, Block, Delgado, Pomares, Van Hecke, & Parlade, 2007; Nichols, Martin, & Fox, 2005). Therefore, joint attention serves an essential role in the study of child behavior within ASD across development.

The present study consists of two manuscripts that explored how joint attention in children with ASD related to sensory responsiveness and social competence (*Study 1*), and how child joint attention related to mother attention and contextual factors (*Study 2*). Specifically, *Study 1* investigated relations among children's sensory responses, dyadic orienting, joint attention, and their subsequent social competence with peers. Participants were 38 children (18 children with autism spectrum disorder (ASD) and 20 developmentally matched children with typical development) between the ages of 2.75 and 6.5 years. Observational coding was conducted to assess children's joint attention and dyadic orienting in a structured social communication task. Children's sensory responses and social competence were measured with

parent report. Group differences were observed in children's joint attention, sensory responses, multisensory dyadic orienting, and social competence, with the ASD group showing significantly greater social impairment and sensory responses compared with their typical peers. Atypical sensory responses were negatively associated with individual differences on social competence subscales. Interaction effects were observed between diagnostic group and sensory responses with diagnostic group moderating the relation between sensory responses and both joint attention and social competence abilities.

Study 2 investigated relations between child joint attention and mother attention during three social contexts (competing demands, teaching, and free play) among 44 children with ASD between the ages of 2.5 and 5.6 years, and their mothers. Observational coding was conducted to assess children's joint attention and mother's dyadic orienting. Children's expressive and receptive language was measured by teacher report. The rate of children's joint attention, and mothers' dyadic orienting differed depending on the context of their interaction. Children's joint attention, expressive and receptive language, age, and ASD severity, and mother dyadic orienting were related, and these relations differed by context. Child initiating joint attention (IJA) was also related to mother attention, and this relation was moderated by the child's expressive and receptive language. A temporal contingency was revealed for the association between child IJA and mother attention with a bi-directional association such that child IJA predicted subsequent mother attention, and mother attention predicted subsequent child IJA. When the sample was split by children's language ability (i.e., minimally-verbal and verbal groups) there was a group by receptive language, and a group by expressive language interaction on the contingency between child IJA and subsequent mother attention.

Conclusion. The results from study 1 and study 2 suggest that individual differences in children with ASD, including their sensory responses and social competence, as well as mother attention and contextual factors are related to children's joint attention. When addressing theory and interventions for children with ASD, it is important to consider children's language and sensory sensitivities, the demands of the interactive context, and factors related to mother attention and approach to her child.

TABLE OF CONTENTS

List of Tables

List of Figures

Acknowledgements

I would like to express my most sincere gratitude and appreciation to those who have supported me along the way to completing this project. First, I would like to thank my advisor, Dr. Laudan Jahromi, whose vast knowledge, support, and mentorship enabled me to not only complete this project, but foster my passion for research. The amount of intellectual growth I experienced while at Teachers College was a direct reflection of the opportunities, critical discourse, and constant support that Dr. Jahromi provided.

A significant portion of this project was made possible through the teamwork and dedication of a research team from Teachers College and the Fred S. Keller School. I am grateful to have been part of this team, and to have learned from and collaborated with Dr. Laudan Jahromi, Dr. Marla Brassard, Dr. Douglas Greer, Dr. Lin Du, and Dr. Jessica Dudek. From early conceptions and study design, through piloting and data collection, the skills I learned during every stage of this project will serve me well in the future.

I would also like to thank the members of my dissertation committee, Dr. Marla Brassard, Dr. Douglas Greer, Dr. Karen Froud, and Dr. Zheng Zhou, who have provided invaluable feedback and support through the dissertation process. I sincerely appreciate your mentorship and guidance.

To the other doctoral student members of the Keller Research Team – Alexis Bancroft, Missy Johnson, Amarelle Hamo, Zoe Chiel, and Katie Kirkman – your dedication to this project, wisdom, and friendship throughout our studies was integral to my experience as a doctoral student, and has helped me achieve this milestone. I will fondly remember our treks to Yonkers and the great times in our lab.

I am grateful to the research assistants who helped make this research possible. Your hours of data collection and video coding were instrumental to this process, and I could not have completed my dissertation without your hard work. I would especially like to thank Christy Yoon and Yi Wei for your dedication and help with this project.

I would also like to thank the Teachers College statistics department, specifically Dr. Elizabeth Tipton and Dr. Brian Keller. I could have never foreseen that I would develop a passion for statistics and math, but through your teaching and mentorship, I was able to discover a hidden skill that will serve me well beyond Teachers College.

I could not have completed this dissertation without the constant encouragement from my family. To my parents, your unwavering support, thoughtfulness, and love has given me strength throughout this process. I love you both and so value each of you. To my brother, there is nothing in this world like the love and support of a brother, and you are the best brother I've ever had. Also, to the Boring family, whose guidance and wisdom has helped lead me through some of the most important decisions of my life, including my doctoral studies. Additionally, to Ben Golden and Aaron Boring, you each are two of my greatest teachers. To the Shirazi family, who has treated me as a son and has always been there for me. To Lynn and Marlys Waller, who exemplified life-long dedication to education, learning, and scholarship. And to Connor Wingo and the Abbas family, whose couches, spare rooms, meals, and support helped me cross the finish line.

Finally, to my wife, Farah, even during the most challenging times you remained unwavering in your support of me. From our talk on the steps of Haines, to this point, you have been my biggest supporter and inspiration throughout my studies, and I could not have achieved this milestone without you. Thank you for encouraging me, for helping me reach my potential, and for always being there for me, I love you. This dissertation is dedicated to you.

I

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social interaction, communication, and restricted and repetitive behaviors (American Psychological Association, 2013). Our understanding of ASD has changed over time, evidenced by changes in diagnostic criteria (American Psychological Association, 2013), as well as shifting understanding of categorization and possible subtypes of ASD (Grzadzinski, Huerta, & Lord, 2013). In 1989, autism prevalence was estimated to be 4 per 10,000 individuals, with approximately 66% identified as having a concurrent intellectual disability, while more recently, prevalence is estimated to be 1 in 88 individuals and only 38% in the range of intellectual disability (Dawson & Bernier, 2013).

Given the heterogeneity of ASD (Grzadzinski et al., 2013), it is important to understand individual differences within the disorder that are related to cognitive and language development, and whether such differences are similar to those that emerge during typical development or those due to other types of developmental delay or psychopathology in children (Sigman & Kasari, 1995). Children with ASD differ in their ability to regulate emotion and their attention, and demonstrate variability in their level of social understanding and interest in people (Sigman & Kasari, 1995). Joint attention, an important component of early social communication in children (e.g. Adamson & Russell, 1999, Mundy & Gomes, 1998; Mundy & Newell, 2007) is considered to be a "core deficit" of ASD (Kasari, Freeman, Paparella, Wong, Kwon, & Gulsrud, 2005).

Individual differences among young children during the development of nonverbal communication skills may contribute to socioemotional and cognitive outcomes (Morales, Mundy, Crowson, Neal, & Delgado, 2005), and specifically, individual differences in joint attention during infancy have been shown to relate to language and cognitive development (Mundy, Block, Delgado, Pomares, Van Hecke, & Parlade, 2007; Nichols, Martin, & Fox, 2005). Joint attention therefore, serves an essential role in the study of child behavior within ASD across development.

Joint Attention

Joint attention consists of an individual's ability to share attention with a social partner, and has been shown to relate to language development (Meltzoff & Brooks, 2008, Mundy, Sigman, & Kasari, 1990), social competence (e.g. Mundy & Newell, 2007; Patten, Ausderau, Watson, & Baranek, 2013), and sensory responsivity (e.g. Baker, Lane, Angley, & Young, 2008; Baranek, Watson, Boyd, Poe, David, & McGuire, 2013; Watson, Patten, Baranek, Poe, Boyd, Freuler, & Lorenzi, 2011) in children with ASD. A robust and well-established body of literature demonstrates that children with ASD, even those with higher functioning language and cognitive development, exhibit deficits in joint attention behaviors compared to their typically developing peers (e.g. Clifford & Dissanayake, 2008; Dawson, Toth, Abbott, Osterling, Munson, Estes, & Liaw, 2004; Meek, Robinson, & Jahromi, 2012), as well as to chronological and mental age matched children with intellectual disabilities (e.g. Baranek et al., 2013; Leekam, Lopez, & Moore, 2000). Despite this rich body of work, there is still much to learn about the role of joint attention in the development of children with ASD and its links to other aspects of the disorder.

Mundy and Jarrold's (2010) parallel and distributed processing (PDP) model of joint attention provides a framework to consider joint attention in children with ASD and the potential overlap in sensory perception and social attention. The PDP model proposes that through practice and experience, joint attention serves a social executive function enabling children to engage in increasingly effortless coordination of social attention that contributes to the development and efficiency of social learning, symbolic thinking, and social-cognitive problem solving (Mundy & Jarrold, 2010). As it relates to joint attention, the PDP model may be supported within Dynamic Systems Theory, which attributes developmental change to self-organizing fluctuations of elements within an "open system" of factors related to child development (Thelen & Smith, 1994). The operations in this 'open system' change as a function of individual's experiences, and what happens on the local level in real-time affects the course of one's development (Smith & Thelen, 1993). Within this system, the PDP model views joint attention as a skill that leads to knowledge development and information sharing, rather than a static advancement in the development of knowledge (Mundy & Jarrold, 2010; Smith & Thelen, 1993).

Both child-specific and external (i.e. aspects of the context or social partner) factors play a role in this process. Thus, in the sense that dynamic systems theory accounts for both internal and external pressures during development, joint attention likely interacts with various other child developmental processes (Adamson & Russell, 1999; Morales et al., 2005). Within such frameworks, unsuccessful integration of joint attention may be understood to contribute to subsequent difficulties in social interaction, above and beyond the child's ultimate language abilities (Tomasello, 1995).

Given this broad hypothesis of the role of joint attention in development, Adamson and Russell's (1999) affective model of joint attention supports inquiry beyond only cognitive factors to explain the development of joint attention. They argue that many other developmental processes including affect and emotion regulation may be critical for the emergence of a stable organization of joint attention. From a Dynamic Systems Theory perspective, Adamson and Russell (1999, p. 290) assert:

> "the theory's metaphors for developmental change may help us place emotion regulation relative to a myriad of other factors, including endogenous ones related

to voluntary attention, cognition, and motor behavior, and exogenous ones such as a partner's social skill, the infant's interactive history with a specific partner, the physical arrangement of the environment, and the culture's interpretation of specific objects."

The theoretical approaches outlined above fit well within the bioecological model of development, which identifies individual differences, experiences within an individual's microsystem (i.e. experiences with parents, caretakers, relatives, friends, teachers etc.), and experiences within their broader macrosystem (i.e. larger systems, organizations, culture, and individuals removed from one's day-to-day life) interacting across time to describe the developmental trajectory of people (Bronfenbrenner & Morris, 2006). Provided these important perspectives, it remains unclear how patterns of joint attention skills may relate to other individual differences, and whether joint attention behaviors interact with demands placed on the social dyad through environmental context, as well as how a social partner may support or discourage joint attention.

Joint Attention and Sensory Experiences

Sensory deficits are an important aspect of ASD and have recently been included in the DSM-V diagnostic criteria for autism (American Psychological Association, 2013). Sensory atypicality in ASD is an important strand of inquiry, especially given the growing body of literature linking individual differences in sensory experiences to core features of ASD including social interaction (Hilton, Harper, Kueker, Lang, Abbacchi, Todorov, & LaVesser, 2010; Liss, Sauliner, Fein, & Kinsbourne, 2006) and restricted and repetitive behaviors (RRBs; Kargas, Lopez, Reddy, & Morris, 2014; Watt, Wetherby, Barber, & Morgan, 2008). Dawson and Bernier (2013) highlight the complexity of these relations by drawing on studies of children at high risk for developing ASD. They illustrate that by 12 months of age, children who went on to develop

ASD exhibited motor delays, unusual repetitive behaviors, atypical visual attention, and deficits in social communication; however none of these behaviors singularly differentiated ASD diagnosis. Rather, a complex constellation of such behaviors indicated their increased risk and subsequent diagnosis (Dawson & Bernier, 2013). Such interrelations warrant further study to disentangle both the developmental progression, and relations between dimensions of ASD diagnosis.

Specifically, sensory processing differences may interfere with children's broader social attention (Baranek, David, Poe, Stone, & Watson, 2006). Decreased shared attention mechanisms in ASD may develop as a means to reduce excessive quantities of sensory information and could lead to atypical social behaviors (Mundy & Newell, 2007). It is important to understand how these processes work together to influence more global aspects of social communication and social interaction in children with ASD (Patten, Ausderau, Watson, & Baranek, 2013).

Purpose of Study 1

The purpose of study 1 was to assess patterns of sensory experiences, social competence, and joint attention in children with high functioning ASD and a language-age matched sample with typical development (TD). The study extends previous work and fills a gap in the literature by examining how sensory responsiveness and joint attention work together to promote social competence in children with ASD. Specifically, the study examined group differences in sensory responsiveness, joint attention, social competence and dyadic orienting among children with ASD with high functioning language and cognitive development. In addition, the study examined whether sensory responsivity was related to joint attention and social competence, and whether patterns of relations between sensory responsivity, social competence and joint attention would be different for children with ASD and their typical peers. This study utilized video-taped experimenter-child interactions using the Early Social Communication Scales (ESCS; Mundy, Hogan, & Doehring, 1996), subsequent observational video coding of child behaviors, and parent report of child behaviors including sensory experiences and social competence.

The Role of Parent-Child Contextual Factors

Most studies have measured joint attention within either contrived or structured experimental scenarios. Many strategies exist to measure joint attention in children with ASD, including parent interactions such as the Communication Play Protocol (CPP; Adamson & Bakeman, 1999) and Parent-Child Free Play Protocol (PCFP; Bottema-Beutel, Yoder, Hochman, & Watson, 2014); experimenter interactions such as the Early Social Communication Scales (ESCS; Mundy, Hogan, & Doehring, 1996) and Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002); peer interactions (e.g. Bakeman & Adamson, 1984); and even robot interactions (e.g. Daglarli, Daglarli, Gunel, & Kose, 2017). Parent report such as the MacArthur-Bates Communicative Development Inventory: Words and Gestures (CDI-WG; Fenson et al., 2007) have been used to measure joint attention as well.

The majority of studies on joint attention have relied on the above-mentioned standardized tasks or naturalistic play contexts, and have not ventured far outside such social contexts. Such contrived settings aim to elicit joint attention behaviors whereas unstructured play settings have been used to demonstrate other behaviors such as joint engagement (e.g. Adamson, Bakeman, Deckner, & Romski, 2009), symbolic play (e.g. Kasari, Freeman, & Paparella, 2006), and sensory responsiveness (e.g. Baranek, Boyd, Poe, David, & Watson, 2007). The fluidity of naturalistic social interactions requires children to constantly assess and reassess the context of their environment while making judgements about themselves, their social partner, and objects or events of interest (Mundy & Jarrold, 2010). It may be that the social partner's behaviors differ according to different task demands, and therefore it is important to understand how contextual differences and task demands may be related to joint attention behaviors of children with ASD.

A number of researchers have explored parent behaviors that may support joint attention with their child during social interaction, and many of these behaviors have been tested in intervention settings (e.g. Gulsrud, Hellemann, Shire, & Kasari, 2016). During early development, an infant's maintenance of joint attention depends on their partner's skillful support (Adamson & Russell, 1999). Such support may consist of managing the child's emotions, interpreting the child's expressions of interest, and modulating their attention to an object (Adamson & Russell, 1999). The social partner's level of support may have an impact on the child's joint attention outcomes (e.g. Parrinello & Ruff, 1988). When we conceive of joint attention from the perspective of an engagement state with a social partner, there is evidence that the social partner's support of such engagement states is a greater predictor of language development than coordinated joint engagement, and this pattern of relations is stronger for children with ASD compared to their typically developing and intellectually disabled peers (Adamson, Bakeman, & Deckner, 2004; Adamson, Bakeman, Deckner, & Romski, 2009). Understanding the relations between parental behaviors and the child's social communication behaviors during an unstructured social exchange may help us to further target intervention strategies, and provide a clearer picture of the contextual elements and behaviors of the social partner that support joint attention in children with ASD.

Purpose of Study 2

The purpose of Study 2 is to examine joint attention behaviors of children with ASD and their mothers in both structured and unstructured contexts (i.e., competing demands, teaching and free play with a parent) and to examine the relation between parental behaviors (i.e., dyadic orienting) and joint attention behaviors of children with ASD. By examining three contexts including competing demands, teaching, and free play, it may be possible to gain insights into aspects of social contexts that promote or discourage joint attention. Each of the three tasks place different attentional demands on the mother and child. During the competing demands task, the mother's focus of attention is away from the child, which provides an opportunity for the child to initiate attention if they are so inclined. In contrast, in the teaching task, the parent's focus is placed solely on the child in order to keep them engaged in completing a construction task. Moreover, this task consists of a concrete objective. Finally, the unstructured free play task provides a social context in which the onus of initiation is ambiguous, theoretically allowing for equal coordination of attention between parent and child. There may also exist differences in children's joint attention skills in structured versus unstructured play settings. Children with ASD may exhibit differences in joint attention skills when they are being explicitly elicited (structured context) versus observed organically (unstructured context).

The present study adds to the literature by looking at how mothers' behaviors may be related to their child's joint attention, and whether this relation is moderated by task demands. While joint attention is widely studied in the field of autism research, there has been little inquiry into specific interactive contextual effects on the joint attention skills of children with ASD. Study 2 utilized video-taped parent-child interactions across a variety of tasks as well as subsequent observational video coding of both parent and child behaviors. This study also examined teacher's reports on child adaptive behaviors, as well as parent's reports of other socio-demographic information through questionnaires.

II

Review of Literature

The present study seeks to further extend our understanding of joint attention in ASD relative to child-specific (e.g. sensory responsivity and social attention) and external (e.g. mother behaviors and social context) factors. The following review of literature will begin with an examination of joint attention in typical development, leading to a discussion of the relative difficulties in joint attention skills that children with ASD experience. Such skill deficits will be examined with respect to child-specific aspects of development including regulation, affect, language, and specifically sensory responsivity. Subsequently, skill deficits in joint attention for children with ASD will be discussed in relation to external aspects of development, including social interactive behaviors of the child's mother, and the social context of dyadic interactions. The proceeding review of literature aims to theoretically support study 1, in which the relation between joint attention and sensory responsiveness, and social competence and sensory responsiveness are assessed between a group of children with ASD and their language-age matched typically developing peers; and study 2, in which the relation between children's joint attention and mothers' social behavior, and children's joint attention and social context are examined in a group of preschool-age children with ASD.

Joint Attention in Typical Development

Joint attention is a critical early step in the development of language, and is situated as an important aspect in the development of social communication. Within development of social communication, infants undergo two integral steps that help "set the stage for subsequent language acquisition" (Travis, Sigman, & Ruskin, 2001). The first step occurs near the ninth month, in which the infant begins to demonstrate awareness that signals they produce have an effect on others (Travis et al., 2001). Next, around 11 months of age, infants begin to integrate objects into their communication. During this shift, infants integrate gestures, eye-contact and verbalizations into symbolic exchanges with others (Travis et al., 2001) for the purpose of requesting, responding, or sharing attention (Clifford & Dissanayake, 2008; Charman, 2003). Broadly speaking, these behaviors are considered joint attention.

Joint attention then, can be conceptualized as the ability to coordinate attention with a social partner (Mundy & Newell, 2007), and takes on two primary forms: responding to joint attention (RJA), which is the ability to follow the gaze and gestures of others in order to share a common referent; and initiating joint attention (IJA), which refers to an individual's use of gestures and eye contact to direct others' attention to objects, events or themselves (Mundy & Newell, 2007). Within an episode of joint attention, the child must coordinate their attention with an object or event, with another person's attention and behavior related to that object or event, and with their own attention and experience of the interaction as a whole (Mundy & Jarrold, 2010).

Theoretical Perspectives of Joint Attention

In typical development, joint attention skills usually emerge between 6 to 12 months of age (Mundy & Gomes, 1998), and may be promoted by the child's realization that others are intentional agents whose behavior is guided by concrete goals or purposes (Tomasello, 1995). The consolidation of others-as-intentional-agents coincides with the consolidation of joint attention behaviors into coordinated social engagement during the second year of life (Adamson et al., 2004), and may also be an essential component in the development of theory of mind (Tomasello, 1995).

It is well-established that near the end of an infant's first year, they begin to share attention with others (e.g. Adamson & Bakeman 1985). For example, Corkum and Moore (1995) found that 7-month-old infants could not be conditioned to consistently follow the gaze of an adult, while their 9-month-old counterparts could. Additionally, they found that 10- and 11-month-olds did not require conditioning of this sort because they spontaneously followed adult gaze (Corkum & Moore, 1995).

Tomasello (1995) proposes a developmental model of joint attention that shifts from *following* attention through gaze following, social referencing and imitative learning at 9 months, to *directing* attention and behavior through coordinated joint engagement, social referencing, and pointing and symbol use at 12 months. The scope of this theory relies on the infant's shift in conceptualizing both themselves and others as separate intentional agents (Tomasello, 1995). This shift is also captured in Mundy & Jarrold's (2010) PDP model of joint attention, which relies on the child's self-referenced processing to integrate implicit, subjective, and pre-reflective information into joint attention episodes. In their PDP model, through practice and experience, a child's capacity for joint-processing of self-other attention is strengthened and this burgeoning social executive function contributes to the "development and efficiency of social learning, symbolic thinking and social cognitive problem solving and development" (Mundy & Jarrold, 2010).

Child-specific aspects of joint attention development. There is a significant period of time before joint attention behaviors are evident, and many more months before sustained periods of joint attention are coordinated with people and objects (Bakeman & Adamson, 1984), therefore, Tronic (1989), and Adamson and Russell (1999) argue emotional variability is an essential component of early social interaction as the infant navigates the exuberance and disappointment of social interactions. Such flare-ups place emotional regulation at the forefront of the development of joint attention (Adamson & Russell, 1999; Sigman & Kasari, 1995). When considering regulation more broadly from the perspective of sensory arousal, sensory responsivity may be another mechanism children must regulate and integrate within their social behavior. The developmental timing of joint attention is likely not coincidental, and its place within social, cognitive, and self-regulatory development provides evidence of its role in language development and possible cascading ontogenetic effects (Mundy & Gomes, 1998).

There is strong evidence that individual differences may account for significant variability in joint attention (e.g. Morales et al., 2005; Mundy & Gomes, 1997), and a considerable amount of work has linked differences in joint attention to executive function (e.g. Dawson, Munson, Estes, Osterling, McPartland, Toth, Carver, & Abbott, 2002; McEvoy, Rogers, & Pennington, 1993; Miller & Marcovitch, 2015), emotion regulation (e.g. Morales et al., 2005; Raver, 1996; Sigman & Kasari, 1995) temperament (Vaughan van Hecke, Mundy, Acra, Block, Delgado, Parlade, Meyer, Neal, & Pomares, 2007; Vaughan, Mundy, Block, Burnette, Delgado, Gomez, Meyer, Neal, & Pomares, 2003), and theory of mind (e.g. Nelson, Adamson, & Bakeman, 2008; Miller, 2006).

Many researchers also consider joint attention from a social-motivational perspective (e.g. Dawson, Bernier, & Ring, 2012; Dawson, Webb, & McPartland, 2005). According to Dawson et al. (2005), brain regions involved in reward processing for properties such as drugs and alcohol, sex, and monetary gain are also involved in viewing social stimuli including faces and when receiving social reinforcement. Adamson and Russell (1999) present this possibility within the framework of dynamic systems theory, and posit that joint attention interactions may serve as attractor states for children. Affective arousal or other forms of arousal (e.g., sensory experiences) could be implicated in this conception because regulation allows for the child to adapt to the social and non-social world as both motivational and cue-producing functions (Adamson & Russell, 1999). In their affective model of joint attention, Adamson and Russell (1999, p. 284) argue that:

> "the key accomplishment of the development of joint attention, the coordination of attention to both a partner and a shared object, can be rephrased readily in terms of emotion regulation to focus on the accomplishment of integrating engagement with social partners with interest in objects."

There is a need to further explore how aspects of arousal and regulation relate to social communication development, especially in the realm of joint attention.

External aspects of joint attention development. Other research on joint attention has focused considerably on the adult's role in facilitating joint attention capabilities in children. For example, Dunham and Dunham's (1995) social contingency hypothesis identifies variability in the adult's contingent and reciprocal responses to children's social overtures as a driver of joint attention development. Tomasello (1995) acknowledges the role of both adults and culture in helping shape the infant's developing communication, a view shared by Bronfenbrenner and Morris' (2006) bioecological model of development. The dominant culture helps to frame and mediate the infant's social world, as their caregiver provides reciprocal interactions that help the infant model and imitate, thus providing structure for the development of joint attention (Tomasello, 1995).

Adamson and Bakeman's work on joint engagement (e.g. Adamson & Bakeman, 1985; Adamson et al., 2009; Bakeman & Adamson, 1984) provides a critical structure to consider parent's roles in their child's communicative development. Joint engagement is defined alongside joint attention, and is characterized by shared attention during "affect-laden and intention-filled social interactions" (Adamson et al., 2009) *punctuated* by episodes of joint attention (Adamson & Bakeman, 2006). Whereas an episode of joint attention is often as brief as an eye glance or distal point, joint engagement can be seen as an extended, connected, social interaction marked by such episodes of joint attention (Adamson et al., 2004). In these extended joint engagement interactions, it is argued that language is given the opportunity to emerge as symbols are infused into the interaction between parent and child (Adamson et al., 2004, Adamson et al., 2009).

Toward this end, joint engagement has been conceptualized as either supported (SJE), or coordinated (CJE) joint engagement (Adamson et al., 2009). SJE involves a child actively sharing events or objects without explicitly acknowledging the partner, requiring the partner to support the engagement state, while CJE involves sustained periods of mutual engagement on a common topic integrated with explicit reciprocal communicative actions (Adamson et al., 2004). The link between joint attention, joint engagement, and subsequent language skill is well-established (e.g. Bottema-Beutel et al., 2014; Adamson et al., 2004). There is evidence that the caregiver’s role in this process is valuable in that the adult is able to scaffold sufficient, but not too cognitively demanding engagement with the child, providing co-occurring linguistic input in which the child can attend to the linguistic aspects of the interaction without having to concurrently regulate attention between the mother and object of interest (Bottema-Beutel et al., 2014).

When conceptualizing external aspects of joint attention, it is not only the social partner, but the greater context of the interaction that may moderate communicative acts within that interaction (Adamson & Russell, 1999). Revisiting the idea that joint attention may be related to social motivation, it follows that the goal orientation of the interactive context may play a role in the child’s communication.

There are numerous child-specific and external factors that are related to children’s joint attention, adding dimension to possibly complex downstream developmental effects. It is clear that in order to develop a complete understanding of joint attention and its role in development, both child factors and social partner factors should be considered (Adamson & Russell, 1999).

Behavior analytic approach to joint attention. The study of developmental processes related to language acquisition – including joint attention – have a rich history in the field of behavior analysis, arguably beginning in the 1950's with Skinner's (1957) operational approach to language development as *verbal behavior* development. Behavior analytic approaches to communication often follow stages or hierarchies of skills, building upon one another to ultimately arrive at social communication as we know it. Tomasello (2008) proposes a general *cooperative communicative infrastructure* that organizes language development from both an evolutionary perspective, as well as a developmental perspective, of which joint intentionality and joint attention form the foundations.

Within behavioral theories of verbal development, a key skill related to children's ability to incidentally learn language is called *naming* (e.g. Horne & Lowe, 1996; Greer & Longano, 2010; Skinner 1957). Skinner's (1957) Theory of Verbal Behavior Development, expanded by Greer and colleagues (e.g. Greer, 2008) identify developmental cusps (i.e., stimulus-stimulus pairing and consequences of behavior) and capabilities (i.e., acquisition of a cusp leading to a new way of learning verbal behavior) that allow children to develop language (Greer, 2008). Greer and colleagues (e.g. Greer & Longano, 2010) argue that naming is possibly *the* developmental skill that serves as the impetus for the explosion of language development in children – usually observed in typically developing children around their third year.

A "naming experience" in the behavior analysis literature has been linked to joint attention in the developmental literature, requiring the child and caregiver to simultaneously look at or interact with an object (Greer & Longano, 2010). Thus, a *naming experience* can be understood as an instance of triadic joint attention, in which the mother or child initiates and directs the other's attention to an object or event of interest. Within the *naming* framework, Greer and Longano (2010) posit that in addition to the caregiver and child's joint focus of attention, there is a sensory component to naming, in which the child and caregiver experience the touch, taste, smell or sound of the object, which integrates both the social and sensory experience of that specific object into its spoken name. For example, if a mother and child were playing together and a cat jumped into their play area, the child may initiate joint attention by pointing to the cat and looking to their mother – possibly touching the cat for a fleeting moment – followed by the mother responding to her child by exclaiming "a cat!" If a child has acquired *naming* as a skill, they would be able to take advantage of this *naming experience* as an opportunity to construct correspondence between the object "cat" and the word "cat," and this experience would reinforce and help embed "cat" in the child's developing vocabulary.

Within Greer and colleague's theory of verbal behavior development, it is possible that joint attention may facilitate *naming experiences*, and play a vital role in children's ability to develop *naming* as a skill. Acquiring *naming* represents the emergence of joint stimulus control across both speaker and listener responding, such that the child is able to accurately respond to a given stimulus (e.g. when asked to point to the cat, the child will point to the cat), and accurately speak when they encounter a particular stimulus (e.g. the child sees a cat, and says, "a cat"; Greer & Longano, 2010). Overall, *naming* is highly complex and encompasses levels of abstraction and generalization (e.g. generalizing "cat" to those of different colors and breeds), orienting (e.g. someone says, "look at the cat," and the child visually orients to the cat), and conditioned seeing (e.g. the child is able to picture "cat" in their mind; Greer & Speckman, 2009). There is evidence that naming may differ for 2-dimensional and 3-dimensional objects, and that naming may differ across sensory modalities (Greer & Speckman, 2009). While there has not been widespread cross-disciplinary research between joint attention and *naming*, parallels may be drawn between the two, and these important links may further inform our understanding of language development in typically developing children and in those with developmental delays, including ASD.

Joint Attention in Autism Spectrum Disorder

Autism spectrum disorder (ASD) provides an especially important perspective on joint attention because of social impairments central to the diagnosis, namely deficits in social interaction and communication (American Psychological Association, 2013; Tomasello, 1995). There is evidence that if joint attention behaviors emerge in children with ASD, they do so at a mental age 8 to 16 months later than children with typical development (Clifford & Dissanayake, 2008). Joint attention is also an important area of study in ASD due to its developmental timing; it serves as one of the best ways to discriminate children with and without ASD at early ages as joint attention typically emerges before language (Charman, 2003).

In studies that have utilized retrospective video tapes of children's first birthday parties, researchers found that children who were later diagnosed with ASD showed impaired joint attention, oriented less to a name-call, and attended less to people compared to children with typical development (TD) and developmental disability (DD) (e.g. Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002). In another retrospective analysis of home videotapes, Clifford and Dissanayake (2008) found that children diagnosed with ASD compared to a chronological age and verbal and non-verbal mental age matched comparison group showed significantly less IJA, RJA, and gaze switches in the second year of life, and less eye contact and response to name in their first year. Werner, Dawson Osterling, and Dinno (2000) also found that the RJA behavior of orienting to a name call when children were between 8-10 months of age most strongly differentiated children subsequently diagnosed with ASD.

Retrospective studies such as these illustrate that children with ASD experience difficulties in social attention and joint attention even before a formal diagnosis can be made, highlighting that these social communicative behaviors may be some of the earliest indications of ASD. Baranek (1999) provided further evidence of the discriminative power of joint attention behaviors at an early age in a sample of children with ASD, DD, and TD. In her analysis of home videos taken when the children were between 9-12 months, results revealed that differences in children's joint attention and sensory behaviors discriminated between groups with over 93% accuracy (Baranek 1999).

Relation Between Initiating and Responding Joint Attention

Joint attention inquiry in autism research has provided evidence for a dissociative relation between IJA (i.e., the ability to initiate triadic attention with a social partner and object or event of interest) and RJA (i.e., the ability to follow the gaze and gestures of others in order to share a common referent). Although children with ASD experience deficits in both IJA and RJA, studies have shown that RJA deficits may decrease in severity with development (Chiang, Soong, Lin, & Rogers, 2008), while IJA remains relatively impaired (Mundy, 2016). In a longitudinal study of children with ASD and their DD and TD peers, children with ASD at 24 months of age demonstrated less joint attention than either comparison group, but by 42 months the differences observed at 24 months were no longer significant (Naber, Bakermans-Kranenburg, van Ijzendoorn, Dietz, Daalen, Swinkels, Buitelaar, & Engeland, 2008). In another study, 2 to 4-year-old children with ASD performed as well as their typically developing peers in RJA, however they exhibited significantly fewer IJA behaviors including gaze shifts, verbalizations and gestures (MacDonald, Anderson, Dube, Geckeler, Green, Holcomb, Mansfield, & Sanchez, 2006).

Joint Attention and Language Development in ASD

Deficits in joint attention are increasingly being studied in terms of their downstream effects, especially on language (e.g. Adamson, Bakeman, Suma, & Robins, 2017; Mundy 2016, Bottema-Beutel, 2016). In a meta-analytic review, Bottema-Beutel (2016) found that across 71 studies, the greatest moderator of effect size in both expressive and receptive language was ASD diagnosis and RJA, thus ASD diagnosis and RJA were found to be the greatest predictors of later language ability. Bottema-Beutel (2016) hypothesized that joint attention may have a greater impact on language for children with ASD compared to those with TD because typically developing children have established a sufficient threshold of joint attention that no longer requires its support in the development of language, whereas the development of language in children with ASD may be more contingent upon their joint attention abilities. It follows that the superior relation of RJA to language development could be explained by its role in social orienting - a necessary skill for exposure to language in young children (Dawson et al., 2004).

For children with ASD who experience difficulty responding to joint attention, they may consequently have fewer opportunities for the types of social interactions critical to building language (Bottema-Beutel, 2016). Adamson et al. (2017) have provided evidence in support of this hypothesis, and found that in a community sample of children referred for ASD screening, those with TD who did not meet diagnostic criteria demonstrated a significantly weaker relation between joint attention and later language ability compared to those ultimately diagnosed with ASD and DD. Children diagnosed with ASD also demonstrated a significant relation between their RJA skill and subsequent expressive language, and this relation was strengthened when the child’s joint engagement was added to the model, whereas for the TD group, there was no relation between joint attention and language outcome (Adamson et al., 2017).

Supported joint engagement allows for experiences that are heavily supported by an adult whose efforts to maintain the child’s attention fosters an environment in which language and social communication become the means by which the child can control the experience (Bottema-Beutel et al., 2014). For children with ASD, evidence supports the important role of

RJA in later development of language (Mundy & Jarrold, 2010), whereas IJA is more strongly related to children's concurrent language functioning (Adamson et al., 2017). Accordingly, Mundy and Jarrold's (2010) PDP model supports the notion of independent functions of IJA and RJA in infancy that ultimately converge in social cognitive development.

Joint Attention and Social Competence

The frequency of IJA is positively related to children's concurrent language acquisition and is considered to be a vital component of social competence (Mundy & Newell, 2007). Difficulties employing social attention may contribute negatively to more global aspects of social communication such as social competence (Patten et al., 2013). Accordingly, deficits in joint attention may point toward a weak shared attention mechanism, which may interfere with children's ability to take the perspective of another person during social interactions (Mundy, Sigman, & Kasari, 1994, Mundy & Newell, 2007). Given its developmental timing, it is not surprising that the majority of studies assessing joint attention in ASD enlist samples of young children (e.g. 18-24 months). Yet a recent study by Sullivan, Mundy and Mastergeorge (2015) demonstrated variability in joint attention even among typically developing 4 and 5-year-olds, supporting the notion that joint attention can be a valid measure of social communication among older children.

Work on joint engagement in high functioning children with ASD has revealed significantly fewer initiating bids for joint attention in this group compared to a matched TD sample during a structured play task with their primary caregiver (Meek, Robinson, & Jahromi, 2012). Moreover, in a study that compared joint attention skills between low and high functioning preschool children with ASD, and a developmentally disabled (DD) matched control group using dyadic and triadic orienting through gaze-following and verbal cues, Leekam, Lopez, and Moore (2000) found that children with high functioning ASD exhibited better joint attention skills than the low functioning ASD group, but did not differ from the high functioning DD group. The authors theorized that children with ASD may need to reach a threshold ability level before they are able to demonstrate commensurate joint attention abilities with similar-aged children with DD (Leekam et al., 2000).

Questions regarding the extent to which joint attention deficits are related to meaningful individual differences in other social behaviors, and the role of sensory processing within the context of social communication among children with ASD compared to their typically developing peers remain.

Child-Specific Aspects of Joint Attention in Autism Spectrum Disorder

Children with ASD have been reported to have diminished self-regulatory capacity (e.g. Hill, 2004). Deficits in aspects of a global structure of self-regulation in children with ASD have been established in their emotion regulation (e.g. Gulsrud, Jahromi, & Kasari, 2010; Mazefsky, Herrington, Siegel, Scarpa, Maddox, Scahill, & White, 2013), executive control (for review see Kenworthy, Yerys, Anthony, & Wallace, 2008), attention regulation (e.g. Jahromi, Chen, Dakopolos, & Chorneau, 2019; Morales et al., 2005) and regulation of sensory information (e.g. Wiggins, Robins, Bakeman, & Adamson, 2009). For example, Baum, Stevenson and Wallace (2015) offer a perspective of sensory responsivity that shifts from a traditional uni-dimensional focus (i.e. solely auditory, or visual, or tactile sensory responsivity) toward a multisensory architecture that implicates brain networks involved in regulation such as executive control, attention, and temporal processes.

It is possible that there exists an imbalance in excitatory and inhibitory processes in sensory domains in children with ASD (Baum et al., 2015) that affect other regulatory processes (Green, Rudie, Colich, Wood, Shirinyan, Hernandez, Tottenham, Dapretto, & Bookheimer , 2013) and exert cascading effects on other developmental domains such as social communication. There is growing evidence of a link between indices of attention regulation and children's joint attention behaviors (e.g. Adamson & Russell, 1999). In a longitudinal study of children with ASD and their mothers, children's RJA skills at 6 months were related to emotion regulation strategies at 24 months (Morales et al., 2005). Given the developmental timing of the emergence of joint attention, there may be factors related to both emotion regulation and cognition that impact joint attention (Adamson & Russell, 1999). With regard to effortful control more broadly, it was found that children with ASD who produced greater RJA at 12 months employed better self regulatory strategies as 36 months during a delay of gratification task (Vaughan van Hecke, Mundy, Block, Delgado, Parlade, Pomares, & Hobson, 2012). Specifically, RJA was negatively related to the children's prompting of an adult while they were waiting, and negatively associated to their anticipation behaviors; children with ASD who employed more RJA behaviors were also more likely to divert their attention from the tempting item and utilize more complex distraction behaviors (Vaughan van Hecke et al., 2012).

In another study utilizing a delay of gratification paradigm, a relation emerged between IJA and temptation-focused behavior, such that children who were *less* focused on the tempting item exhibited more joint attention initiations (Jahromi et al., 2019). While relations between joint attention and sensory responsivity are still emerging in the literature (e.g. Baranek et al., 2013), it may be of utility to consider sensory responsivity from a regulation perspective.

Sensory Responsiveness in ASD

Recent studies on the sensory experiences of children with ASD have reported that between 69% and 90% of preschoolers with ASD demonstrate sensory atypicality (Baranek et al., 2013). In its current form, sensory responsivity has been characterized by three primary components, which include hyporesponsivity (an absence of, delayed, or higher threshold response to a stimulus), hyperresponsivity (exaggerated, aversive, or avoidant behavioral reactions to a stimulus), and sensory seeking (an action that perpetuates or intensifies a sensory experience; Brock, Freuler, Baranek, Watson, Poe, & Sabatino, 2012; Watson et al. 2011).

The current conception of sensory processing in ASD suggests that varying levels of sensory hyporesponsiveness, hyperresponsiveness, and seeking co-occur across modalities of sensory stimuli which produce constellations of sensory experiences (Watson et al., 2011). Abnormal patterns of sensory responsivity are an important feature of ASD, but there is evidence that abnormal sensory responsivity may relate to ASD symptoms, rather than the disorder itself. That is, individuals without an ASD diagnosis, but who exhibit symptoms of ASD, may also experience sensory abnormalities. In a study of typically-developing individuals by Robertson and Simmons (2013), self-reported measures of sensory sensitivity and autism symptomology were found to be significantly positively related. Similarly, Bayliss and Kritikos (2011) demonstrated that neurotypical individuals who scored above-average on the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), were less likely than those who scored below-average to filter out distracting visual stimuli at greater levels of perceptual loads. The results of these studies suggest that abnormal sensory responsiveness may be closely related to core symptoms of autism.

There is also evidence that the strength of the association between sensory responsiveness and core symptoms of ASD may be a function of mental age. In a study of children with ASD, other developmental disability (DD), and typical development (TD), Baranek et al. (2013) found a significant interaction between mental age and group affiliation when regressed onto sensory hyporesponsiveness. Their results indicated that for children with ASD, as mental age increased, sensory hyporesponsiveness decreased at a significantly greater rate than within either the DD or TD groups. This evidence supports the notion that patterns of sensory responsiveness may interact with developmental trajectories differently for children with ASD than those with developmental delay or typical development.

Much of the research to date has relied on parent report to measure sensory abnormalities (e.g. Sensory Experiences Questionnaire; Baranek et al., 2006; Sensory Profile, Dunn 1999). These measures generally ask parents to rate the intensity of their child's sensory responses such as aversion to touch, or sensitivity to lights. However, a number of studies have also been successful in creating observational measures of sensory responsiveness. Baranek et al. (2013), and Baranek, Boyd, Poe, David, and Watson (2007), used the Sensory Processing Assessment (SPA; Baranek, 1999) to measure sensory hyporesponsiveness and hyperresponsiveness in both social and non-social domains. Children were presented with a sensory probe (e.g. name call, air puff, shoulder tap), and experimenters measured whether the child oriented their attention in the direction of the sensory stimuli. In another study, Leekam and Ramsden (2006) constructed a measure of attention orienting to auditory, visual, or tactile stimuli, which they termed "dyadic orienting." In this study, an experimenter made a request of the child in one of three sensory domains (auditory, visual, or tactile), and an observational coder measured whether the child directed their attention to the experimenter. Although Leekam and Ramsden's (2006) measure of dyadic orienting was used by the authors to assess joint attention and is not a validated measure of sensory atypicality, such work may offer a window into sensory elements of social communication.

Observing sensory responsiveness during a social interaction could help elucidate communication breakdowns related to social competence and joint attention during the interaction. Both the SPA and measure of dyadic orienting emphasized sensory elements in auditory, visual, and tactile domains to measure attention orienting behavior in children with

ASD and found significant differences in their respective measure between children with ASD, and those with TD and DD (Baranek et al., 2013; Leekam & Ramsden, 2006).

Multiple studies have explored links between sensory processing differences and other core symptoms of ASD such as restricted and repetitive behaviors (Kargas, Lopez, Reddy, & Morris, 2014; Watt, Wetherby, Barber, & Morgan, 2008). Studies have found a strong association between sensory hyperresponsiveness and repetitive behaviors for both children with ASD and their DD matched controls (Boyd, Baranek, Sideris, Poe, Watson, Patten, & Miller, 2010), and in children with high functioning autism (Boyd, McBee, Holtzclaw, Baranek, & Bodfish, 2009). Leekam, Prior, and Uljarevic (2011) argued that sensory overload could trigger RRBs due to increased arousal. Importantly, the aforementioned studies have paved the way for research to more broadly link severity of sensory processing abnormalities with functioning in other domains and with overall ASD severity (Brandwein et al., 2015; Watson et al., 2011).

Sensory responsiveness and joint attention. Sensory responsiveness has increasingly been shown to relate to social communication in children with ASD (e.g., Watson et al., 2011; Baranek, et al., 2013; Baker, Lane, Angley, & Young, 2008). In a study by Watson et al. (2011), children with ASD and DD were compared on composite measures of sensory hyporesponsive, hyperresponsive, and seeking behavior taken from four different sensory measures. They found that patterns of hyporesponsiveness and seeking were related to core social-communication symptoms of autism. Three other studies, including Liss, Sauliner, Fein, and Kinsbourne (2006), Hilton, Harper, Kueker, Lang, Abbacchi, Todorov, and LaVesser (2010), and Hilton et al. (2007) found similar relations between social symptom severity and sensory processing in samples of children with ASD.

In addition, Baranek et al. (2013) showed that sensory hyporesponsiveness was negatively correlated with both initiating and responding joint attention for ASD, TD, and DD children, with group differences diminishing as mental age increased. This study also demonstrated that sensory hyporesponsiveness was significantly negatively correlated with language ability for the ASD group, but not for the TD or DD groups. Evidence from these studies suggest that individuals with autism demonstrate different patterns of sensory responsiveness than their neurotypical and DD peers, however further research is required to understand how patterns of sensory responsiveness relate to other behaviors in children with ASD.

Watson et al. (2011) proposed a developmental model of sensory responsiveness for individuals with ASD in which atypical sensory processing during infancy may lead to consequences in other developmental domains such as social communication later on. Baranek et al. (2013) refer to this process as "cascading effects" of sensory processing dysfunction. Early brain development may be impeded by sensory hyperresponsivity and hyporesponsivity, such that abnormal constraints on information processing in the early developing brain could result in later abnormal cortical organization and processes in order to accommodate for those initial constraints (Belmonte et al., 2004). Dysfunction of global neural pathways in autism could help to put both social communication deficits, and restricted and repetitive behaviors within a sensory perspective (Brandenwein et al., 2015; Marco, Hinkley, Hill, & Nagarajan, 2011).

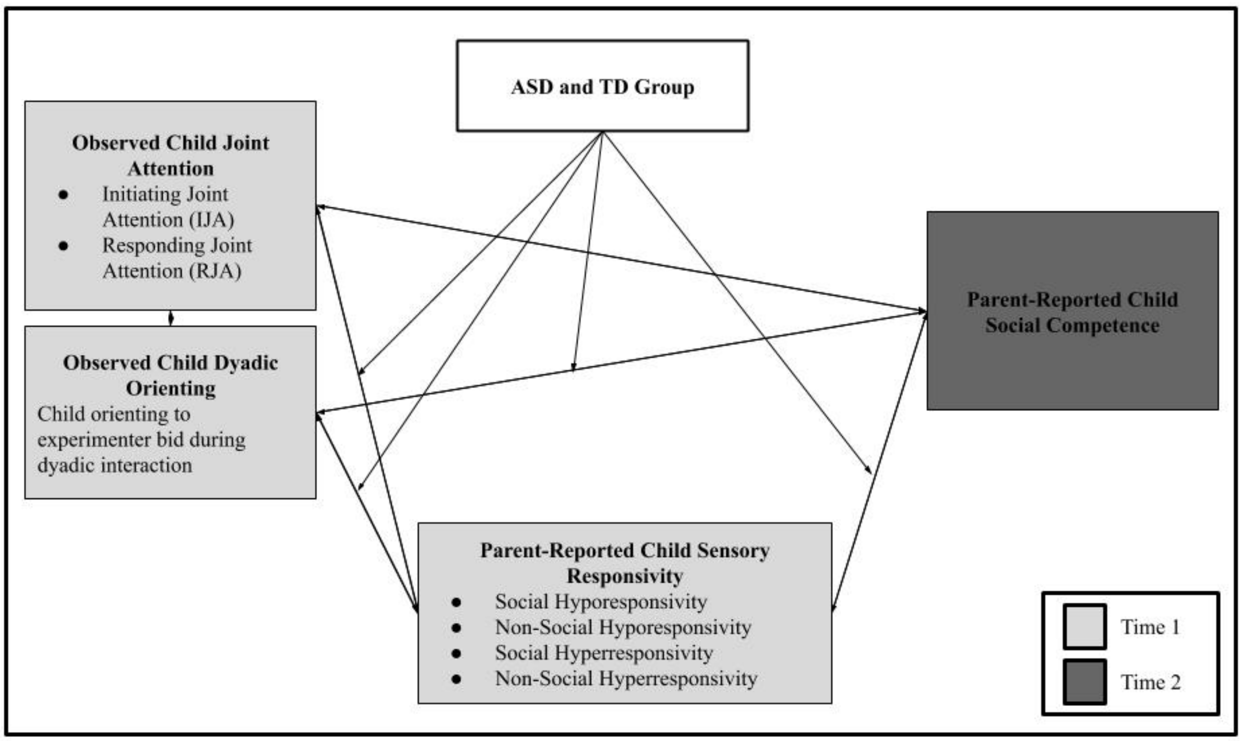
Individuals with ASD may be unable to efficiently filter out primary sensory information due to signal-to-noise interference (Sanchez-Marin, & Padilla-Medina, 2008), processing latencies (Ferri, Elia, Agarwal, Lanuzza, Musumeci, & Pennisi, 2003), and disrupted cortical pathways (Courchesne, & Pierce, 2005), resulting in altered or deficient mechanisms necessary to attend to social and communicative stimuli appropriately (O'Connor & Kirk, 2008). It is argued that from the earliest months of infancy, top-down underselective sensory processing may overload higher-order cognitive processes and in turn sabotage brain areas responsible for developmental skills (Belmonte & Yurgelun-Todd, 2003).

Differences in sensory responsiveness in ASD may help describe social communication deficits such as joint attention (Baranek et al., 2013). In a review of literature, O’Connor and Kirk (2008) hypothesize that atypical social behaviors in ASD are a consequence of greater neurological processing differences. Decreased shared attention mechanisms in ASD may develop as a means to reduce excessive quantities of sensory information and could lead to the atypical social behaviors seen in the disorder (Mundy & Newell, 2007).

Sensory responsiveness and social competence. It may be the case that sensory challenges are related to social competence due to their impact on children’s social communication skills, and therefore interfere with children’s broader social competencies. Social competence can be defined as both risk factors (e.g. aggression, hyperactivity-distractibility, asocial behavior, anxiety-fearfulness), and promotive factors (e.g. prosocial behaviors, empathy, cooperation) that influence an individual’s social adjustment (Ladd, 2005). In their study of typically developing adults in the general population, Robertson and Simmons (2013) found that sensory processing differences may be implicated in specific social interaction difficulties. Specifically, autistic symptom severity subscales including attention switching, attention to detail, communication, and imagination were significantly related to sensory processing abnormalities. In another study, Hilton, Graver, and LaVesser (2007) found strong correlations between measures of social competence on the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005) and sensory processing on the Sensory Profile (SP; Dunn, 1999) in a sample of 36 children with high functioning autism. After splitting their sample into levels of functioning, they found that increased sensory processing difficulties were related to greater ASD symptom severity. Additionally, Watson et al. (2011) demonstrated a significant positive relation between sensory hyporesponsiveness and social-communication severity within an ASD sample after accounting for mental age, however this relation was non-significant for a comparable DD group. Finally, Patten, et al., (2013) showed that sensory hyporesponsiveness and sensory seeking predicted later verbal or non-verbal status. They provide evidence that heightened or diminished sensory responsivity may have a negative effect on language development for children with ASD.

These results suggest that atypical sensory responsiveness may be related to social interaction difficulties experienced by children with ASD. It will be important to further examine the relation between sensory processing and social communication for children with ASD who have commensurate language abilities with their TD peers. It also remains to be determined if a differential relation between sensory processing and social communication exists for children with ASD compared to their typically developing peers. To that end, the goal of Study 1 was to assess patterns of sensory responsiveness, social competence, and joint attention in children with high functioning autism and a language-age matched sample with typical development (TD). The study hypothesized that regulation – particularly sensory responsiveness – adversely affects the social attention and social skills of children with ASD compared to their typically developing peers. The study aimed to answer the following questions (1) do preschool children with ASD differ from their typically developing peers in their joint attention skills, social competence, and sensory responsiveness?; (2) are joint attention, social competence, and sensory responsiveness related among children in our sample?; and (3) do children with ASD exhibit different patterns of relations between social skills (i.e. joint attention and social competence) and sensory responsiveness compared to their typically developing peers? The study predicted that (a) children with ASD and TD would differ in their sensory responsiveness, social competence skills, and joint attention skills, with children with ASD showing more impairments in each of these domains, and (b) sensory responsiveness would be related to children's broader social competences and social-communication skill (i.e., joint attention). Finally, the study explored (c) whether a differential pattern of relations existed between sensory responsiveness and social competence, and sensory responsiveness and joint attention for children with ASD as compared to those with TD.

Figure 1. *Study 1 Conceptual Model*



Note. At Time 1 participants were administered the ESCS and parents completed sensory responsiveness questionnaire. At Time 2, approximately 1-year later, participants caregiver reported on their child's social competence

External Aspects of Joint Attention in Autism Spectrum Disorder

There is utility in looking beyond child-initiated attention and consider how other arrangements of attention may allow children to access language facilitating interactions (Adamson et al., 2009). It may be that aspects of social partner's (e.g., parent) behaviors or other dimensions of the context (e.g., structure, task goals) may be associated with joint attention behaviors of children in such situations.

Parent Behaviors and Joint Attention

There is ample evidence that the interactive partner plays an important role in promoting language and social communication in children with ASD (Adamson et al., 2009; Bottema-Beutel et al., 2014). From both a skills perspective and an engagement perspective, the adult or caretaker's role in joint attention is very important. As joint attention behaviors are dyadic in nature, the social partner's ability to scaffold and support the child during social overtures may be critical to the child's language development (e.g. Bottema-Beutel, 2016; Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012; Kasari, Paparella, Freeman, & Jahromi, 2008). The parent's role in scaffolding social interactions has long been acknowledged in the development of joint attention (e.g. Adamson & Bakeman, 1985; Bakeman & Adamson, 1984; Baldwin, 1995). Adamson, Bakeman, and colleagues have added to our understanding of the parent's role through their work on joint engagement (e.g. Adamson et al., 2009; Adamson et al, 2004; Adamson and Bakeman, 1985, Bakeman & Adamson, 1984). This work has centered on distinguishing between supported and coordinated, and symbol-infused versus non-symbol infused joint engagement (Adamson & Bakeman, 2004).

Supported joint engagement (SJE) is conceptualized as an event in which a child actively shares events or objects without explicitly acknowledging their social partner, leaving it up to the social partner to monitor and direct the interaction (Adamson et al., 2009). Coordinated joint engagement (CJE), on the other hand, consists of sustained periods of social interaction punctuated by explicit communicative actions such as eye contact, vocalizations, or gestures (Adamson et al., 2009). Whether symbols are considered to be infused during joint engagement is determined by the level of symbolic acts the child produces or attends to (for examples refer to Adamson et al., 2009).

The engagement approach to social attention is a complementary view to joint attention, as joint attention behaviors are conceptualized as skills encompassed within joint engagement states (Adamson et al., 2017). In a longitudinal study of 56 TD children, observed at 18, 21, 24, 27, and 30 months, Adamson and Bakeman (2004) found that variability in the amount of symbol-infused supported joint engagement accounted for a significant amount of variation in the children's expressive and receptive language at 30 months, controlling for the child's initial language level. Symbol-infused supported joint engagement can be understood as a particularly potent context for language development, especially when considering the supportive nature that the adult plays during the interaction (Adamson & Bakeman, 2004; Siller & Sigman, 2002). In a follow-up study utilizing the same method as Adamson and Bakeman (2004), Adamson et al. (2009) expanded their sample to include children with ASD and Down Syndrome. While symbol-infused joint engagement emerged as a particularly strong predictor of language ability for all three groups, the ability to infuse symbols during joint engagement states was dependent on current language ability, which meant that on average, this skill emerged much later for children with ASD and Down Syndrome compared to children with TD (Adamson et al., 2009). Although children with ASD demonstrated significantly fewer coordinated and symbol-infused engagement states than those with TD, there were no significant differences in the duration of supported joint engagement states across groups, indicating that parents were equally able to scaffold social interactions with their children (Adamson et al., 2009).

While there is evidence that parents do not differ in their ability to support joint engagement states, there is more to be learned about caregivers' contributions to children's joint attention or joint engagement (Adamson et al., 2009), and to break down mother behaviors to determine if there are differences in the type, intensity, or level of their behavior that may facilitate joint attention (Adamson et al., 2009). Siller and Sigman (2002) found that in a sample of children with ASD, DD, and TD, the frequency of parent behaviors including *indicating* (i.e. pointing to, showing, or offering a toy to their child), *demanding verbalizations* (i.e. demanding a change in the child's activity), and *undemanding verbalizations* (i.e. maintaining the child's ongoing activity by offering reinforcement or a comment) did not significantly differ by group. In addition, all three parent behaviors were related to gains in both initiating joint attention and responding joint attention one year later (Siller & Sigman, 2002). While Siller and Sigman (2002) acknowledge that some of their relations may have been driven by outliers, their results indicate that the parents' behaviors during social interactions may play a significant role in the development of joint attention, and that the frequency of these behaviors do not significantly differ based on the child's disability.

Parent behaviors synchronous to the attention of their child have been shown to predict later language ability across a sample of children with ASD, DD, and TD (Siller & Sigman, 2002), as well as for a sample of children with ASD (Siller & Sigman, 2008). These findings are theoretically supported as Mundy and Gomes (1998) argue that a caregiver's ability to follow the line of regard of infants during joint attention interactions is related to language development.

Another research group has conceptualized parent behaviors similarly to Siller and Sigman (2002). McDuffie and Yoder (2010) have employed the term "follow-in" utterances to characterize vocalizations made by a social partner that are synchronous with the child's attentional focus. *Follow-in comments* (e.g., an utterance that describes what the child is looking at or playing with) map onto Siller and Sigman's (2002) definition of undemanding verbalizations, while *follow-in directives* (e.g., a request that the child change some aspect of their play) are synonymous with demanding verbalizations (Bottema-Beutel et al., 2014).

Bottema-Beutel et al. (2014) found that parents' follow-in utterances during episodes of supported joint engagement were predictive of subsequent receptive language, but not expressive language in a sample of 63 24- to 47-month-old initially minimally-verbal children with ASD. Given these results, caregivers provide an important role in promoting language and social communication in children with ASD (Bottema-Beutel et al., 2014).

Contrary to the findings of Siller and Sigman (2002, 2008) and Bottema-Beutel et al. (2014), Dawson, Hill, Spencer, Galpert, and Watson (1990) found that although children with ASD did not differ from their peers in the frequency or duration of social smiles, the mothers of children with ASD smiled less frequently overall, and responded with a smile to their child's smiles less frequently than the mothers of children with TD. Additionally, Adamson et al., (2017) found that their measures of quality of parent scaffolding and parent follow-in were significantly different for the ASD versus TD groups. One explanation they offer for this difference is that the inherent dyadic nature of the quality of parents' follow-in and scaffolding relies in part on the quality of social communication skills that the child brings to the interaction (Adamson et al., 2017). Currently, it is not clear whether there exists a transactional relation between parents' ability to scaffold and support interactions with their child based on their child's social communicative abilities.

There is growing evidence that specific parent behaviors during social interactions do in fact promote children's later joint attention and joint engagement. In one intervention study focused on enhancing parent responses to the communication of their children with ASD, synchronous parent communication acts were measured at baseline, and at 12-month follow-up (Aldred, Green, Emsley, & McConachie, 2012). As a result of the parent education intervention, the intervention group demonstrated significantly increased parent synchronous behavior as well as significant decreases in their children's social communication ADOS score compared to the control group (Aldred et al., 2012).

Another intervention that has demonstrated efficacy in increasing joint attention and joint engagement behaviors of children with ASD is the Joint Attention Symbolic Play Engagement and Regulation (JASPER) parent-mediated intervention (e.g. Kasari, Gulsrud, Paparella, Hellemann, & Berry, 2015). Using the JASPER intervention, Gulsrud et al. (2016) identified four broad parent behaviors embedded in the intervention, including mirrored pacing, environmental arrangement, prompting, and communication. The parenting behaviors of mirrored pacing and environmental arrangement were found to significantly increase through intervention, and were also significant predictors of children's joint engagement at the completion of intervention (Gulsrud et al., 2016). These findings support the notion that specific parent behaviors likely contribute to longitudinal increases in the joint engagement skills of children with ASD.

Contextual Factors and Joint Attention

An additional aspect of joint attention interactions that is often overlooked is the environmental context of the interaction. In triadic joint attention, the child, a social partner, and an object or event of interest are the key players, however during these interactions, there may be a contextual effect on the coordination of joint attention between the three actors. Although the question of context has been posed by some (e.g. Adamson & Russell 1999; Chawarska, Ye, Shic, & Chen, 2016; Sigman & Kasari, 1995) there is little evidence of systematic inquiry of joint attention abilities across contexts.

One study by Sigman and Kasari (1994; In Sigman & Kasari, 1995) found that across three contexts including structured play, social referencing (either to fear or amusement), and response to someone else's distress, TD children age 8-30 months demonstrated similarities in gaze shift across contexts. In another study, children with ASD were found to be more unengaged during commenting contexts compared to social interaction and requesting contexts, while children with TD did not demonstrate significant differences between any of these contexts (Adamson et al., 2009). In addition, the duration of symbol-infused joint engagement was greatest during commenting tasks for ASD, TD and DD groups compared to the requesting and interacting contexts (Adamson et al., 2009).

Theoretically, Sigman and Kasari (1995) suggest that children's goals may differ across contexts, and that children may exert more effort to share attention and affect in some contexts, however there may be some common form of social awareness that allows children who are attentive in one situation, to also be attentive in the others. In a study of children with ASD, TD, and DD across contexts of parent and experimenter distress, fear, and discomfort, children with ASD looked at the adult less than the TD or DD children across contexts (Sigman, Kasari, Kwon, & Yirmiya, 1992). In a study of imitation in children with ASD versus TD, researchers found a significant interaction between group and imitative context such that children with ASD were more impaired in imitation ability during spontaneous versus elicited tasks than their typically developing peers (Ingersoll, 2008). Despite these interesting findings, little is still known about differences in the frequency of joint attention of children with ASD across contexts.

There are many instruments used to measure joint attention and social communication behaviors (see Anagnostou et al., 2015 for a detailed review). One of the most common tools, the Early Social Communication Scales (ESCS; Mundy et al., 1996) utilizes a standardized set of toys and objects to elicit joint attention behaviors from children in a structured play setting with an experimenter. The coding scheme for the ESCS allows researchers to adapt the measure based on the developmental level and characteristics of the sample (e.g. Clifford & Dissanayake, 2008; Jahromi et al., 2009; Sullivan, Mundy, & Mastergeorge, 2015).

The Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002), a clinical diagnostic tool for autism has also been utilized to measure joint attention (e.g. Chawarska, Klin, Paul, Macari, & Volkmar, 2009), as single measures of IJA and RJA are obtained during the clinician-led play-based administration. Other measurement tools include The Communication and Symbolic Behavior Scales (CSBS; Wetherby & Prizant, 1993); Caregiver-Infant Reciprocity Scale (CIRS; Apicella, Chericoni, Costanzo, Baldini, Billeci, Cohen, & Muratori, 2013); Screening Tool for Autism in Toddlers (STAT; Stone et al., 2000), and The Social Communication Assessment for Toddlers with Autism (SCATA; Drew, Baird, Taylor, Milne, & Charman, 2007).

Joint engagement has also been measured using similar methods, such as the Communication Play Protocol (CPP; Adamson et al. 2004) and the Parent-Child Free Play Procedure (PCFP; Bottema-Beutel et al., 2014). Each of these measurement instruments incorporate a play component with an adult, along with coding of behaviors emitted by the child, and in some instances, the social partner as well. During the CPP, children engage with an adult in three contexts including commenting, where children share pictures and discuss objects in a container; requesting, in which the child must elicit help obtaining toys from a high shelf and operating complex toys; and social interaction, in which the experimenter shares music with the child and engages in turn-taking (Adamson et al., 2004).

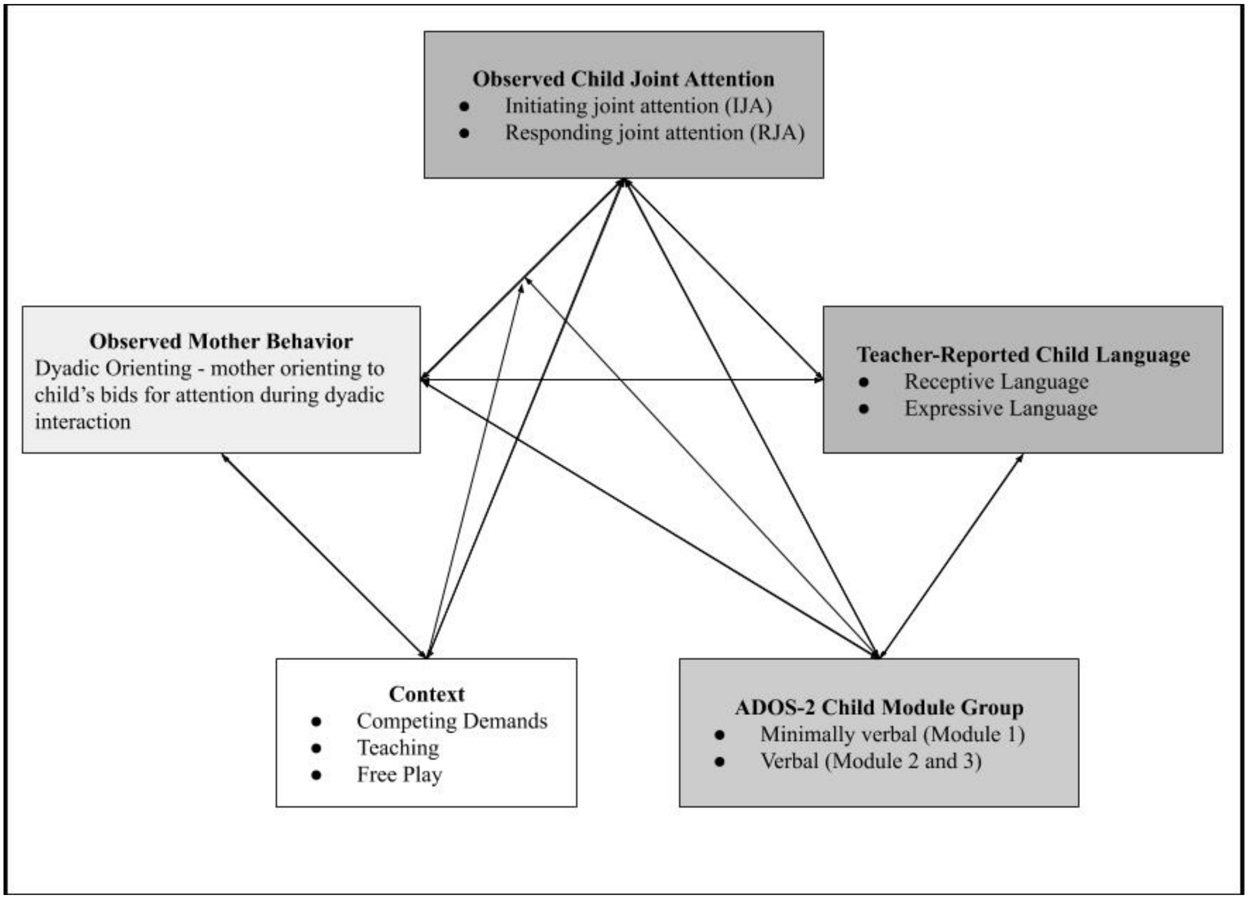
Joint attention is typically measured by behavioral observations during structured (e.g. Chiang, Soong, Lin, & Rogers, 2008; Kasari, Sigman, Mundy & Yirmiya, 1990) or unstructured (e.g. Casenhiser, Binns, McGill, Morderer, & Shanker, 2015) play with an experimenter (e.g. Drew et al., 2006) or caregiver such as a parent (e.g. Meek, Robinson, & Jahromi, 2012). A number of studies have also used retrospective home videos of children to subsequently code joint attention and joint engagement (e.g. Apicella et al., 2013; Baranek, 1999; Osterling et al., 2002; Osterling & Dawson, 1994).

As measurement modalities and technology have improved, measurement of joint attention has increasingly utilized eye-tracking paradigms in which children look at a computer or television screen and their eye movements and eye gaze are recorded in real time (e.g. Campbell, Shic, Macari, & Chawarska, 2013; Chawarska et al., 2016; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; for review see Guillon, Hadjikhani, Baduel, & Roge, 2014). Virtual reality (VR) scenarios have also been utilized to measure joint attention (e.g. Cheng & Huang 2012; Courgeon, Rautureau, Martin, & Grynszpan, 2014), including the use of electroencephalography (EEG) based brain-computer interface with VR goggles to help train individuals with ASD on joint attention skills in an online simulated interaction (Amarel, Simoes, Mouga, Andrade, & Castelo-Branco, 2017). There is evidence that the social partner may influence the social attention of children (Sigman & Kasari, 1995), and to that end, researchers have extended this line of inquiry to autonomous robots (e.g. Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Bekele, Lahiri, Swanson, Crittendon, Warren, & Sarkar, 2013).

Although there is some evidence that different measurement instruments of joint attention may not fully align when measuring certain joint attention behaviors (Ellawadi & Weismer, 2014), results across instruments have consistently identified relative deficits in joint attention skills for children with ASD. The present study sought to assess the joint attention behaviors of children with ASD in contexts that may moderate those social behaviors including a competing demands task, teaching task, and unstructured free play task. The specific qualities and communicative opportunities for the child within each context are of particular interest. It was predicted that competing demands may elicit self-regulatory behaviors and seeking of parent attention (e.g. Jahromi et al., 2009); teaching may diminish opportunities for child initiation depending on parent behaviors (e.g. Fogel et al., 2002); and an unstructured free play context may create an environment in which naturalistic communication between the parent and child may be observed, unencumbered by the necessity to elicit any specific behaviors (e.g. Ungerer & Sigman, 1981).

The purpose of study 2 was to assess joint attention skills of preschool children with ASD in relation to parent behaviors and across different social contexts including unstructured play, competing demands, and teaching. The study hypothesized that children's joint attention would be related to, and moderated by their mother's attention and contextual factors. Study 2 aimed to address the following research questions: (1) does children's joint attention relate to their developmental characteristics and their mothers' attention?; (2) does child joint attention and mother attention differ depending on the social context of their interaction?, and (3) is child joint attention and mother attention temporally related? The study predicted that (a) children's joint attention in the competing demands, teaching, and free play tasks would relate to children's developmental characteristics and mother's attention, as measured by mothers' successful dyadic orienting in each task, and (b) the rate of children's initiating joint attention, children's responding to joint attention, and mothers' dyadic orienting would differ as a function of context (i.e., competing demands, teaching, and free play contexts). The study also predicted that (c) a temporal association existed between joint attention and dyadic orienting, such that the more joint attention children with ASD directed toward their mothers, the more attentive mothers would be toward their children, and conversely, the more attentive mothers were to their children, the more joint attention children would direct toward their mothers.

Figure 2. *Study 2 Conceptual Model*



III

Study 1 Manuscript

Differences in Sensory Processing among Children with High Functioning Autism and Typical Development: Links to Joint Attention and Social Competence

Andrew J. Dakopolos and Laudan B. Jahromi

Teachers College, Columbia University

Received: 2 September 2017 | Revised: 20 June 2018 | Accepted: 17 September 2018

DOI: 10.1002/icd.2117

RESEARCH ARTICLE

WILEY

Differences in sensory responses among children with autism spectrum disorder and typical development: Links to joint attention and social competence

Andrew J. Dakopolos | **Laudan B. Jahromi**

Teachers College, Columbia University, New York, New York, USA

Correspondence
Andrew J. Dakopolos, Teachers College, Columbia University, 525 W 120th Street Box 223, New York, NY 10027, USA.
Email: ajd2190@tc.columbia.edu

Abstract

The current study investigated relations among children's sensory responses, dyadic orienting, joint attention, and their subsequent social competence with peers. Participants were 38 children (18 children with autism spectrum disorder [ASD] and 20 developmentally matched children with typical development) between the ages of 2.75 and 6.5 years. Observational coding was conducted to assess children's joint attention and dyadic orienting in a structured social communication task. Children's sensory responses and social competence were measured with parent report. Group differences were observed in children's joint attention, sensory responses, multisensory dyadic orienting, and social competence, with the ASD group showing significantly greater social impairment and sensory responses compared with their typical peers. Atypical sensory responses were negatively associated with individual differences on social competence subscales. Interaction effects were observed between diagnostic group and sensory responses with diagnostic group moderating the relation between sensory responses and both joint attention and social competence abilities.

Highlights

- We explored patterns of relations between sensory responses, social competence, and joint attention among preschoolers with high functioning autism and typical development.

- Differential relations were found between sensory responses, social competence, and joint attention for children with autism compared with those with typical development.
- Individuals with ASD may process sensory stimuli differently compared to individuals with TD.

KEYWORDS

autism spectrum disorder, communication, joint attention, sensory, sensory responsiveness, social competence

1 | INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social–emotional communication and restricted and repetitive behaviours and interests (American Psychological Association, 2013). Although unusual sensory responses are considered an aspect of autistic symptomology by many, it has only been recently that the American Psychological Association (2013) formalized abnormal sensory experiences and interests into its ASD diagnostic criteria. There is a need to better understand sensory behaviours in various subpopulations of children with ASD, including populations with fewer cognitive or language delays. In addition, there is more to be known about the extent to which challenges associated with sensory responses are related to broader social competence with peers for children with ASD and, more specifically, social communication behaviours (Watson et al., 2011).

1.1 | Sensory responses

Recent studies on the sensory responses of children with ASD have reported that between 69% and 90% of preschoolers with ASD demonstrate sensory atypicality (Baranek et al., 2013). There is growing evidence supporting the view that sensory processing is a central component of ASD and a means to better understand the disorder (for review, see Baum, Stevenson, & Wallace, 2015). In their current form, sensory responses have been characterized by three primary components, which include hyporesponsivity (an absence of, delayed, or higher threshold response to a stimulus), hyperresponsivity (exaggerated, aversive, or avoidant behavioural reactions to a stimulus), and sensory seeking (an action that perpetuates or intensifies a sensory experience; Watson et al., 2011; Brock et al., 2012). Within the sensory literature, some researchers use terminology such as sensory reactivity and sensory sensitivity interchangeably, whereas others differentiate between the two. In the present study, the focus is on observable sensory reactivity (i.e., sensory responses). The current conception of sensory responses in ASD suggests that varying levels of sensory hyporesponsiveness, hyperresponsiveness, and seeking co-occur across modalities of sensory stimuli, which produce constellations of sensory experiences (Watson et al., 2011). Abnormal patterns of sensory responses are an important feature of ASD, but there is evidence that abnormal sensory responses may relate to ASD symptoms, rather than the disorder itself. That is, individuals without an ASD diagnosis but who exhibit symptoms of ASD may also experience abnormal sensory responses. In a study of typically developing individuals (Robertson & Simmons, 2013), self-reported measures of sensory sensitivity and autism symptomology were found to be significantly positively related. Similarly, Bayliss and Kritikos (2011) demonstrated that neurotypical individuals who scored above average (i.e., those who reported more autism symptoms) on the autism spectrum quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001)—a self-reported measure of autism symptoms designed for typically developing or high-functioning individuals with ASD in social and attention domains—were less likely than those who scored below average (i.e., fewer autism symptoms) to filter out distracting visual stimuli at greater levels of perceptual loads. The results of these studies suggest that abnormal sensory responses may be closely related to core symptoms of autism. There is also evidence that the strength of the association between sensory responses and core symptoms of ASD may be a function of mental age. In a study of children with ASD, other developmental disability (DD), and typical development (TD), Baranek et al. (2013) found a significant interaction between mental age and group affiliation when regressed onto sensory hyporesponsiveness. Their results indicated that for children with ASD, as mental age increased, sensory hyporesponsiveness decreased at a significantly greater rate than within either the DD or TD group. This evidence supports the idea that patterns of sensory responses may interact with developmental trajectories differently for children with ASD than those with developmental delay or TD.

Much of the research to date has relied on parent report to measure sensory responses (e.g., Sensory Experiences Questionnaire [SEQ], Baranek, David, Poe, Stone, & Watson, 2006; Sensory Profile, Dunn, 1999). These measures generally ask parents to rate the intensity of their child's sensory responses such as aversion to touch or sensitivity to lights. However, a number of studies have also been successful in creating observational measures of sensory responses. Baranek et al. (2013) and Baranek, Boyd, Poe, David, and Watson (2007) used the sensory processing assessment (SPA; Baranek, 1999) to measure sensory hyporesponsiveness and hyperresponsiveness in both social and nonsocial domains. Children were presented with a sensory probe (e.g., name call, air puff, and shoulder tap), and experimenters measured whether the child oriented their attention in the direction of the sensory stimuli. In another study, Leekam and Ramsden (2006) constructed a measure of attention orienting to auditory, visual, or tactile stimuli, which they termed "dyadic orienting." In this study, an experimenter made a request of the child in one of three sensory domains (auditory, visual, or tactile), and an observational coder measured whether the child directed their attention to the experimenter. Although Leekam and Ramsden's measure of dyadic orienting was used by the authors to assess joint attention and is not a validated measure of sensory responses, such work may offer a window into sensory elements of social communication. Observing sensory differences during a social interaction could help elucidate communication breakdowns related to social competence during the interaction. Both the SPA and measure of dyadic orienting emphasize sensory elements in auditory, visual, and tactile domains to capture attention-orienting behaviour in children with ASD and indicate significant differences between children with ASD and those with TD and DD (Baranek et al., 2013; Leekam & Ramsden, 2006). Using the SPA, Baranek et al. (2013) found that at 6 months mental age, children with ASD oriented significantly less to both social and nonsocial stimuli compared with their TD and DD peers; however, at a mental age of 60 months, these differences between groups were no longer evident. In Leekam and Ramsden's study utilizing their measure of dyadic orienting, they found that children with ASD responded to significantly fewer dyadic bids than those with DD, as well as fewer vocal bids than the DD group. Although children with ASD responded to fewer dyadic bids that combined two or more modalities (e.g., vocal bid accompanied by touch) than the DD group, this difference did not reach statistical significance.

1.2 | Sensory responses and social competence

Multiple studies have explored links between differences in sensory responses and other core symptoms of ASD such as restricted and repetitive behaviours (RRBs) (Kargas, Lopez, Reddy, & Morris, 2014; Watt, Wetherby, Barber, & Morgan, 2008). Studies have found a strong association between sensory hyperresponsiveness and repetitive behaviours for both children with ASD and their DD matched controls (Boyd et al., 2010) and in children with high functioning autism (Boyd, McBee, Holtzclaw, Baranek, & Bodfish, 2009). Leekam, Prior, and Uljarevic (2011) argued that sensory overload could trigger RRBs due to increased arousal. Importantly, the aforementioned studies have paved the way for research to more broadly link severity of sensory responses with functioning in other domains and with overall ASD severity (Brandwein et al., 2015; Watson et al., 2011).

Specifically, sensory responses may also interfere with children's broader social competencies. Social competence can be defined as both risk factors (e.g., aggression, hyperactivity–distractibility, asocial behaviour, and anxiety–fearfulness) and promotive factors (e.g., prosocial behaviours, empathy, and cooperation) that influence an individual's social adjustment (Ladd, 2005). In their study of typically developing adults in the general population, Robertson and Simmons (2013) found that sensory response differences may be implicated in specific social interaction difficulties. That is, autistic symptom severity subscales including attention switching, attention to detail, communication, and imagination were positively related to sensory response abnormalities. In another study, Hilton, Graver, and La Vesser (2007) found strong correlations between measures of social competence on the social responsiveness scale (Constantino & Gruber, 2005) and sensory responses on the Sensory Profile (Dunn, 1999) in a sample of 36 children with high-functioning autism. After splitting their sample into levels of functioning, they found that increased sensory response difficulties were related to greater ASD symptom severity (Hilton et al., 2007). Additionally, Watson et al. (2011) demonstrated a significantly positive relation between sensory hyporesponsiveness and social communication severity within an ASD sample after accounting for mental age; however, this relation was non-significant for a comparable DD group. Finally, Patten, Ausderau, Watson, and Baranek (2013) showed that sensory hyporesponsiveness and sensory seeking predicted later verbal or non-verbal status. They provide evidence that atypical sensory responses may have a negative effect on language development for children with ASD. These results suggest that atypical sensory responses may be related to social interaction difficulties experienced by children with ASD. It will be important to further examine the relation between sensory responses and social communication for children with ASD who have commensurate language abilities with their TD peers. It also remains to be determined if a differential relation between sensory responses and social communication exists for children with ASD compared with their typically developing peers and compared with peers with other developmental disorders.

1.3 | The role of joint attention

It may be the case that sensory responses are related to social competence due to their impact on children's social communication skills, such as joint attention. Joint attention refers to an individual's ability to coordinate visual attention with a social partner in conjunction with an object of interest or event and is a fundamental aspect of early social development (Mundy & Gomes, 1998). Forms of joint attention include initiating joint attention (IJA; i.e., the ability to initiate triadic attention with a social partner and object or event of interest) and responding joint attention (RJA; i.e., the ability to follow the gaze and gestures of others in order to share a common referent). Typically developing children acquire joint attention in the first 2 years of life, but joint attention skills have consistently been shown to be weaker in children with ASD (American Psychological Association, 2013; Mundy & Gomes, 1998; Mundy & Newell, 2007).

The frequency of IJA is positively related to children's language acquisition (Mundy & Newell, 2007). Difficulties employing social attention may contribute to negative downstream effects on aspects of social communication such as joint attention (Patten et al., 2013). Accordingly, deficits in joint attention may point toward a weak shared attention mechanism, which may interfere with children's ability to take the perspective of another person during social interactions (Mundy & Newell, 2007; Mundy, Sigman, & Kasari, 1994). Given its developmental timing, it is not surprising that the majority of studies assessing joint attention in ASD enlist samples of young children (e.g., 18–24 months) as joint attention serves as one of the best ways to discriminate children at risk for ASD at early ages due to its emergence before language (Charman, 2003). However, a recent study by Sullivan, Mundy, and Mastergeorge (2015) demonstrated variability in joint attention even among typically developing 4 and 5-year-olds, supporting the notion that joint attention can be a valid measure of social communication among older children. Work on joint engagement in high-functioning children with ASD has revealed significantly fewer initiating bids for joint attention in this group compared with a matched TD sample during a structured play task with their primary caregiver (e.g., Meek, Robinson, & Jahromi, 2012). Moreover, in a study that compared joint attention skills between low- and high-functioning preschool children with ASD and a DD-matched control group using dyadic and triadic orienting through gaze following and verbal cues, Leekam, Lopez, and Moore (2000) found that children with high-functioning ASD exhibited better joint attention skills than those in the the low-functioning ASD group but did not differ from the high-functioning DD group. The authors theorized that children with ASD may need to reach a threshold ability level before they are able to demonstrate commensurate joint attention abilities with similar-aged children with DD (Leekam et al., 2000). Similarly, there is evidence that if joint attention behaviours emerge in children with ASD, they do so at a mental age 8 to 16 months later than children with TD (Clifford & Dissanayake, 2008). Questions remain regarding the extent to which joint attention deficits are related to meaningful individual differences in other social behaviours, and the role of sensory responses within the context of social communication among children with ASD compared with their typically developing peers.

1.4 | Sensory responses and joint attention

Limited research has explored joint attention and sensory responses in children with ASD. In their review of sensory literature, Glod, Riby, Honey, and Rodgers (2015) only identified one study (i.e., Baranek et al., 2013) since 1997 to have explicitly examined joint attention and sensory responses in children with ASD. Although this construct has previously been examined (e.g., Mundy, Sigman, & Kasari, 1994), no relation was found between joint attention skills in the early social communication scales (ESCS; Mundy et al., 2003) and sensory behaviours measured by subscales of the Autism Behavior Checklist (Krug, Arick, & Almond, 1980). However, sensory responses have increasingly been shown to relate to social communication in children with ASD (e.g., Watson et al., 2011; Baranek et al., 2013; Baker, Lane, Angley, & Young, 2008). In a study by Watson et al. (2011), children with ASD and DD were compared on composite measures of sensory hyporesponsive, hyperresponsive, and seeking behaviours taken from four different sensory measures. They found that patterns of hyporesponsiveness and seeking were related to core social communication symptoms of autism. Three other studies, including Liss, Sauliner, Fein, and Kinsbourne (2006), Hilton et al. (2010), and Hilton et al. (2007) found similar relations between social symptom severity and sensory responses in samples of children with ASD. In addition, Baranek et al. (2013) showed that sensory hyporesponsiveness was negatively correlated with both IJA and RJA for ASD, TD, and DD children; whereas there were no significant group differences between the TD and DD groups, the significant differences observed between the ASD group and others diminished as mental age increased. This study also demonstrated that sensory hyporesponsiveness was significantly negatively correlated with language ability for the ASD group but not for the TD or DD groups. Evidence from these studies suggest that individuals with autism demonstrate different patterns of sensory responses than their neurotypical and DD peers, however research is necessary to further understand how patterns of sensory responses relate to joint attention behaviours in children with ASD.

Watson et al. (2011) proposed a developmental model of sensory responses for individuals with ASD in which atypical sensory responses during infancy may lead to consequences in other developmental domains such as social communication later on. Baranek et al. (2013) refer to this process as “cascading effects” of sensory dysfunction. Early brain development may be impeded by sensory hyperresponsivity and hyporesponsivity, such that abnormal constraints on information processing in the early developing brain could result in later abnormal cortical organization and processes in order to accommodate for those initial constraints (Belmonte et al., 2004). Dysfunction of global neural pathways in autism could help to put both social communication deficits and restricted and repetitive behaviours within a sensory perspective (Brandwein et al., 2015; Marco, Hinkley, Hill, & Nagarajan, 2011). Individuals with ASD may be unable to efficiently filter out primary sensory information due to signal-to-noise interference (Sanchez-Marin & Padilla-Medina, 2008), processing latencies (Ferri et al., 2003), and disrupted cortical pathways (Courchesne & Pierce, 2005), resulting in altered or deficient mechanisms necessary to attend to social and communicative stimuli appropriately (O'Connor & Kirk, 2008). It is argued that from the earliest months of infancy, top-down underselective sensory processing may overload higher order cognitive processes and in turn sabotage brain areas responsible for developmental skills (Belmonte & Yurgelun-Todd, 2003). In a review of literature, O'Connor and Kirk (2008) hypothesize that atypical social behaviours in ASD are a consequence of greater neurological processing differences. Decreased shared attention mechanisms in ASD may develop as a means to reduce excessive quantities of sensory information and could lead to atypical social behaviours seen in ASD (Mundy & Newell, 2007).

1.5 | The current study

The purpose of the present study was to assess patterns of sensory responses, social competence, and joint attention in children with ASD (without cognitive delays) and a language–age matched sample with TD. There is evidence that the developmental trajectory of joint attention and sensory behaviours may show improvements with age, especially in children who are higher functioning in terms of cognitive and language development (Baranek et al., 2013, Lord & Jones, 2012). We hypothesized that (a) children with ASD and TD would differ in their sensory responses, social competence skills, and joint attention skills, with children with ASD showing more impairments in each of these domains and (b) sensory responses would be related to children's broader social competences and social communication skill (i.e., joint attention). Finally, we explored (c) whether a differential pattern of relations existed between sensory responses and social competence and sensory responses and joint attention for children with ASD as compared with those with TD.

2 | METHOD

2.1 | Participants

Participants included 38 children (34 males) ranging from 2.6 to 6 years of age. The participants were part of a larger study of children's social and emotional development. The sample was drawn from a local autism family resource centre and two university-based preschools in a metropolitan area in the Southwestern United States. The sample consisted of 18 children with autism (M_{age} = 57.94, *SD* = 11.66 months), each of whom had a DSM diagnosis of autism at the time of the study provided by developmental paediatricians or clinical psychologists, and whose research diagnosis was further confirmed with the Autism Diagnostic Interview (ADI-R; Lord et al., 1994) conducted at the time of study, and 20 typically developing children (M_{age} = 50.20, *SD* = 11.12 months) who formed a matched comparison group. Children in the ASD group were excluded if they had other diagnoses, as reported by the parent. It was also confirmed that no biological relatives of the TD sample had a diagnosis of ASD or PDD. The majority of children's parents identified as White (77.5%), with 10% Latino, 7.5% Asian, and 5% identifying as "Other/Mixed," and the majority of parents were married (97.3%). In terms of educational attainment, 47.2% of mothers completed a graduate degree, 50% completed college, and 2.8% completed high school. For fathers, 47.2% completed a graduate degree, 47.2% completed college, and 5.6% completed high school.

In order to ensure that participants would be of adequate developmental level to participate in all tasks within the study, inclusion criteria required children to have verbal language, and possess the ability to put together complex sentences. Subsequently, children with receptive language levels of at least 3 years were included. Subjects were matched based on sex and expressive language level (Charman, 2003). Finally, no significant differences were found between the groups in terms of mental age or receptive and expressive language (see Table 1).

2.2 | Procedures

Data were collected during two laboratory visits that occurred approximately 1 month apart. A follow-up questionnaire was completed approximately 1 year later to measure children's social competence with peers. At the first visit,

TABLE 1 Developmental characteristics of study participants by group

Characteristics	Autism (*n* = 18)			Typical (*n* = 20)			Statistics	
	Mean	*SD*	Range	Mean	*SD*	Range	*t*	*p*
Chronological age	57.94	11.96	40–77	50.20	11.12	33–78	2.09	0.04
Mental age	57.25	17.20	32.2–93.3	52.95	13.66	28.7–85.8	0.85	0.39
Receptive language age	58.89	13.49	39–81	58.05	11.63	45–81	0.20	0.83
Expressive language age	55.50	12.21	32–83	58.05	12.01	37–81	−.64	0.52

children's cognitive and language assessments were conducted, and parents of children with autism completed an ADI-R interview. During the second visit, children and parents engaged in a series of laboratory tasks, including a measure of the ESCS (Mundy et al., 2003) adapted to assess joint attention in higher functioning and older children (see Jahromi et al., 2009), which was videotaped for subsequent coding. The task consisted of a semistructured interaction between the experimenter and child using a variety of toys. Parents also completed a series of questionnaires during this visit, including the measure of sensory experiences (Baranek et al., 2006). The follow-up assessment was conducted approximately1 year (*M* = 1.845 years; *SD* = 0.67) after the completion of the initial study, to assess parents' ratings of their children's social competence (Ladd & Profilet, 1996). The follow-up was conducted at a time point that marked most participants' transition from preschool to kindergarten to measure social competence with children they were likely to spend more time in a group and/or peer setting.

2.3 | Measures

2.3.1 | Autism diagnosis and developmental status

To confirm the diagnosis of children in the autism group, their parents completed the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994), a standardized, structured parent interview that assesses the presence and severity of symptoms of autism. Children's expressive and receptive language was assessed using the Preschool Language Scale 4, an assessment of language abilities in children 12 months through 6 years and 11 months of age (Zimmerman, Steiner, & Pond, 2002). From this assessment, children's expressive language age and receptive language age were derived. Children's mental age was assessed using the Differential Abilities Scale II, a comprehensive assessment used to evaluate the cognitive abilities of children ages 2 years and 6 months through 17 years and 11 months (Elliott, 2007). This measure yields a global composite ability (GCA) score from which we derived children's mental age (mental age = chronological age GCA/100).

2.3.2 | Social communication

An adapted version of the ESCS (Mundy et al., 2003) designed to be developmentally appropriate for higher functioning preschoolers was administered to capture initiating joint attention (IJA) and response to the experimenter's bids for joint attention (RJA). The adapted version has been used in previous work on older children with pervasive developmental disorders (Jahromi et al., 2009) and includes only those items that differentiated children with autism from children with nonspecific developmental delays and typically developing children in previous research (Mundy, Sigman, Ungerer, & Sherman, 1986). During the ESCS, an experimenter and child sat facing one another at a table, while the experimenter engaged in a semistructured interaction with the child using a variety of toys including wind-up toys, books, glasses, pictures on the wall, a silly hat, and toy cars. The procedure was videotaped and subsequently coded. Coding was completed by an observer who was blind to diagnostic status, and measures of reliability were conducted with an independent coder. Instances of each behaviour were tallied and then summed to derive a total score. After reaching an acceptable level of agreement for coding, coder drift reliability was assessed on 18% of the sample. The intraclass correlation coefficient (ICC) reliability was 0.98 for IJA and 0.92 for RJA.

2.3.3 | Social competence

Social competence with peers was assessed using the Child Behavior Scale (CBS; Ladd & Profilet, 1996), a 59-item parent report. The CBS consists of subscales, which include prosocial behaviours (i.e., helping, cooperation, and kindness; Cronbach's α = 0.83), asocial behaviours (i.e., solitary play and peer avoidance; Cronbach's α = 0.88), exclusion by peers (i.e., the extent the child is excluded from peer activities; Cronbach's α = 0.92), aggression (i.e., the child's verbal and physically aggressive behaviours; Cronbach's α = 0.52), hyperactive distractibility (i.e., restlessness and lack of attention; Cronbach's α = 0.77), anxious fearfulness (i.e., sad, worried, or distressed behavioural displays; Cronbach's α = 0.79). An overall social competence score was derived from the subscales.

2.3.4 | Sensory responses

The SEQ (Baranek et al., 2006) was used to measure children's sensory responses. The SEQ asks parents to respond to 30 questions about the frequency of their child's responses to typical encounters of sensory stimuli. The SEQ has been validated for children with autism, DD, and TD children ages 6 months through 6 years, with a demonstrated ability to discriminate sensory features among known diagnostic groups (Baranek et al., 2006). Summary scores were derived for hyporesponsiveness and hyperresponsiveness in both social (e.g., name call; α_{hypo} = 0.53; α_{hyper} = 0.41) and nonsocial (e.g., flashing light; α_{hypo} = 0.59; α_{hyper} = 0.55) domains.

2.3.5 | Dyadic sensory orienting

Dyadic sensory orienting was measured according to the procedures described in Leekam, Nieto, Libby, Wing, and Gould (2006), who coded dyadic orienting between the experimenter and child during the ESCS (Mundy et al., 2003). The coding method was adapted for the present study to account for the developmental level and age of the sample. Coding was conducted by an observer who was blind to diagnostic status of participants and who did not code the joint attention in the ESCS. Reliabilities were conducted with an independent coder. Attention bids made by the experimenter were coded as auditory (a verbal request), visual (a visual prompt such as extending their hand to ask for a toy), tactile (e.g., a shoulder touch), and multisensory (consisting of any combination of the previous bids in conjunction with one another). For each attention bid made by the experimenter, the coder recorded whether the child attended to the bid or not. An "attend" was coded if the participant looked at the eye region of the experimenter, complied with the request, or verbally acknowledged the experimenter's request regardless of whether the child complied. A "failure to attend" was coded if the child failed to look at the eye region of the experimenter or failed to look in the direction of the stimulus (e.g., the experimenter pointing to a poster on the wall). Tactile dyadic orienting occurred infrequently and was therefore not included in subsequent analyses. After reaching an acceptable level of agreement for coding, coder drift reliability was assessed on 15% of the sample. The ICC reliability was 0.87 for auditory attention failures, 0.94 for visual attention failures, and 0.85 for multisensory attention failures.

3 | RESULTS

3.1 | Sensory responses

To test for differences in sensory responses of the ASD and TD groups, four one-way ANCOVAs with mental age as the covariate and the participant group as a fixed factor were tested with hyporesponsiveness and hyperresponsiveness in both social and nonsocial domains as dependent variables. Results of the analysis revealed significant group differences for social hyporesponsiveness (partial η^2 = 0.42, F(1, 34) = 25.17, p < 0.001), nonsocial hyporesponsiveness (partial η^2 = 0.20, F(1, 34) = 8.63, p = 0.006), and social hyperresponsiveness (partial η^2 = 0.19, F(1, 34 = 8.00,p = 0.008), however there was no evidence of a difference in groups for nonsocial hyperresponsiveness (partial η^2 = 0.092, F(1, 34) = 3.45,p = .07). In these analyses, Type 1 error rate was controlled using Holm's correction method (Holm, 1979). Overall, the ASD group obtained significantly higher mean scores than the TD group on measures of sensory responses in both social and nonsocial domains after accounting for differences in mental age (see Figure 1).

ANCOVA models were also fit to test group differences for dyadic sensory orienting. Given that these scores were derived from an observed interaction, receptive language age and mental age were used as covariates. Results of the ANCOVA revealed non-significant differences in mean auditory attention failures (partial η^2 = 0.05, F(1, 34) = 1.94, p = 0.17) and in mean visual attention failures (partial η^2 = 0.07, F(1, 33) = 2.54, p = 0.12) for the ASD and TD groups. For multisensory attention failures, we found that the ASD group had significantly more multisensory failures than the TD group (partial η^2 = 0.32, F(1, 34) = 16.24, p < 0.001) after adjusting for mental age and receptive language age (see Figure 1 for group means and standard deviations).

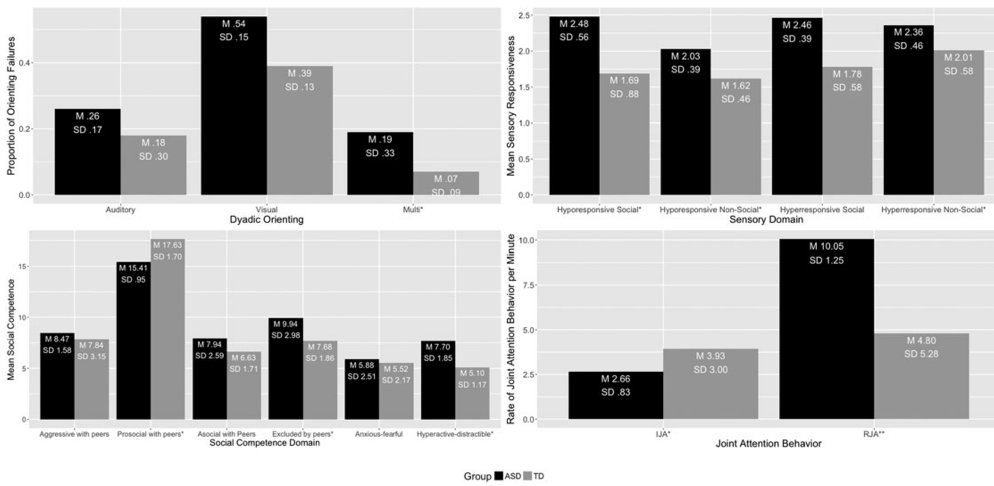


FIGURE 1 Means and standard deviations of study variables. ASD, autism spectrum disorder; TD, typical development

3.2 | Social competence

To test for differences in social competence between the ASD and TD groups, a one-way ANCOVA with mental age as a covariate and the participant group as a fixed factor was tested with a composite social competence variable as the dependent measure. Results revealed that children with ASD had significantly lower levels of social competence than their typically developing peers after accounting for differences in mental age ($F(1, 29) = 5.37$, $p = 0.027$). In addition, a MANCOVA model consisting of social competence subscales (aggressive with peers, prosocial with peers, asocial with peers, excluded by peers, anxious–fearful, and hyperactive–distractible) as dependent measures, with group as a fixed factor and mental age used as a covariate resulted in an overall significant model, Wilks λ (6, 28) = 3.63, $p = 0.009$. Follow-up pairwise comparisons using Bonferroni corrections revealed significant group differences on prosocial with peers ($F(1, 28) = 4.84$, $p = 0.03$), excluded by peers ($F(1, 28) = 6.55$, $p = 0.01$), and hyperactive–distractible ($F(1, 28) = 20.93$, $p < 0.001$), indicating that the ASD group was less prosocial with their peers, more excluded by their peers, and had greater levels of hyperactive distractibility than the typically developing group after accounting for differences in mental age. Group differences in social competence subscales including aggressive with peers ($F(1, 28) = 2.91$, $p = 0.09$), asocial with peers ($F(1, 28) = 2.53$, $p = 0.12$), and anxious–fearful ($F(1, 28) = 0.19$, $p = 0.66$),were found to be non-significant after controlling for mental age.

3.3 | Joint attention abilities

To test for differences in joint attention abilities between the ASD and TD groups, a one-way ANCOVA with mental age as a covariate and the participant group as a fixed factor was tested with IJA used as the dependent measure. Results revealed that children with ASD had significantly fewer initiations for joint attention than their typically developing peers after accounting for differences in mental age ($F(1, 31) = 21.52$, $p < 0.001$). Similarly, a one-way ANCOVA with mental age as a covariate and group as a fixed factor was tested with RJA used as the dependent measure. This analysis controlled for the number of attentional bids made by the experimenter to account for opportunity for response. Results revealed no significant difference in RJA after accounting for the number of attentional bids made by the experimenter. Refer to Figure 1 for means and standard deviations.

TABLE 2 Correlations among study variables, controlling for mental age (N = 38)

	1	2_{opp}	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Initiating joint attention	–																
2. Responding joint attention$_{opp}$	−0.17	–															
3. Sensory seeking	0.40*	0.10	–														
4. Hyporesponsive social	−0.20	0.26	0.32	–													
5. Hyporesponsive nonsocial	−0.10	0.06	0.46**	0.73***	–												
6. Hyperresponsive social	−0.23	0.20	0.25	0.66***	0.62***	–											
7. Hyperresponsive nonsocial	0.08	0.39*	0.36*	0.62***	0.52**	0.65***	–										
8. Auditory failures	−0.39*	−0.09	−0.28	−0.13	−0.01	−0.15	−0.19	–									
9. Visual failures	−0.25	−0.00	−0.17	0.20	−0.21	0.04	0.04	0.18	–								
10. Multisensory failures	−0.46**	−0.12	−0.08	0.40*	0.21	0.16	0.24	0.37*	0.30	–							
11. Aggressive with peers	−0.24	−0.09	0.19	0.31	0.47**	0.43**	0.25	−0.11	−0.05	0.19	–						
12. Prosocial with peers	0.37*	0.10	−0.08	−0.39*	−0.50**	−0.31	−0.22	−0.09	0.02	−0.33	−0.45**	–					
13. Asocial with peers	−0.25	0.09	−0.15	0.24	0.20	0.27	0.17	0.05	0.10	0.18	0.20	−0.42*	–				
14. Excluded by peers	−0.20	0.30	0.17	0.36*	0.43*	0.40*	0.45**	0.04	−0.01	0.31	0.54**	−0.43*	0.35*	–			
15. Anxious–fearful	−0.14	0.26	0.31	0.14	0.43*	0.33	0.29	0.13	−0.29	−0.20	0.08	−0.21	0.23	0.50**	–		
16. Hyperactive–distractible	−0.29	0.14	0.19	0.60***	0.54**	0.47**	0.43*	0.01	−0.04	0.46**	0.42*	−0.34*	0.23	0.72***	0.27	–	
17. Social competence	0.37*	−0.14	−0.17	−0.51**	−0.62***	−0.52**	−0.43*	−0.06	0.04	−0.34	−0.60***	0.75***	−0.61***	−0.85***	−0.54**	−0.72***	–

Note. Subscript “opp” indicates that correlations controlled for number of opportunities for responding.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

3.4 | Associations between sensory responses and dyadic sensory orienting

Partial Pearson correlations were conducted to examine the relation between sensory responses and dyadic sensory orienting (see Table 2). After controlling for mental age, results revealed that multisensory attention failures were significantly correlated with social hyporesponsiveness ($r(31) = 0.40$, $p = 0.02$). Visual and auditory attentional failures, however, had non-significant relations with all levels of sensory responses.

3.5 | Sensory responses and social competence

Partial Pearson correlations were conducted to examine the relation between measures of sensory abnormalities (dyadic sensory orienting and sensory responsiveness) and social competence (see Table 2). After controlling for mental age, results revealed that observational measures of dyadic sensory orienting and parent report of sensory responsiveness were related to subscales of social competence. Multisensory dyadic orienting was related to the hyperactive–distractible subscale $r(31) = 0.46$, $p = 0.007$. Social hyporesponsiveness, nonsocial hyporesponsiveness, social hyperresponsiveness, and nonsocial hyperresponsiveness were all significantly positively related to hyperactive–distractibility and excluded by peers and significantly negatively related to the composite social competence measure. In addition, sensory hyporesponsiveness in both social ($r(31) = -0.39$, $p = 0.02$) and nonsocial ($r(31) = -0.50$, $p = 0.003$) contexts were significantly negatively related to prosocial with peers, whereas nonsocial sensory hyporesponsiveness was significantly positively related to aggressive with peers ($r(31) = 0.47$, $p = 0.005$) and anxious–fearful subscales ($r(31) = 0.43$, $p = 0.01$). Finally, social sensory hyperresponsiveness was significantly positively related to the aggressive with peers subscale ($r(31) = 0.43$, $p = 0.01$). Across each of these relations, greater levels of atypical sensory responses correlated with poorer social competence after controlling for mental age.

To further assess the relation between social competence and sensory responsiveness, linear models were fitted (see Figure 2). Each model used the group factor (ASD, TD), sensory variable (i.e., social hyporesponsiveness, nonsocial hyporesponsiveness, social hyperresponsiveness, and nonsocial hyperresponsiveness), and interaction between the ASD group and sensory variable to predict social competence. Social competence scores were derived from subscale scores (e.g., hyperactivity, aggressive with peers, and accepted by peers) and combined to obtain a total score. Lower values of social competence are indicative of better overall social competence, so lower scores are more

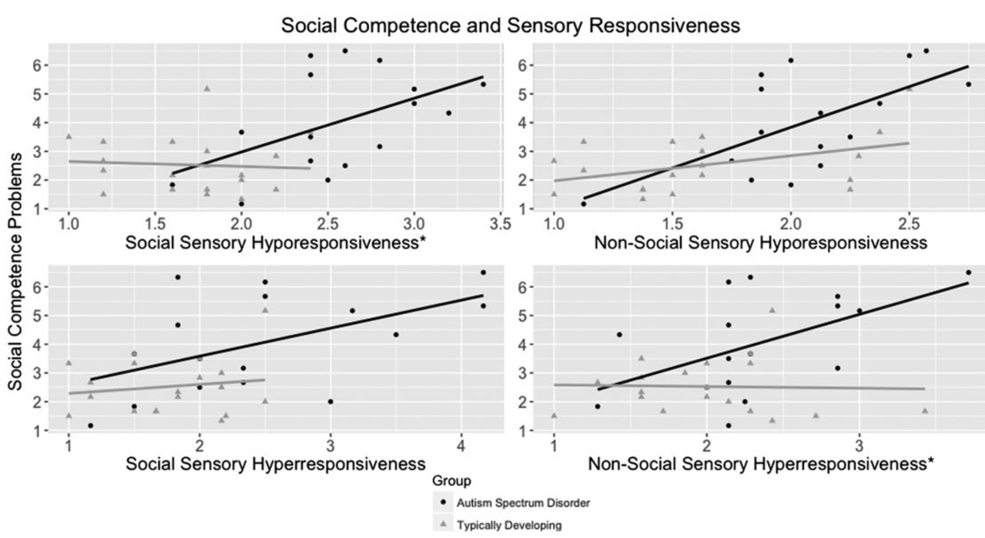


FIGURE 2 Social competence as a function of sensory responses controlling for mental age

desirable than higher scores. Each model first controlled for mental age. The purpose of each model was to test whether the association between sensory variables and social competence differed for the ASD versus typical group. Results of the analyses revealed a significant model (adjusted R^2 = 0.38, $F(5, 29)$ = 3.59, p = 0.012) and significant interaction between the ASD group and social hyporesponsiveness when regressed onto social competence (partial η^2 = 0.126, $F(1, 29)$ = 4.19, p = 0.04), indicating that for the ASD group, increasing levels of social hyporesponsiveness resulted in poorer social competence scores, but for the TD group, greater levels of social hyporesponsiveness resulted in better social competence. A similar relation was found for the interaction between the ASD group and nonsocial hyperresponsiveness when regressed onto social competence (partial η^2 = 0.13, $F(1, 29)$ = 4.58, p = 0.04), indicating that for the ASD group, greater levels of nonsocial hyperresponsiveness related to poorer social competence scores, yet for the TD group, greater levels of nonsocial hyperresponsiveness were related with better social competence (full model; R^2 = 0.36, $F(5, 29)$ = 3.37, p = 0.016) . The other two models examining social competence and nonsocial hyporesponsiveness (full model; adjusted R^2 = 0.49, $F(5, 29)$ = 5.73, p = 0.001) and social competence and social hyperresponsiveness (full model; adjusted R^2 = 0.37, $F(5, 29)$ = 3.42, p = 0.015) were significant overall, however their interactions were non-significant (partial η^2 = 0.11, $F(1, 29)$ = 3.67, p = 0.06; partial η^2 = 0.03, $F(1, 29)$ = 1.11, p = 0.30, respectively).

3.6 | Sensory responses and joint attention

Partial Pearson correlations were conducted to examine the relation between sensory responses and joint attention skills (see Table 2). After controlling for variability in mental age and number of opportunities for children to respond, a significant relation was found between RJA and nonsocial hyperresponsiveness ($r(31)$ = 0.39, p = 0.02). In addition, IJA was significantly negatively correlated with both auditory ($r(31)$ = −0.39, p = 0.02) and multisensory ($r(31)$ = −0.46, p = 0.007) dyadic orienting failures. This pattern suggests that higher levels of atypical sensory responses were negatively related to both responding and initiating joint attention.

To further assess the relation between joint attention skills and sensory responsiveness, linear models were fitted (see Figure 3). Each model used the grouping factor (ASD, TD), sensory variable (i.e., social hyporesponsiveness, nonsocial hyporesponsiveness, social hyperresponsiveness, and nonsocial hyperresponsiveness), and interaction

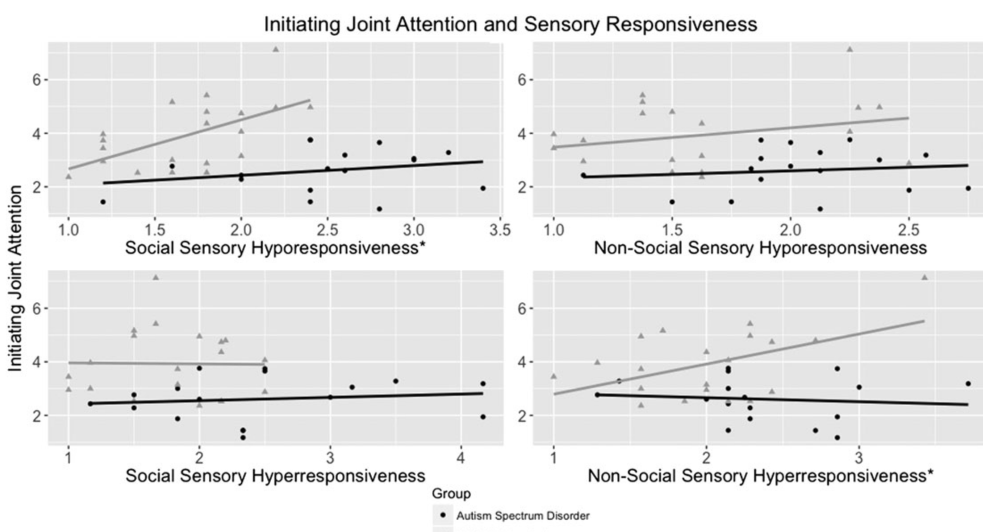


FIGURE 3 Initiating joint attention as a function of sensory responses controlling for mental age

between the ASD group and sensory variable to predict joint attention skills. Each model first controlled for mental age. The purpose of the regression model was to test whether the association between sensory variables and IJA differed for the ASD versus typically developing group. Results of the analyses revealed a significant interaction between the ASD group and social hyporesponsiveness when regressed onto IJA (partial η^2 = 0.167, F(1, 29) = 6.19, p = 0.01), indicating that for the ASD group, IJA levels remained relatively stable regardless of level of social sensory hyporesponsiveness, but for the TD group, greater levels of social hyporesponsiveness resulted in more instances of IJA (full model; R^2 = 0.57, F(5, 31) = 8.28, p < 0.001). When regressing the ASD group, nonsocial hyperresponsiveness and their interaction onto IJA, a significant interaction effect was also found (partial η^2 = 0.149, F(1, 31) = 5.43, p = 0.02), which demonstrated that for the ASD group, nonsocial hyperresponsiveness was negatively related to IJA, whereas for the TD group, nonsocial hyperresponsiveness was positively related to IJA (full model; R^2 = 0.49, F(5, 31) = 6.03, p = 0.001). The interaction model including nonsocial hyporesponsiveness was found to be significant, R^2 = 0.42, F = 4.51, p = 0.003, however the interaction term was non-significant; the inclusion of the interaction term did not account for a significant increase in explanatory power in the model (partial η^2 = 0.023, F(1, 31) = 0.72, p = 0.40). In addition, similar results were found for social hyperresponsiveness. In that model, the interaction term did not account for a significant increase in explanatory power, η^2 = 0.007, F(1, 31) = 0.21, p = 0.64.

Finally, despite our acknowledged small sample size, which generally limits a study's ability to show significant effects while controlling for multiple comparisons, we attempted to account for multiple comparisons among the interaction terms using the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995), which is designed to control for the false-discovery rate. When applying this procedure, the interaction between group and social hyporesponsiveness and the interaction between group and nonsocial hyperresponsiveness regressed onto IJA remained significant, whereas; the other two originally significant interactions terms between group and social hyporesponsiveness and group and nonsocial hyperresponsiveness regressed onto social competence were non-significant using the Benjamini–Hochberg procedure.

4 | DISCUSSION

This study sought to better understand patterns of relations between children's sensory responses, social competence, and joint attention among preschoolers with ASD and TD. As hypothesized, we found significant group differences in several indices of sensory responses, joint attention, and social competence, and correlations among these variables that varied by group. Although a number of our results validated prior research, a unique aspect of our work is that we identified a differential pattern of relations between sensory responses and social competence and sensory responses and joint attention for children with ASD as compared with those with TD in our sample. Increased sensory responses related to poorer joint attention and social competence for the ASD group, and these responses predicted higher levels of joint attention and improved social competence for the TD group.

4.1 | Differences in sensory responses, social competence skills, and joint attention skills

This study sought to contribute to the literature by addressing the relation between sensory responses, social competence, and joint attention skills among preschool children with ASD. One strength of this study was its use of multimethod approach (i.e., both parent report and observed measures corroborate one another). Our results indicated that even among a high-functioning group of preschoolers with autism, children were reported to have more atypical sensory responses than a developmentally matched sample of their typically developing peers in both social and nonsocial sensory domains and that these differences were present for both hyperresponsiveness and hyporesponsiveness to sensory stimuli. Moreover, the laboratory measure of dyadic sensory orienting corroborated these results and provided evidence that as a higher sensory perceptual load (i.e., greater multisensory failures) was placed on the children with ASD, their social attentional orienting capacity was significantly reduced compared with their typically developing peers. Together, our findings are consistent with previous research describing sensory responses in children with ASD (Ben-Sasson, Carter, & Briggs-Gowan, 2010). We did not find significant group differences in the single modality measures of visual and auditory dyadic sensory orienting. The children in our sample with ASD may have effectively tuned out the requests of the dyadic partner due to a perceived overload in sensory stimuli in the environment (O'Connor & Kirk, 2008) or may have experienced relatively greater difficulty filtering out salient information when multiple modalities of sensory information were presented compared with that from a single modality. It is also important to note that heightened sensory arousal is common during early development irrespective of diagnosis (e.g., DeGangi & Greenspan, 1989). Baranek et al. (2013) demonstrated that across groups of children with TD, DD, and ASD, there was a negative relation between mental age and sensory hyporesponsiveness, such that as mental age increased, sensory responsiveness decreased. Thus, when measuring sensory aspects of children's behavior, it may be important to consider the child's course of development as well.

Despite their relatively high-functioning levels and match to peers with TD in mental age, it is important that children with ASD in our sample nevertheless showed significantly poorer social competence and joint attention skills. Interestingly, we found that the ASD group exhibited significantly fewer social initiations than the TD group, but no differences emerged between groups in their RJA skills once we controlled for opportunity (attentional bids). Joint attention is a skill that is often measured when children are in preverbal stages of development (i.e., 6–18 months), yet consistent with Sullivan et al.'s (2015) findings, our sample of children with higher chronological ages demonstrated significant variability in IJA. Joint attention assessment may be a useful tool for understanding individual differences related to social behaviour development for school-age children (Sullivan et al., 2015). Meek et al. (2012) provided evidence that higher instances of child-initiated social interactions with a parent predict greater social competence with peers after controlling for mental age for a sample of preschoolers with ASD and TD. In light of these results, even after controlling for mental age in our higher functioning sample, joint attention skills can appear to show meaningful variability in the preschool years.

Our findings also point to important links between sensory responses, social competence, and joint attention. Specifically, multisensory dyadic orienting was found to be correlated with parents' report of their child's social hyporesponsivity. Our measure of dyadic orienting may exclusively tap into suppressed sensory responses in social contexts. Other researchers have found significant relations between observational sensory response measures and parent report of sensory responses (e.g., Baranek et al., 2007; Baranek et al., 2013), but our other non-significant relations between dyadic orienting and the SEQ indicate some degree of disconnect between the two measures. Watson et al. (2011) conducted a factor analysis model that included two parent report sensory measures and two observational sensory measures that loaded onto three distinct constructs including hyporesponsiveness, hyperresponsiveness, and seeking behaviour. Constructing multimodal models such as this may provide a richer and more nuanced account of sensory responses in children. Our replication of Leekam et al.'s measure of dyadic orienting may still be tapping into aspects of atypical sensory responses in children with ASD. Our findings are commensurate with Patten et al. (2013), who argue that attention orienting may not be clearly separable from sensory hyporesponsiveness. It remains to be determined if the underlying constructs of sensory processing and dyadic orienting are related or if they may be tapping slightly different aspects of a broader construct such as attention (Patten et al., 2013).

We also found important links between sensory responses and discrete aspects of social competence. Sensory measures taken from the SEQ (Baranek et al., 2006) including sensory hyporesponsiveness and sensory hyperresponsiveness in both social and nonsocial domains were significantly positively related to social competence subscales of excluded by peers and hyperactive distractible, such that more extreme levels of sensory responses were related to increased exclusion by peers and higher levels of hyperactivity and distractibility. These results indicate that children who exhibit comparatively heightened sensory responses also experience a higher degree of exclusion by their peers, as well as more frequent behavioural manifestations associated with attentional difficulties. Additionally, greater nonsocial sensory hyporesponsiveness was significantly related to higher levels of aggression toward peers, higher anxiety and fearfulness, and less prosocial behaviours with peers. Finally, there was a significant positive relation between social sensory hyperresponsiveness and aggression toward peers, as well as a significant negative relation between social sensory hyporesponsiveness and prosocial behaviours. Taken as a whole, this pattern of relations between social competence and sensory responses shed light on important aspects of social functioning that may be implicated in atypical sensory responses. Heightened and/or diminished sensory reactivity may manifest in atypical behavioural responses such as distractibility, aggression, and anxiety, which in turn can alienate children from others and/or potential social interactions. This may be particularly true for children with ASD who have difficulty initiating and engaging in social interactions, and whose differences in sensory responses could exacerbate challenged social interactions. Our findings support previous research that has found relations between sensory responses and decreased social competence (e.g., Hilton et al., 2007, 2010). It is possible that disrupted early-stage sensory processing may contribute to poor attentional mechanisms, which subsequently interfere with important social learning opportunities integral to the development of social competence skills (Patten et al., 2013).

Finally, we had a different pattern of relations overall between children with ASD and those with TD. Interestingly, for the children with ASD, sensory responses were related to negative social outcomes (poorer IJA and poorer social competence), but the reverse pattern appeared for TD children. These results suggest that individual with ASD may process sensory stimuli differently compared with individuals with TD. When looking at the interaction plots (Figures 2 and 3), increased levels of sensory responses (at low intensity) predicted better joint attention performance for the TD group, whereas at the higher intensity of sensory responses reported for the ASD group, sensory responses were not related to joint attention ability. Indeed, the ASD group slopes were all relatively flat, suggesting that deficits in IJA may not depend on their sensory sensitivities, but rather, are quite robust to individual differences in sensory responses. The results may support the notion of a "threshold" when considering the meaning of sensory "issues," such that at low levels (i.e., for the TD group) scores reflect sensory perception or perceptual sensitivity more broadly, which can be conceptualized as a positive capacity that facilitates social interaction (Dunn, 2001).

The pattern of relations between sensory responses and social competence for the children with ASD compared with those with TD may provide additional evidence for the groups' differential sensory responses. For children with ASD, greater sensory responses predicted poorer social competence, whereas the children with TD exhibited generally flat slopes, indicating that their social competence remained at high levels regardless of their sensory responses. There is evidence that greater sensory atypicality is related to restricted and repetitive behaviours in ASD (e.g., Boyd et al., 2009; Chen, Rodgers, & McConachie, 2009), and these and other adaptive behaviours such as aggressiveness or distractibility may be related to differences in sensory responses (Dunn, Little, Dean, Robertson, & Evans, 2016) and subsequent social stigma. Sensory responses were found to be related to fewer prosocial behaviours and the child's exclusion by peers. Heightened sensory responses may contribute to or exacerbate social communication difficulties associated with ASD. It may also be that for children with ASD, atypical sensory responsiveness during development hinders their ability to learn important social behaviours due to poor social attention, and these missed opportunities in early development can impact later social competencies (Patten et al., 2013).

Our study was not without limitations. Due to the small sample size, we may have lacked sufficient statistical power to identify group differences. Additionally, the heterogeneous nature of ASD and the wide range of child functioning across the spectrum make the analysis of specific groups within the spectrum important, thus we focused on higher functioning children in the present study. However, focusing on a more homogeneous group limits the degree to which a particular study can be generalized to the greater population of children with autism. Our focus on a relatively homogenous sample of high-functioning children with autism limits our ability to generalize to children with ASD in general. Although our interactions help us to understand patterns of differences, they should be interpreted with caution as controlling for multiple comparisons indicated that interactions within the social competence domain were no longer significant. In addition, our measure of joint attention and social competence were taken 1 year apart. Although we expect that the vast majority of children with ASD received a range of interventions during that time, our research did not track the specific interventions of our participants. It would be important for future work to explicitly examine whether intervention moderates associations reported in the present study. Future research should also attempt to validate these findings through more objective measures of sensory processing abnormalities. Given our consolidated measure of RJA, future research is also needed to further parse these behaviours to better understand differences in the types of responding behaviours frequently utilized by children with ASD and their typical peers. Due to the strong correlation between IJA and multisensory failures, as well as between measures of dyadic sensory orienting and the SEQ, the conception of dyadic orienting as a sensory measured should be further explored and validated. Given the interesting pattern of findings concerning the different relations between sensory responses and joint attention between groups, future research should expand this line of work with other samples, including children with DD, and further investigate the positive role that sensory responses may play in relation to joint attention in children with TD. Finally, future work should aim to include observational measures of social competence with peers to better understand how sensory responses during such social interactions may interfere with children's healthy social functioning.

In conclusion, sensory responses were found to be related to social communication and social competence in preschool children, and these relations differed for children with high-functioning autism and TD. Future social competence interventions should consider and intervene on sensory responses in children with ASD, especially during early development. In addition, there are many peer interventions aimed at integrating children with ASD into typically developing peer groups and inclusive settings (e.g., Kasari, Rotheram-Fuller, Locke, & Gulsrud, 2011). Future peer interventions may consider addressing sensory responses among children with ASD in addition to the other foci of peer training. Sensory responses have received increased attention in the study of ASD in recent years, and a broader understanding of their relation with adaptive functioning, behaviour, and social communication is emerging (Baum et al., 2015; Dunn et al., 2016). Future work also might consider how sensory responses are implicated in other aspects of children's social competence such as behavioural self-regulation, affect, and temperament.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

ORCID

Andrew J. Dakopolos http://orcid.org/0000-0002-7175-6046

REFERENCES

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (DSM-V)*. Arlington, VA: American Psychiatric Publishing. https://doi.org/10.1176/appi.books.9780890425596

Baker, A. E., Lane, A., Angley, M. T., & Young, R. L. (2008). The relationship between sensory processing patterns and behavioral responsiveness in autistic disorder: A pilot study. *Journal of Autism and Developmental Disorders*, *38*(5), 867–875. https://doi.org/10.1007/s10803-007-0459-0

Baranek, G. T. (1999). *Sensory processing assessment for young children (SPA)*. Unpublished manuscript. Carolina at Chapel Hill: University of North.

Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. *American Journal on Mental Retardation*, *112*(4), 233–245. https://doi.org/10.1352/0895-8017(2007)112[233:HSPIYC]2.0.CO;2

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory feature in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry*, *47*, 591–601. https://doi.org/10.1111/j.1469-7610.2005.01546.x

Baranek, G. T., Watson, L. R., Boyd, B. A., Poe, M. D., David, F. J., & McGuire, L. (2013). Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. *Development and Psychopathology*, *25*, 307–320.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism spectrum quotient (AQ): Evidence from Asperger syndrome/high functioning autism, males, and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/A:1005653411471

Baum, S. H., Stevenson, R. A., & Wallace, M. T. (2015). Behavioral, perceptual, and neural alterations in sensory and multisensory function in autism dpectrum disorder. *Progress in Neurobiology*, *134*, 140–160. https://doi.org/10.1016/j.pneurobio.2015.09.007

Bayliss, A. P., & Kritikos, A. (2011). Brief report: Perceptual load and the autism spectrum in typically developed individuals. *Journal of Autism and Developmental Disorders*, *41*, 1573–1578. https://doi.org/10.1007/s10803-010-1159-8

Belmonte, M., & Yurgelun-Todd, D. (2003). Functional anatomy of impaired selective attention and compensatory processing in autism. *Cognitive Brain Research*, *17*(3), 651–664. https://doi.org/10.1016/S0926-6410(03)00189-7

Belmonte, M. K., Cook, E. H., Anderson, G. M., Rubenstein, J. R. L., Greenough, W. T., Beckel-Mitchener, A., … Tierney, E. (2004). Autism as a disorder of neural information processing: Directions for research and targets for therapy. *Molecular Psychiatry*, *9*, 646–663. https://doi.org/10.1038/sj.mp.4001499

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*, *57*(1), 289–300.

Ben-Sasson, A., Carter, A. S., & Briggs-Gowan, M. J. (2010). The development of sensory over-responsivity from infancy to elementary school. *Journal of Abnormal Child Psychology*, *38*(8), 1193–1202. https://doi.org/10.1007/s10802-010-9435-9

Boyd, B. A., Baranek, G. T., Sideris, J., Poe, M. D., Watson, L. R., Patten, E., & Miller, H. (2010). Sensory features and repetitive behaviors in children with autism and developmental delays. *Autism Research*, *3*(2), 78–87. https://doi.org/10.1002/aur.124

Boyd, B. A., McBee, M., Holtzclaw, T., Baranek, G. T., & Bodfish, J. W. (2009). Relationships among repetitive behaviors, sensory features, and executive functions in high functioning autism. *Research in Autism Spectrum Disorders*, *3*(4), 959–966. https://doi.org/10.1016/j.rasd.2009.05.003

Brandwein, A. B., Foxe, J. J., Butler, J. S., Frey, H.-P., Bates, J. C., Shulman, L. H., & Molholm, S. (2015). Neurophysiological indices of atypical auditory processing and multisensory integration are associated with symptom severity in autism. *Journal of Autism and Developmental Disorders*, *45*, 230–244. https://doi.org/10.1007/s10803-014-2212-9

Brock, M. E., Frueler, A., Baranek, G. T., Watson, L. R., Poe, M. D., & Sabatino, A. (2012). Temperament and sensory features of children with autism. *Journal of Autism and Developmental Disorders*, *42*, 2271–2284. https://doi.org/10.1007/s10803-012-1472-5

Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions: Biological Sciences*, *358*(1430), 31–324.

Chen, Y. H., Rodgers, J., & McConachie, H. (2009). Restricted and repetitive behaviours, sensory processing and cognitive style in children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*, 653–642.

Clifford, S. M., & Dissanayake, C. (2008). The early development of joint attention in infants with autistic disorder using home video observations and parental interview. *Journal of Autism and Developmental Disorders*, *38*, 791–805. https://doi.org/10.1007/s10803-007-0444-7

Constantino, J. N., & Gruber, C. P. (2005). Social responsiveness scale (SRS). Western Psychological Services.

Courchesne, E., & Pierce, K. (2005). Why the frontal cortex in autism might be talking only to itself: Local over-connectivity but long-distance disconnection. *Current Opinion in Neurobiology*, *15*(2), 225–230. https://doi.org/10.1016/j.conb.2005.03.001

DeGangi, G. A., & Greenspan, S. L. (1989). The development of sensory functions in infants. *Physical and Occupational Therapy in Pediatrics*, *8*(4), 21–33. https://doi.org/10.1080/J006v08n04_02

Dunn, W. (1999). *The Sensory Profile: User's manual*. San Antonio, TX: Psychological Corporation.

Dunn, W. (2001). The sensations of everyday life: Empirical, theoretical, and pragmatic considerations, 2001 Eleanor Clarke Slagle lecture. *American Journal of Occupational Therapy*, *55*, 608–620. https://doi.org/10.5014/ajot.55.6.608

Dunn, W., Little, L., Dean, E., Robertson, S., & Evans, B. (2016). The state of the science on sensory factors and their impact on daily life for children: A scoping review. *OTJR: Occupation, Participation and Health*, *36*(2S), 3S–26S.

Elliott, C. D. (2007). *Differential ability scales*. San Antonio, TX: The Psychological Corporation.

Ferri, R., Elia, M., Agarwal, N., Lanuzza, B., Musumeci, S. A., & Pennisi, G. (2003). The mismatch negativity and the P3a components of the auditory event-related potentials in autistic low-functioning subjects. *Clinical Neurophysiology*, *114*, 1671–1680. https://doi.org/10.1016/S1388-2457(03)00153-6

Glod, M., Riby, D. M., Honey, E., & Rodgers, J. (2015). Psychological correlates of sensory processing patterns in individuals with autism spectrum disorder: A systematic review. *Review Journal of Autism and Developmental Disorders*, *2*, 199–221. https://doi.org/10.1007/s40489-015-0047-8

Hilton, C., Graver, K., & La Vesser, P. (2007). Relationship between social competence and sensory processing in children with high functioning autism spectrum disorders. *Research in Autism Spectrum Disorders*, *1*, 164–173. https://doi.org/10.1016/j.rasd.2006.10.002

Hilton, C. L., Harper, J. D., Kueker, R. H., Lang, A. R., Abbacci, A. M., Todorov, A., & LaVesser, P. D. (2010). Sensory responsiveness as a predictor of social severity in children with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *40*, 937–945. https://doi.org/10.1007/s10803-010-0944-8

Holm, S. (1979). Sequentially rejective multiple test procedures. *Scandinavian Journal of Statistics*, *6(2)*, 65–70.

Jahromi, L. B., Kasari, C. L., McCracken, J. T., Lee, L. S.-Y., Aman, M. G., McDougle, C. J., … Posey, D. J. (2009). Positive effects of methylphenidate on social communication and self-regulation in children with pervasive developmental disorders and hyperactivity. *Journal of Autism and Developmental Disorders*, *39*, 395–404. https://doi.org/10.1007/s10803-008-0636-9

Kargas, N., Lopez, B., Reddy, V., & Morris, P. (2014). The relationship between auditory processing and restricted, repetitive behaviors in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *45*, 658–668.

Kasari, C., Rotheram-Fuller, E., Locke, J., & Gulsrud, A. (2011). Making the connection: Randomized control trial of social skills at school for children with autism spectrum disorders. *The Journal of Child Psychology and Psychiatry*, *53*(4), 431–439. https://doi.org/10.1111/j.1469-7610.2011.02493.x

Krug, D. A., Arick, J., & Almond, P. (1980). Behavior checklist for identifying severely handicapped individuals with high levels of autistic behavior. *Journal of Child Psychology and Psychiatry*, *21*, 221–229. https://doi.org/10.1111/j.1469-7610.1980.tb01797.x

Ladd, G. W. (2005). *Children's peer relations and social competence: A century of progress*. New Haven, CT: Yale University Press.

Ladd, G. W., & Profilet, S. (1996). The child behavior scale: A teacher-report measure of young children's aggressive, withdrawn, and prosocial behavior. *Developmental Psychology*, *32*, 1008–1024. https://doi.org/10.1037/0012-1649.32.6.1008

Leekam, S. R., Lopez, B., & Moore, C. (2000). Attention and joint attention in preschool children with autism. *Developmental Psychology*, *36*(2), 261–273. https://doi.org/10.1037/0012-1649.36.2.261

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2006). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders*, *37*, 894–910.

Leekam, S. R., Prior, M. R., & Uljarevic, M. (2011). Restricted and repetitive behaviors in autism spectrum disorders: A review of research in the past decade. *Psychological Bulletin*, *137*(4), 562–593. https://doi.org/10.1037/a0023341

Leekam, S. R., & Ramsden, C. A. H. (2006). Dyadic orienting and joint attention in preschool children with autism. *Journal of Autism and Developmental Disorders*, *36*(2), 185–197. https://doi.org/10.1007/s10803-005-0054-1

Liss, M., Sauliner, C., Fein, D., & Kinsbourne, M. (2006). Sensory and attention abnormalities in autistic spectrum disorders. *Autism*, *10*(2), 155–172. https://doi.org/10.1177/1362361306062021

Lord, C., & Jones, R. M. (2012). Re-thinking the classification of autism spectrum disorders. *Journal of Child Psychology and Psychiatry*, *53*(5), 490–509.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, *24*, 659–685. https://doi.org/10.1007/BF02172145

Marco, E. J., Hinkley, L. B. N., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in autism: A review of neuropsychologic findings. *Pediatric Research*, *69*(5), 48–54.

Meek, S. E., Robinson, L. T., & Jahromi, L. B. (2012). Parent-child predictors of social competence with peers in children with and without autism. *Research in Autism Spectrum Disorders*, *6*, 815–823.

Mundy, P. (1995). Joint attention and social emotional approach behavior in children with autism. *Development and Psychopathology*, *7*, 63–82. https://doi.org/10.1017/S0954579400006349

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). A manual for the abridged early social communication scales (ESCS).

Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development*, *21*(3), 469–482. https://doi.org/10.1016/S0163-6383(98)90020-0

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current Directions in Psychological Science*, *16*(5), 269–274. https://doi.org/10.1111/j.1467-8721.2007.00518.x

Mundy, P., Sigman, M., & Kasari, C. (1994). Joint attention, developmental level, and symptom presentation in autism. *Development and Psychopathology*, *6*, 389–401. https://doi.org/10.1017/S0954579400006003

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contribution of non-verbal communication measures. *The Journal of Child Psychology and Psychiatry*, 27(5), 657-669.

O'Connor, K., & Kirk, I. (2008). Brief report: Atypical social cognition and social behaviours in autism spectrum disorder: A different way of processing rather than an impairment. *Journal of Autism and Developmental Disorders*, *38*, 1989–1997. https://doi.org/10.1007/s10803-008-0559-5

Patten, E., Ausderau, K. K., Watson, L., & Baranek, G. T. (2013). Sensory response patterns in nonverbal children with ASD. *Autism Research and Treatment*, *2013*, 1–9. https://doi.org/10.1155/2013/436286

Robertson, A. E., & Simmons, D. R. (2013). The relationship between sensory sensitivity and autistic traits in the general population. *Journal of Autism and Developmental Disorders*, *43*(4), 775–784. https://doi.org/10.1007/s10803-012-1608-7

Sanchez-Marin, F. J., & Padilla-Medina, J. A. (2008). A psychophysical test of the visual pathway of children with autism. *Journal of Autism and Developmental Disorders*, *38*, 1270–1277. https://doi.org/10.1007/s10803-007-0507-9

Sullivan, L., Mundy, P., & Mastergeorge, A. M. (2015). Joint attention in preschool children: Is it a meaningful measure? *International Journal of School and Cognitive Psychology*, *2*(1), 1–8.

Watson, L. R., Patten, E., Baranek, G. T., Poe, M., Boyd, B. A., Freuler, A., & Lorenzi, J. (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. *Journal of Speech, Language, and Hearing Research*, *54*, 1562–1576. https://doi.org/10.1044/1092-4388(2011/10-0029)

Watt, N., Wetherby, A. M., Barber, A., & Morgan, L. (2008). Repetitive and stereotyped behaviors in children with autism spectrum disorders in the second year of life. *Journal of Autism and Developmental Disabilities*, *38*, 1518–1533.

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2002). *Preschool language scale (PLS)*The Psychological Corporation.

How to cite this article: Dakopolos AJ, Jahromi LB. Differences in sensory responses among children with autism spectrum disorder and typical development: Links to joint attention and social competence. *Inf Child Dev*. 2018;e2117. https://doi.org/10.1002/icd.2117

Table 1. *Developmental characteristics of study participants by group*

Characteristics	Autism (n = 18)			Typical (n = 20)			Statistics	
	Mean	SD	Range	Mean	SD	Range	*t*	*p*
Chronological Age	57.94	11.96	40-77	50.20	11.12	33-78	2.09	.04
Mental Age	57.25	17.20	32.2-93.3	52.95	13.66	28.7-85.8	.85	.39
Receptive Language Age	58.89	13.49	39-81	58.05	11.63	45-81	.20	.83
Expressive Language Age	55.50	12.21	32-83	58.05	12.01	37-81	-.64	.52

Table 2. *Correlations among study variables, controlling for mental age (N = 38)*

	1.	$2._{opp}$	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Initiating joint attention	- -																
2. Responding joint attention$_{opp}$	-.17	- -															
3. Sensory seeking	.40*	.10	- -														
4. Hyporesponsive social	-.20	.26	.32	- -													
5. Hyporesponsive non-social	-.10	.06	.46**	.73**	- -												
6. Hyperresponsive social	-.23	.20	.25	.66**	.62**	- -											
7. Hyperresponsive non-social	.08	.39*	.36*	.62**	.52**	.65**	- -										
8. Auditory failures	-.39*	-.09	-.28	-.13	-.01	-.15	-.19	- -									
9. Visual failures	-.25	-.00	-.17	.20	-.21	.04	.04	.18	- -								
10. Multi-sensory failures	.-	-.12	-.08	.40*	.21	.16	.24	.37*	.30	- -							
11. Aggressive with peers	-.24	-.09	.19	.31	.47**	.43**	.25	-.11	-.05	.19	- -						
12. Prosocial with peers	.37*	.10	-.08	-.39*	-.50**	-.31	-.22	-.09	.02	-.33	-.45**	- -					
13. Asocial with peers	-.25	.09	-.15	.24	.20	.27	.17	.05	.10	.18	.20	-.42*	- -				
14. Excluded by peers	-.20	.30	.17	.36*	.43*	.40*	.45**	.04	-.01	.31	.54**	-.43*	.35*	- -			
15. Anxious-fearful	-.14	.26	.31	.14	.43*	.33	.29	.13	-.29	-.20	.08	-.21	.23	.50**	- -		
16. Hyperactive-distractible	-.29	.14	.19	.60**	.54**	.47**	.43*	.01	-.04	.46**	.42*	-.34*	.23	.72**	.27	- -	
17. Social competence	.37*	-.14	-.17	-.51**	-	-.52**	-.43*	-.06	.04	-.34	-	.75**	-	-	-	-	- -

p <. 05; ** p < .01; *** p < .001; subscript opp indicates that correlations controlled for number of opportunities for responding

Figure 3. *Means and standard deviations for ASD and TD group*

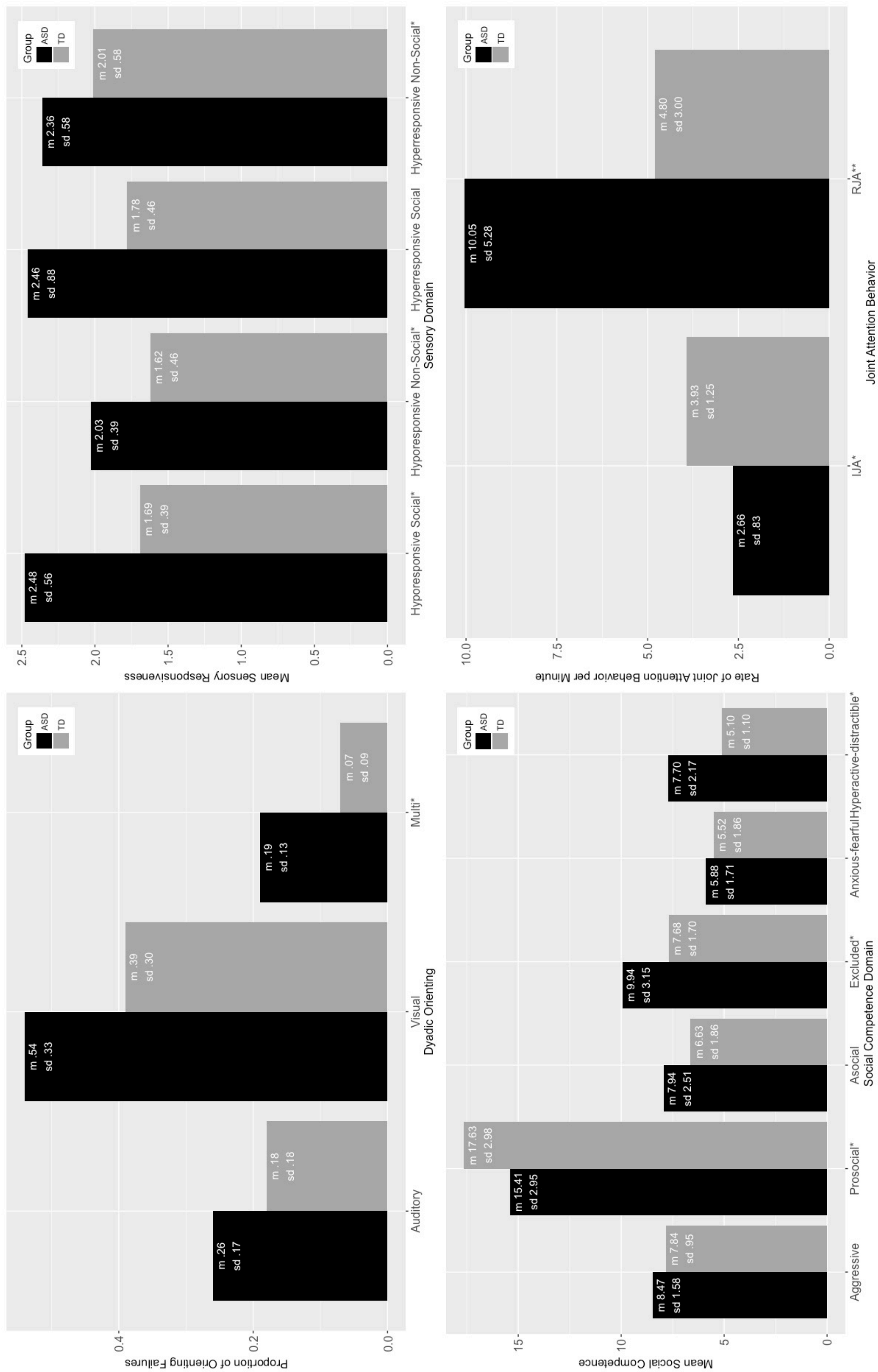
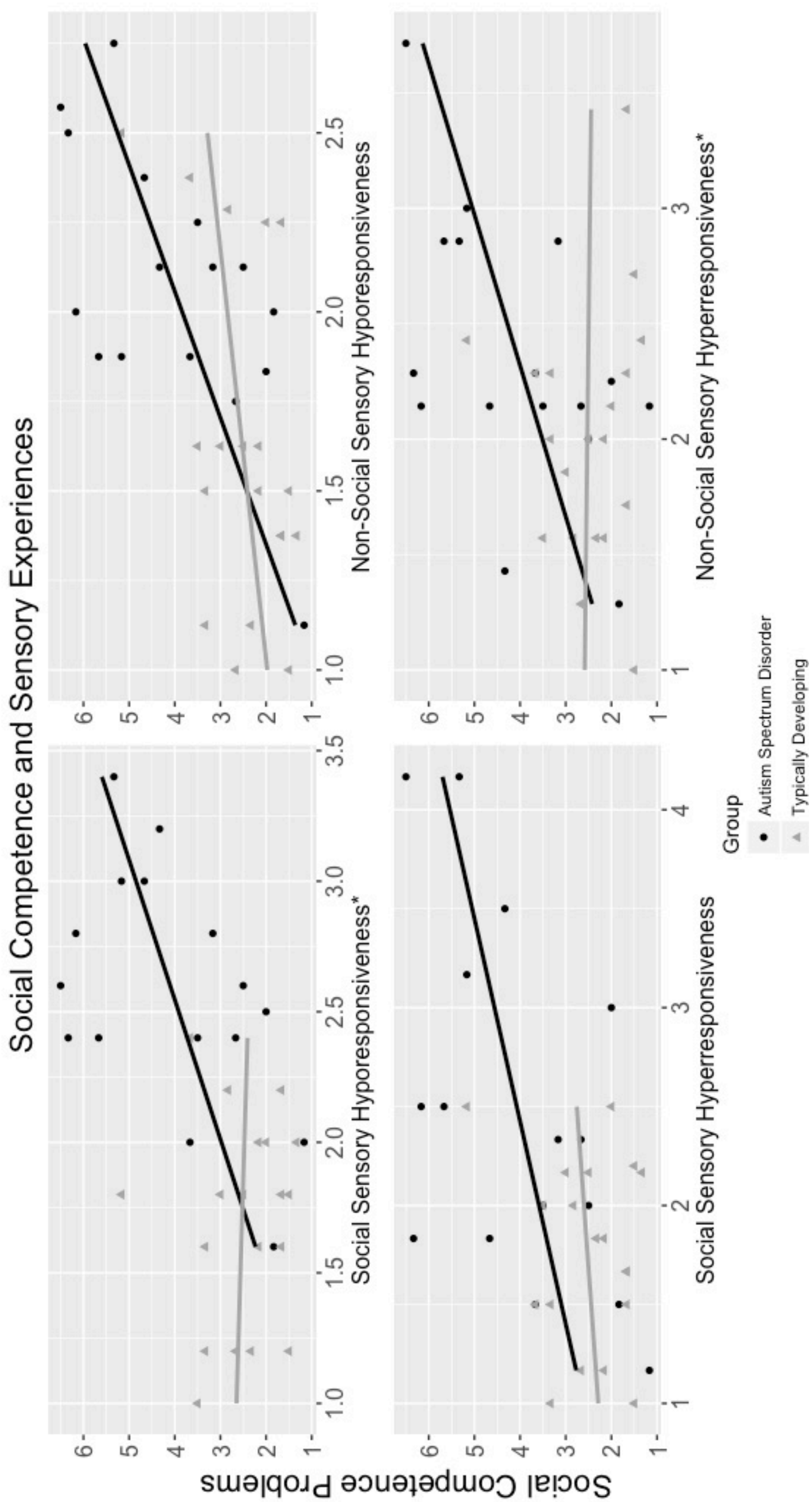


Figure 4. *Relation between social competence and sensory responsiveness*



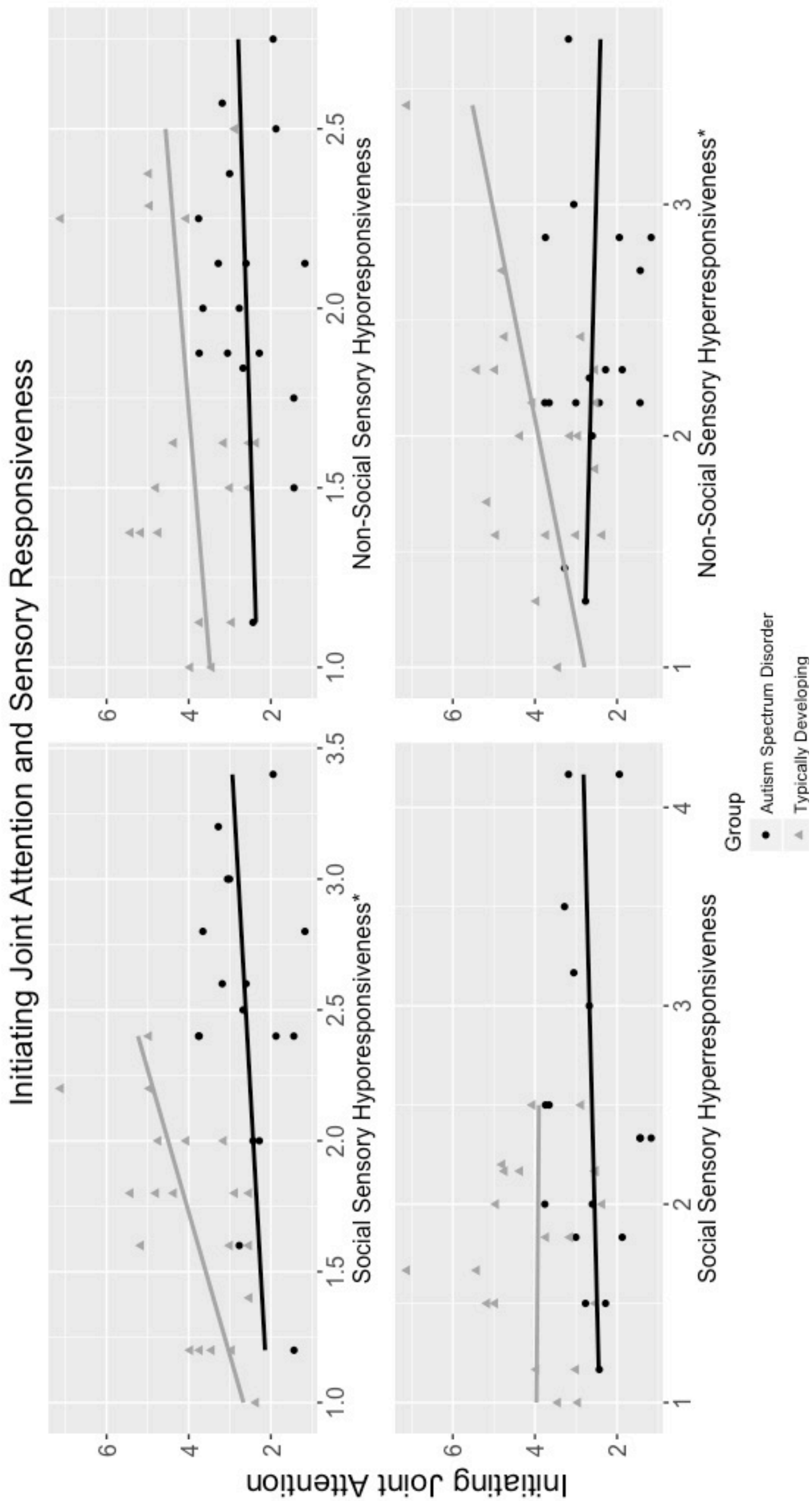


Figure 5. *Relation between initiating joint attention and sensory responsiveness*

Wiley Copyright

Differences in Sensory Processing among Children with High Functioning Autism and Typical Development: Links to Joint Attention and Social Competence

Copyright and Photocopying

IV

Study 2 Method

Participants

Participants in the study included 48 children with a disability ages 30-66 months who attended a specialized pre-school and their biological mothers. Inclusion criteria for the study required that children have a current diagnosis of autism verified by the Autism Diagnostic Observation Scale (ADOS; Lord, Rutter, DiLavore, & Risi, 2002), and that their biological mother be available to participate in the study. Of the original sample of 48 children, two did not meet diagnostic criteria for autism spectrum disorder, and data for four participants was corrupted due to technological error and excluded from subsequent analyses, leaving a final sample of 44 children with ASD (35 males) between the ages of 30 and 66 months (M_{age}= 49.33, *SD* = 10.01 months). Mothers were between the ages of 27 and 47 (M_{age}= 36.62, *SD* = 4.10 years) and 40.5% identified as White, 28.6% Hispanic, 19% Black, and 9.5% Asian or Pacific islander, and one participant (2.4%) did not identify her race. The majority of mothers (76.2%) reported that they were married, while 4.8% said that they were divorced, 4.8% identified as separated, and 14.3% indicated that they had never been married or partnered. Mother's highest level of education also varied, with 4.8% earning a high school diploma or GED, 11.9% attending some college, 45.2% earning a bachelor, associate or professional degree, and 33.4% earning a masters or doctoral degree.

Procedures

Data were collected during an assessment session located at the child's preschool. The mother and child were asked to complete a twenty-minute interaction together, and afterward, the mother completed a parent questionnaire. For the purposes of the present study, parent and child behaviors in three tasks from the parent-child interaction were observed, including *competing demands, teaching* and *free play,* each of which lasted 5 minutes. These tasks were designed to elicit child-behaviors during common mother-child interactions. Each task commenced when the experimenter left the room and closed the door and terminated when the experimenter entered the room to deliver instructions to the parent. All interactions took place in a small room that was approximately 10 x 10 feet in measurement. In the center of the room was a small table and two chairs positioned on a common corner of the table. Near the back of the room was a square cushioned play mat. No toys or other objects were initially placed inside the room. Two GoPro video cameras were affixed to opposing walls of the room in order to capture the faces and actions of both the parent and child regardless of their orientation in the room. The parent wore a small cordless microphone on her shirt collar to capture the verbal expressions of the mother and child. Videos were edited to synchronize audio and combine both camera angles in one frame for subsequent video coding. In addition to the assessment session, children were administered the ADOS (Lord, Rutter, DiLavore, & Risi, 2002) by research reliable doctoral research assistants. Finally, each child's teacher provided adaptive behavioral ratings using the Vineland Adaptive Behavior Scales III (VABS II; Sparrow, Cicchetti, & Saulnier, 2016).

Parent-Child Interaction

Competing demands task During the 5-minute competing demands task, an experimenter provided the mother and child with a brief overview of the interaction activities, and inquired whether large or small Lego blocks would be most appropriate for the child in the following task. The experimenter then provided the mother with the parent questionnaire and instructed the parent to begin filling it out while the researcher went to retrieve the blocks. The researcher also intentionally "forgot" their iPad on the table to serve as an enticing object for the child. The parent and child were left in the room without any instructions other than for the mother to complete the forms. The task is designed to capture children's behaviors when their parent is busy or otherwise occupied.

Teaching task. During the 5-minute teaching task, the mother and child were presented with either Lego or Duplo blocks, as requested by the mother in the previous competing demands task. During the teaching task, the experimenter provided the mother with a picture of a completed Lego or Duplo block structure, and directed the mother to teach their child how to build the completed structure. The task was designed to be slightly demanding for the child so that some assistance from the parent would be needed. Once the instructions were given to the mother, the researcher left the room.

Free play task. During the 5-minute free play task the researcher entered the room with a brightly colored bag filled with toys including a Magna Doodle, a family of small dolls, an inflatable ball, crayons, paper, toy phone, a set of matchbox cars, and the Legos or Duplos from the teaching task. These toys were spread out across the play mat near the back of the room and the parent and child were instructed to play as they normally would.

Measures

Autism diagnosis. The Autism Diagnostic Observation Schedule-2 (ADOS-2; Lord, Rutter, DiLavore, Risi, Gotham, & Bishop, 2012) was used to confirm ASD status. The ADOS-2 is a standardized play-based observation used to diagnose autism. Children in the study were administered either module 1, module 2, or module 3 based on language ability and adaptive functioning. Doctoral researchers were trained on ADOS-2 administration until research reliability (above 80% agreement on coding) was achieved. The ADOS-2 is split into five domains to be coded by the evaluator which include language and communication, reciprocal social interaction, play/imagination, stereotyped behaviors and restricted interests, and other abnormal behaviors. Only select codes from the language and communication, reciprocal social interaction, and stereotyped behaviors and restricted interests domains are used to calculate the final ADOS-2 score. Children had to score a 3 or higher to meet ASD criteria per the tool, and to meet eligibility criteria for the study.

Joint attention. An adapted version of the Early Social Communication Scales (Mundy et al. 2003) was administered to capture the child's initiations of joint attention (IJA), and response to the mother's bids for joint attention (RJA). The adapted version has been used in previous work on older children with pervasive developmental disorders (Jahromi et al., 2009), and includes only those items that differentiated children with autism from children with nonspecific developmental delays and typically developing children in previous research (Mundy Sigman, Ungerer, & Sherman, 1986). Coding was completed by two research assistants who were blind to diagnostic status, and measures of reliability were conducted with an independent coder. Instances of each behavior were tallied and then summed to derive a total score. After reaching an acceptable level of agreement for coding, coder drift reliability was assessed on approximately 20% of the sample. The ICC reliability for the components of IJA were: .74 for alternating eye contact, .85 for showing, .79 for point to share, .85 for eye contact, and .82 for verbal initiations. The ICC reliability for the components of RJA were: 1.0 for giving, .91 for orienting, and .72 for verbal responses to the mother's joint attention.

Mother behaviors.

Dyadic orienting. Dyadic orienting was measured according to the procedures described in Leekam et al. (2006), who coded dyadic orienting between the experimenter and child during the ESCS (Mundy et al., 1996). The coding method was adapted for the present study to measure the mothers' attention orienting to her child, and to account for the developmental level and age of the sample. Coding was conducted by an observer who was blind to diagnostic status of participants. Reliabilities were conducted by an independent coder. Attention bids made by the child were coded as auditory (a verbal request), visual (a visual prompt such as extending their hand to ask for a toy), tactile (a shoulder touch), and multi-sensory (consisting of any combination of the previous bids in conjunction with one-another). For each attention bid, the coder recorded whether the partner attended to the bid or not. An "attend" was coded if the responder looked at the eye region of their partner, complied with the request, or verbally acknowledged their partner's request regardless of whether the responder complied. A "failure to attend" was coded if the responder failed to look at the eye region of their partner or failed to look in the direction of the stimulus (e.g. the mother pointing to an object of interest). After reaching an acceptable level of agreement for coding, coder drift reliability was assessed on approximately 20% of the sample. ICC reliability was .97 for auditory attention successes, .85 for visual attention successes, and .87 for multi-sensory attention successes.

Number of spoken words. The total number of words spoken by the mother in each context was gathered in order to measure the amount of language used by the mother. Transcripts from the interaction were used to obtain a total word count for the mother in the competing demands, teaching, and free play task.

Adaptive behavior. Children's adaptive behavior was measured with the Vineland Adaptive Behavior Scales III (Vineland III; Sparrow, Cicchetti, & Saulnier, 2016). The Vineland-III is a parent or teacher report, and for the present study, was completed by each child's classroom teacher. The Vineland-III produces standardized scores in the domains of communication, daily living skills, socialization, motor skills, and maladaptive behaviors, however for the present study, the communication domain was of primary interest. The communication domain consists of receptive, expressive, and written communication, and has reported internal consistency between $\alpha = .84$ to $\alpha = .93$ ($\alpha = .85$ in the present study).

V

Study 2 Results

Descriptive Statistics of Primary Study Variables

Tables 3, 4, and 5 provide descriptive statistics for the sample. Table 3 provides descriptive data for primary study variables, Table 4 provides descriptive statistics for primary study variables split by the verbal grouping of children in the sample (minimally verbal and verbal groups), and Table 5 provides a summary of maternal demographic variables.

Relation between demographic, developmental and mother variables. Table 6 provides correlations between demographic and child developmental variables. Of the mothers in the study, 19 (43.2%) identified as White. Mothers who identified as White were more likely to be married (r (41) = 0.38, p = .01). Mothers who identified as White also had significantly higher incomes than the other mothers (r (38) = 0.40, p = .01). There were 12 mothers (27.3%) who identified as Hispanic, and these mothers were less likely to be married (r (41) = -0.39, p = .009) and have a lower income (r (41) = -0.39, p = .01). Within the sample, 34 mothers (77.3%) indicated that they were either married or in a committed partnership, and being married or in a committed partnership was related to a significantly higher household income (r (39) = 0.63, p < .001). Household income was positively related to mothers' education level (r (39) = 0.58, p < .001).

Mothers who identified as White were more likely to speak more during the competing demands task (r (41) = 0.32, p = .04). Mothers who emitted more spoken language during the competing demands task had more years of education (r (41) = 0.34, p = .03), and the number of words the mother spoke during the competing demands task was positively correlated to their child's receptive (r (42) = 0.40, p = .006) and expressive language (r (42) = 0.36, p = .02). The mother's number of spoken words during the teaching task and free play task were also significantly related to their child's receptive and expressive language, as well as the child's age (see Table 6). Maternal age (*M* = 36.75, *SD* = 4.05) was negatively related to their child's ADOS-2 severity scores (r (39) = -0.46, p = .002), such that as mother's age increased, their children were rated as having less severe autism on the ADOS-2. Finally, children's expressive language was

Table 3. *Means and standard deviations of primary study variables*

Variable	n	Minimum	Maximum	Mean	SD
Child Age	44	2.52	5.56	4.14	0.84
Expressive Language	44	0	61	19.25	18.42
Receptive Language	44	0	52	23.93	11.25
ADOS-2 Score	41	2	10	7.27	2.16
Maternal Age	44	27	47	36.75	4.05
Initiating joint attention Competing Demands Task	44	0	14	3.95	3.35
Initiating joint attention Teaching Task	44	0	8	1.43	1.50
Initiating joint attention Free Play Task	44	0	6	1.57	1.77
Responding joint attention Competing Demands Task	44	0	7	1.86	1.65
Responding joint attention Teaching Task	44	0	10	3.36	2.66
Responding joint attention Free Play Task	44	0	12	3.45	2.76
Dyadic orienting Competing Demands Task	44	0	1	0.62	0.26
Dyadic orienting Teaching Task	44	0	1	0.81	0.30
Dyadic orienting Free Play Task	44	0	1	0.83	0.34

Note. Units for variables are: child age and maternal age measured in years; child's expressive language and receptive language are raw scores from the Vineland Communication Domain; initiating joint attention and responding joint attention in each context are frequency counts; and dyadic orienting in each task is a proportion of child bids attended to by their mother divided by total number of child bids for attention

Table 4. *Means and standard deviations of study variables by verbal ability groups (minimally verbal vs verbal) and results of MANOVA with Type I error adjustments*

Variable	Minimally Verbal (n = 21)			Verbal (n = 20)			Statistics[adj.]	
	Mean	SD	Range	Mean	SD	Range	F	p
IJA competing demands	2.80	2.31	0.0 – 8.0	5.38	3.81	1.0 – 14.0	4.37	.04
IJA teaching	0.85	1.84	0.0 – 8.0	1.95	1.56	0.0 – 6.0	2.81	.10
IJA free play	0.65	0.75	0.0 – 2.0	2.48	1.54	0.0 – 6.0	20.56	< .001
RJA competing demands	2.00	1.78	0.0 – 7.0	1.86	1.62	0.0 – 7.0	0.32	.58
RJA teaching	3.30	2.56	0.0 – 10.0	3.29	2.72	0.0 – 8.0	0.29	.60
RJA free play	3.15	1.35	0.0 – 5.0	3.48	3.20	0.0 – 12.0	0.05	.83
Dyadic orienting competing demands	0.60	0.31	0.0 – 1.0	0.65	0.20	.22 – 1.0	0.08	.78
Dyadic orienting teaching	0.78	0.31	0.0 – 1.0	0.81	0.30	0.0 – 1.0	.12	.73
Dyadic orienting free play	0.70	0.43	0.0 – 1.0	0.94	0.22	0.0 – 1.0	4.02	.05
ADOS-2 score	7.70	2.11	3 – 10	6.86	2.18	2 – 10	2.67	.11
Expressive language	3.10	3.92	0 – 12	32.90	14.17	4 – 61	97.95	< .001
Receptive language	14.85	6.60	0 – 30	31.57	8.38	18 – 52	46.45	< .001
Child chronological age	4.18	0.82	2.6 – 5.5	4.03	0.80	2.5 – 5.5	1.03	.32

Note. Units for variables: initiating joint attention (IJA) and responding joint attention (RJA) in each context are frequency counts; dyadic orienting in each task is a proportion of child bids attended to by their mother divided by total number of child bids for attention; ADOS-2 score derived from instrument algorithm for respective module and represents overall autism severity (greater value is *more* severe); child's expressive language and receptive language are raw scores from the Vineland Communication Domain; child age measured in years. Statistics[adj.] indicates *p*-values that underwent Bonferroni Type-I error adjustment

Table 5. *Means and standard deviations of maternal demographic variables, and their correlations with primary study variables*

Variable	*n*	*M*	*SD*	IJA CD	IJA T	IJA FP	RJA CD	RJA T	RJA FP	DO CD	DO T	DO FP
Race/ethnicity (White vs. not)	43	0.44	0.50	.03	-.04	.12	.10	-.13	-.12	.04	-.12	.18
Race/ethnicity (Hispanic vs. not)	43	0.28	0.45	.27	.08	.17	-.10	.28	.26	.01	.26	-.03
Marital status (married vs. not)	44	0.77	0.42	-.06	-.27	-.01	.12	-.05	.23	.03	.04	-.20
Mother's age	44	36.75	4.05	.32*	.17	.21	-.13	.10	-.11	-.16	.12	.20
Mother's education level	43	--	--	.09	-.11	-.02	.31*	.08	-.20	.35*	-.04	.27
Number of adults in household	42	2.17	1.03	-.09	-.17	-.22	.01	-.04	-.07	-.11	.09	.05
Number of children in household	42	1.86	0.81	-.04	-.01	-.03	-.07	-.13	.25	-.12	.18	-.09
Household income	41	--	--	.19	.07	.16	.28	.00	-.13	.20	.11	.10
Mother's spoken words competing demands task	44	144.02	106.06	.25	.17	.19	.21	-.01	-.26	.39**	-.05	.17
Mother's spoken words teaching task	44	458.18	117.16	.09	.16	-.02	.02	-.01	-.07	.25	.12	.23
Mother's spoken words free play task	44	370.27	104.28	.21	.05	-.05	.03	.05	-.03	.27	.07	.27

Note. IJA = initiating joint attention; RJA = responding joint attention; DO = dyadic orienting; CD = competing demands task; T = teaching task; FP = free play task. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 6. *Correlations among demographic, child developmental, and mother variables (n = 41 – 44)*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Race/ethnicity (White vs. not)	- -														
2. Race/ethnicity (Hispanic vs. not)	-.55***	- -													
3. Marital status (married vs. not)	.38*	-.39**	- -												
4. Mother's spoken words competing demands task	.32*	-.09	-.10	- -											
5. Mother's spoken words teaching task	-.02	.05	-.01	.33*	- -										
6. Mother's spoken words free play task	.06	.04	.10	.27	.79***	- -									
7. Mother's age	.13	.20	-.01	.10	.12	.23	- -								
8. Mother's education level	.12	-.12	.27	.34*	.18	.29	.04	- -							
9. Number of adults in household	.08	-.26	.25	-.03	.12	.11	-.17	.20	- -						
10. Number of children in household	.02	.16	.05	-.29	-.11	-.15	.10	-.29	.09	- -					
11. Household income	.40*	-.39*	.63***	.12	.06	.17	.15	.58***	.17	-.19	- -				
12. Child age	.17	-.12	.12	.09	.49**	.49**	.12	.26	.11	.08	.24	- -			
13. Child receptive language	.30	.04	-.10	.41**	.45**	.33*	.26	.17	-.09	.14	.10	.10	- -		
14. Child expressive language	.27	.02	-.05	.36*	.37*	.31*	.28	.16	-.10	.08	.11	.27	.86***	- -	
15. Child ADOS-2 score	-.27	.10	.17	-.08	.08	.02	-.46**	.25	.19	-.10	.05	.23	-.26	-.32*	- -

Note. *$p < .05$, **$p < .01$, ***$p < .001$

significantly related to their ADOS-2 score (*r* (39) = -0.32, *p* = .04) such that greater expressive language ability related to lower autism severity scores, however there was a nonsignificant relation between receptive language and ADOS-2 scores (*r* (39) = -0.26, *p* = .10).

Demographic Variables and their relation to study variables. Table 5 summarizes maternal demographic variables and their relation to primary study variables in each context (i.e., competing demands, teaching, and free play). Maternal age was positively related to child initiating joint attention in the competing demands task (*r* (42) = 0.32, *p* = .03). Mother's level of education was also related to both child responding to joint attention and mother dyadic orienting in the competing demands task *r* (41) = 0.31, *p* = .04, and *r* (41) = 0.35, *p* = .02 respectively. Mother's number of spoken words in the competing demands task was positively related to mother dyadic orienting during competing demands (*r* (42) = 0.39, *p* = .01). There were no other statistically significant associations between demographic variables and primary study variables.

Children within the sample were split into two groups based on the module of the ADOS-2 they were administered. There are strict criteria to determine which module of the ADOS-2 to administer, which are primarily based upon the child's language ability (for more information see Lord et al., 2012). Within the sample, 20 children were administered module 1, 14 children were administered module 2, and 7 children were administered module 3. Two groups were created for subsequent analyses; the minimally-verbal group (n = 20) consisted of children who were administered module 1, and the verbal group (n = 21) consisted of children who were administered either module 2 or module 3 (see table 4 for descriptive statistics split by verbal group).

A MANOVA was run to test for group differences in primary study variables and covariates between the minimally verbal and verbal groups (see Table 4). Results of the analysis revealed an overall significant group factor (Wilk's λ = 3.36, *F* (13, 24) = 6.21, *p* < .001). When examining follow-up pairwise comparisons using Bonferroni corrections, significant group differences emerged for child initiating joint attention during the competing demands task (F (1, 36) = 4.37, p = .04), initiating joint attention during the free play task (F (1, 36) = 20.56, p < .001), as well as receptive language (F (1, 36) = 46.45, p < .001) and expressive language (F (1, 36) = 97.95, p < .001), with the verbal group exhibiting more initiating joint attention bids and higher receptive and expressive language ability compared to the minimally-verbal group.

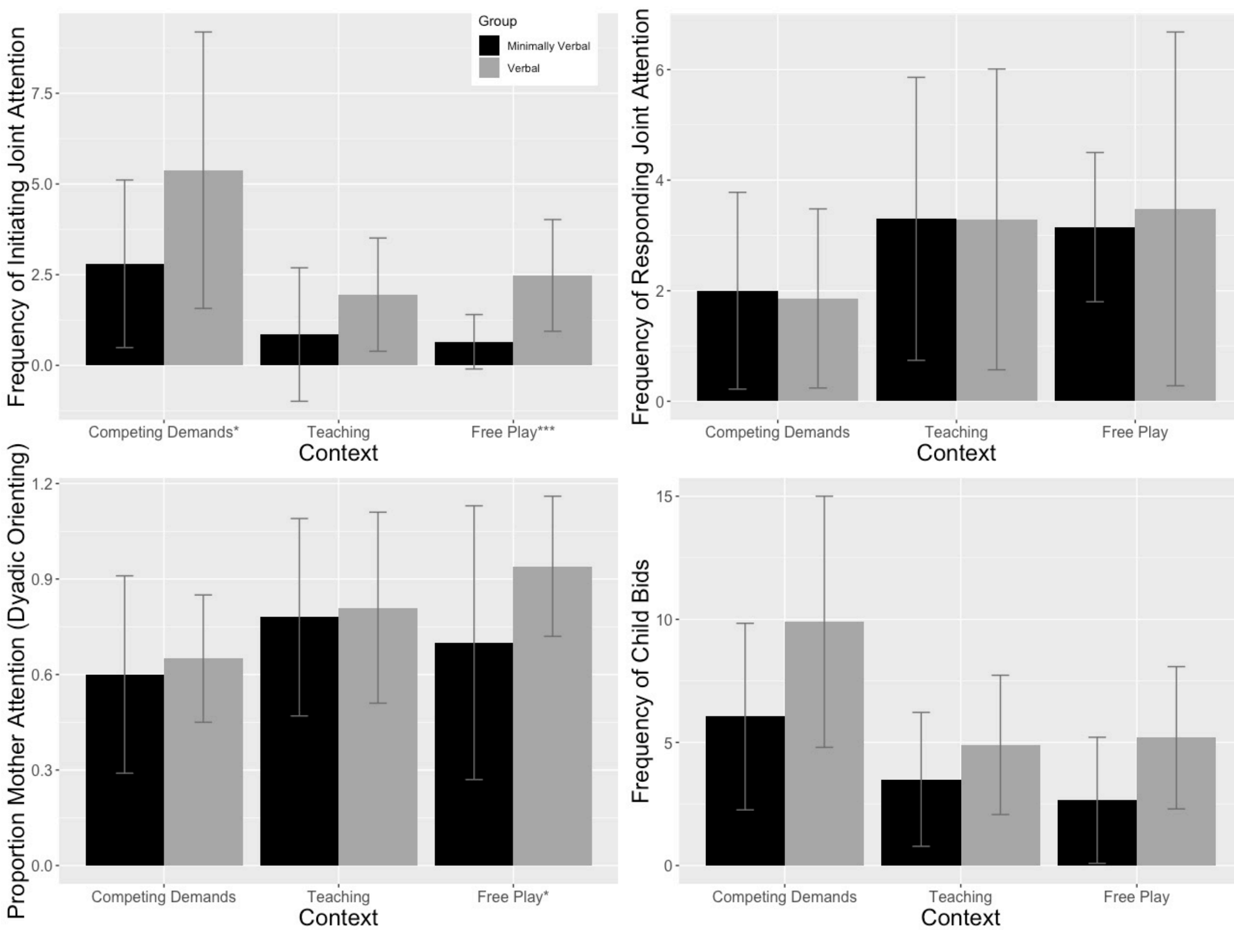
Interestingly, there were no significant group differences in terms of child RJA or mother dyadic orienting in any of the contexts (i.e. competing demands, teaching and free play), nor were significant group differences identified in children's age (F (1, 36) = 1.03, p =.32), or ADOS-2 severity score (F (1, 36) = 2.67, p = .11). Figure 6 summarizes descriptive statistics for observed parent and child behaviors within each social context, and Figure 7 summarizes developmental variables and covariates.

Testing Research Questions

All hypotheses were tested with R Version 3.5.2 (R Core Team, 2013).

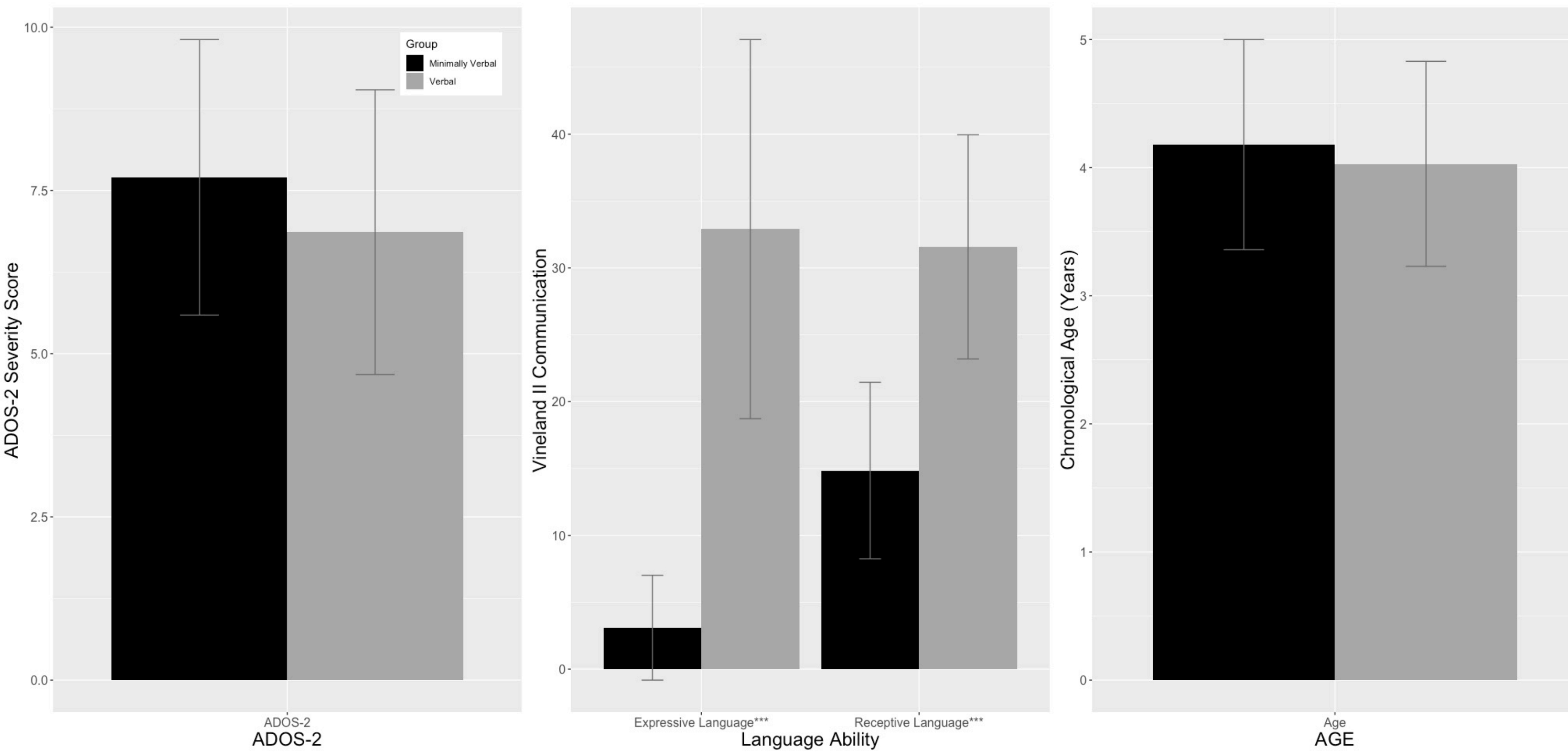
Research Question 1. To examine whether children's joint attention in the competing demands, teaching, and free play tasks were related to children's developmental characteristics and mothers' attention, as measured by mothers' successful dyadic orienting in each task, a correlation analysis of the study variables was conducted (see Table 7) followed by regression models with interaction terms. Results of the analyses revealed significant relations between child joint attention and proportion of successful dyadic orienting by the mother. Children's joint attention and mothers' successful dyadic orienting were also related to children's developmental characteristics including receptive and expressive language as measured by the *Vineland Communication Domain*. initiating joint attention in the free play task was related to the proportion of successful mother dyadic orienting in the free play task. There were no other significant relations between initiating joint attention and dyadic orienting.

Figure 6. *Means and standard deviations of study variables by minimally-verbal and verbal groups across contexts*



Note. *$p < .05$, **$p < .01$, ***$p < .001$

Figure 7. *Means and standard deviations of demographic variables by minimally-verbal and verbal groups*



Note. ****p* < .001

Table 7. *Correlations among primary study variables (n = 44)*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Initiating joint attention CD	- -												
2. Initiating joint attention T	.36*	- -											
3. Initiating joint attention FP	.36*	.31*	- -										
4. Responding joint attention CD	-.10	.23	.15	- -									
5. Responding joint attention T	-.00	.18	.07	.32*	- -								
6. Responding joint attention FP	-.18	.-.08	-.11	.-.07	.31*	- -							
7. Dyadic Orienting CD	.32*	.13	.02	.17	.12	-.01	- -						
8. Dyadic Orienting T	.11	.07	.15	.12	.11	.02	.23	- -					
9. Dyadic Orienting FP	.23	.11	.33*	.04	.01	-.19	.11	.07	- -				
10. Receptive Language	.31*	.35*	.52***	-.05	-.10	-.15	.11	-.01	.32*	- -			
11. Expressive Language	.39**	.26	.53***	-.13	-.16	-.17	.17	.23	.39**	.86***	- -		
12. ADOS-2 Score	-.19	-.15	-.32*	.07	.26	.31*	.30	-.06	-.23	-.26	-.32*	- -	
13. Child Age	-.05	-.16	.39**	-.09	-.13	.10	.25	.08	.04	.10	.17	.23	- -

Note. CD = competing demands task, T = teaching task, FP = free play task. *$p < .05$, **$p < .01$, ***$p < .001$

Child initiating joint attention in the competing demands, teaching, and free play tasks was positively related to the child's receptive language (r (42) = .32, p = .04; r (42) = .36, p = .02; r (42) = .53, p < .001 respectively), and also the child's initiating joint attention in the competing demands and free play task was positively related to the child's expressive language (r (42) = .39, p = .008; r (42) = .54, p < .001 respectively). Importantly, both initiating joint attention and responding to joint attention in the free play task was related to the child's ADOS-2 severity score, such that greater frequency of initiating joint attention and responding to joint attention related to lower ASD severity on the ADOS-2 (IJA, r (42) = -.32, p = .04; RJA, r (42) = .31, p = .04). Child initiating joint attention during free play was also the only joint attention measure related to chronological age (r (42) = .39, p = .009).

Furthermore, regression models were constructed to identify moderating effects of child developmental characteristics including receptive language and expressive language on the relation between joint attention and dyadic orienting in each context. A total of 12 models were constructed (see Table 8). Models were built for each context (competing demands, teaching, free play), and each model's dependent variable was either initiating or responding joint attention and included the child's age as a covariate. Then, either expressive or receptive language, mother dyadic orienting, and the interaction between expressive/receptive language and mother dyadic orienting was added to the model. Each model was assessed for violations of statistical assumptions. For each model, QQ plots and histograms of residuals were visually inspected, and Shapiro-Wilk tests for normality were conducted. If model assumptions were violated, square root transformations of the dependent variable were conducted, and in all cases, subsequently satisfied model assumptions. Table 8 summarizes the moderator effect in each model. During the teaching task, expressive language and receptive language moderated the relation between dyadic orienting and IJA, (F (1, 39) = 4.44, p = .04; F (1, 39) = 4.75, p = .03 respectively such that greater levels of both expressive language and receptive language promoted a stronger relation between mother dyadic orienting and child initiating joint attention. In addition, during

Table 8. *Interaction models with child joint attention as dependent variable, and the interaction between language and mother dyadic orienting, controlling for the child's chronological age within each context (competing demands, teaching, and free play)*

Context	Dependent Variable	Moderator	*DF*	*F*	*p*
Competing demands	Initiating joint attention	Expressive language	(1, 39)	1.16	.29
Teaching	Initiating joint attention ^{T}	Expressive language	(1, 39)	4.44	.04*
Free play	Initiating joint attention	Expressive language	(1, 39)	0.09	.77
Competing demands	Initiating joint attention ^{T}	Receptive language	(1, 39)	2.33	.13
Teaching	Initiating joint attention	Receptive language	(1, 39)	4.75	.03*
Free play	Initiating joint attention	Receptive language	(1, 39)	0.54	.47
Competing demands	Responding joint attention ^{T}	Expressive language	(1, 39)	0.78	.38
Teaching	Responding joint attention ^{T}	Expressive language	(1, 39)	0.84	.36
Free play	Responding joint attention ^{T}	Expressive language	(1, 39)	4.15	.04*
Competing demands	Responding joint attention ^{T}	Receptive language	(1, 39)	0.26	.61
Teaching	Responding joint attention ^{T}	Receptive language	(1, 39)	0.50	.48
Free play	Responding joint attention ^{T}	Receptive language	(1, 39)	2.46	.13

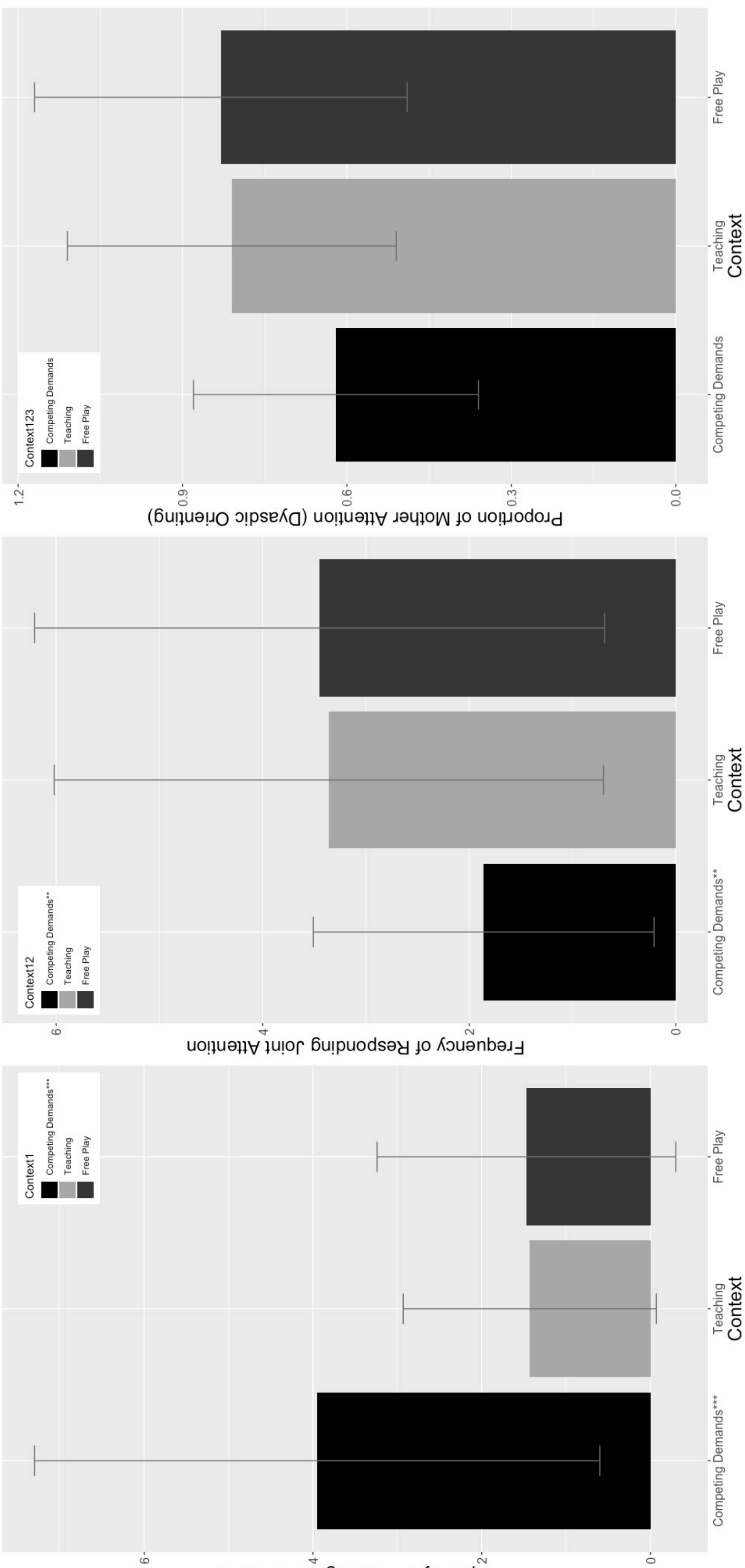
Note. $^*p < .05$; ^{T} denotes a model that required square root transformation of the dependent variable in order to satisfy statistical assumptions

the free play task expressive language moderated the relation between dyadic orienting and RJA, (F (1, 39) = 4.15, p = .04) such that greater levels of expressive language promoted a stronger relation between mother dyadic orienting and child responding joint attention. To control the false-discovery rate among interaction terms, the Benjamini Hochberg Procedure (Benjamini & Hochberg, 1995) was used. When applying this procedure with a 10% false discovery rate, none of the interaction terms met the required threshold, thus results should be interpreted with caution.

Finally, post-hoc multiple regression models were tested to determine if the mother's number of spoken words in each task moderated the relation between child initiating joint attention and mother dyadic orienting above and beyond the effect of child language ability (expressive language and receptive language). Models were fit for each context with child's initiating joint attention as the dependent variable, then controlling for child's receptive and expressive language, followed by the main effect for mother dyadic orienting and mother's number of spoken words, and finally – the variable of interest – the interaction between mother dyadic orienting and mothers' number of spoken words. Results of these models revealed that, after controlling for the child's receptive and expressive language, the mother's number of spoken words moderated the relation between mother dyadic orienting and child initiating joint attention in the competing demands task (F (1, 38) = 6.90, p = .012), such that more words spoken by the mother during the task strengthened the relation between mother dyadic orienting and child initiating joint attention. The mother's number of spoken words did not moderate the relation between mother dyadic orienting and child initiating joint attention in the teaching task (F (1, 38) = 0.09, p = .77) and free play task (F (1, 38) = 0.68, p = .41).

Research Question 2. To test whether the rate of children's initiating joint attention, children's responding to joint attention, and mothers' dyadic orienting differed as a function of context (i.e., competing demands, teaching, and free play contexts), mixed models were fitted with context as a fixed factor and participant as a random factor (see figure 8). Random effects models were chosen in order to control for individual variability across contexts, given that the same participants were measured on outcome variables in each of the three contexts. The mixed

Figure 8. *Means and standard deviations of primary study variables by context.*



Note. $*p < .05$, $**p < .01$, $**p < .001$

effect model was preferred over a repeated measures design given that its covariance structure allows for non-constant correlation among observations and there is no requirement for balance in the data (Laird & Ware, 1982). Within each model, children's expressive and receptive language were controlled. Additionally, post-hoc pairwise contrasts using Bonferroni corrections were analyzed for each model.

For child's initiating joint attention, an initial model including children's receptive and expressive language, fixed effect of context, and random effect of participant was fit. Model assumptions were assessed, which revealed violations to homogeneity of variance using Bartlett's test of sphericity (K^2 (2) = 32.37, $p < .001$), as well as violations to normality of residuals through visual inspection of the residual QQ plot and histogram, as well as results of the Shapiro-Wilk test for normality ($W = 0.93$, $p < .001$). Given these violations to model assumptions, the dependent variable underwent a square root transformation, which subsequently satisfied the violations to sphericity as well as residual normality (Bartlett's test of sphericity (K^2 (2) = 2.46, $p = .29$; Shapiro-Wilk test for normality, $W = 0.99$, $p = .91$).

Results of the mixed effect model revealed an overall significant effect of context (conditional $R^2 = .57$, F (2, 86) = 26.96, $p < .001$). Follow-up pairwise comparisons with Bonferroni corrections revealed a significant difference in child initiating joint attention between the competing demands task and teaching task, t (86) = 6.82, $p < .001$, and the competing demands task and free play task, t (86) = 5.77, $p < .001$, such that children displayed significantly more bids for joint attention during the competing demands task than either the teaching or free play task. The difference in child initiating joint attention was non-significant between the teaching task and free play task, t (86) = -1.04, $p = .55$.

For child's responding to joint attention, a model including children's receptive and expressive language, fixed effect of context, and random effect of participant was fit. The model also controlled for the mother's number of spoken words in order to take into account the possibility of more opportunities for the child to respond when the mother spoke more. Model assumptions were assessed, which revealed violations to homogeneity of variance using Bartlett's test of sphericity (K^2 (2) = 12.19, p = .002), as well as violations to normality of residuals through visual inspection of the residual QQ plot and histogram, as well as results of the Shapiro-Wilk test for normality (W = 0.93, p < .001). Given these violations of model assumptions, the dependent variable underwent a square root transformation, which subsequently satisfied the violations to sphericity as well as residual normality (Bartlett's test of sphericity K^2 (2) = 1.33, p = .51; Shapiro-Wilk test for normality, W = 0.99, p = .57). Results of the mixed effect model revealed an overall significant effect of context (conditional R^2 = .32, F (2, 86) = 7.55, p < .001) on children's responding to joint attention. Follow-up pairwise comparisons with Bonferroni corrections revealed a significant difference in child responding to joint attention between the competing demands task and teaching task, t (86) = -3.15, p = .006, and the competing demands task and free play task, t (86) = -3.54, p = .002, such that children displayed significantly fewer responses to joint attention during the competing demands task than either the teaching or free play task. The difference in children's responding to joint attention was non-significant between the teaching task and free play task, t (86) = -0.39, p = .92.

Next, the proportion of mother dyadic orienting was used as the dependent variable, with independent variables including the fixed effect of context and random effect of participant, controlling for children's receptive and expressive language. Model assumptions were met for sphericity (Bartlett's test of sphericity K^2 (2) = 3.67, p = .16) however normality of residuals was not met based on examination of the residual histogram and QQ plot, as well as results of the Shapiro Wilk Test (W = 0.86, p < .001). Multiple transformations were performed including log and natural log, as well as square root, squared and cubed transformations. Each of these transformations resulted in models that violated essential statistical assumptions. Given these violations, model fitting was terminated for mother dyadic orienting. From a descriptive standpoint, for mother dyadic orienting across contexts, mothers attended to their child's bids for attention with approximately 80% accuracy in the free play and teaching tasks, but were comparatively lower during the competing demands task, with approximately 60% accuracy.

Research Question 3. Contingency analyses were conducted to investigate the hypothesis that a temporal association existed between joint attention and dyadic orienting. During the parent-child interaction, each task was observationally coded in 15 second intervals. Interval-level data was subsequently coded with a 1 (behavior was present during the interval) or 0 (behavior was absent during the interval) for child initiating and responding joint attention and mother dyadic orienting. To examine the temporal association between child and parent behaviors, contingency analyses were conducted to identify every lag-1 association between child joint attention and subsequent mother dyadic orienting (i.e. an antecedent child behavior occurred in a given interval, and a contingent parent behavior occurred in the subsequent interval). To identify whether the parent's behavior was more likely to serve as an antecedent for the child's behavior, contingency analyses were also run in the opposite direction to identify every lag-1 association between mother dyadic orienting and subsequent child joint attention behavior. For each analysis, a composite Yule's Q score was derived from a 2 x 2 contingency table for each mother-child pair. Contingency scores were assigned (1) child behavior present and parent behavior present; (2) child behavior present and parent behavior absent; (3) child behavior absent and parent behavior present; and (4) child behavior absent and parent behavior absent. The Yule's Q score is an odds ratio ranging from -1 to +1 and indicates the strength of contingency between behaviors. An important feature of this statistic is that it controls for each participant's base rate of behavior (Bakeman & Gottman, 1997).

Findings revealed that following intervals in which the child initiated joint attention, mothers were more attentive to their child's attentional bids through dyadic orienting in subsequent intervals ($t\,(31) = 3.77$, $p < .001$). Additionally, for intervals in which mothers attended to their child's bid for attention, children were more likely to initiate joint attention in the subsequent interval ($t\,(28) = 3.96$, $p < .001$). However, during intervals in which children responded to joint attention, there was no evidence that their mothers were more or less likely to attend to their child through dyadic orienting in the subsequent interval, $t\,(26) = 1.34$, $p = .19$. Likewise, during intervals in which mothers attended to their child through dyadic orienting, there was no evidence to suggest children were more or less likely to respond to joint attention in the subsequent interval ($t\,(30) = 0.45$, $p = .65$). Thus, there was evidence of a contingency between mothers' dyadic orienting and their child's initiating joint attention, but not responding to joint attention.

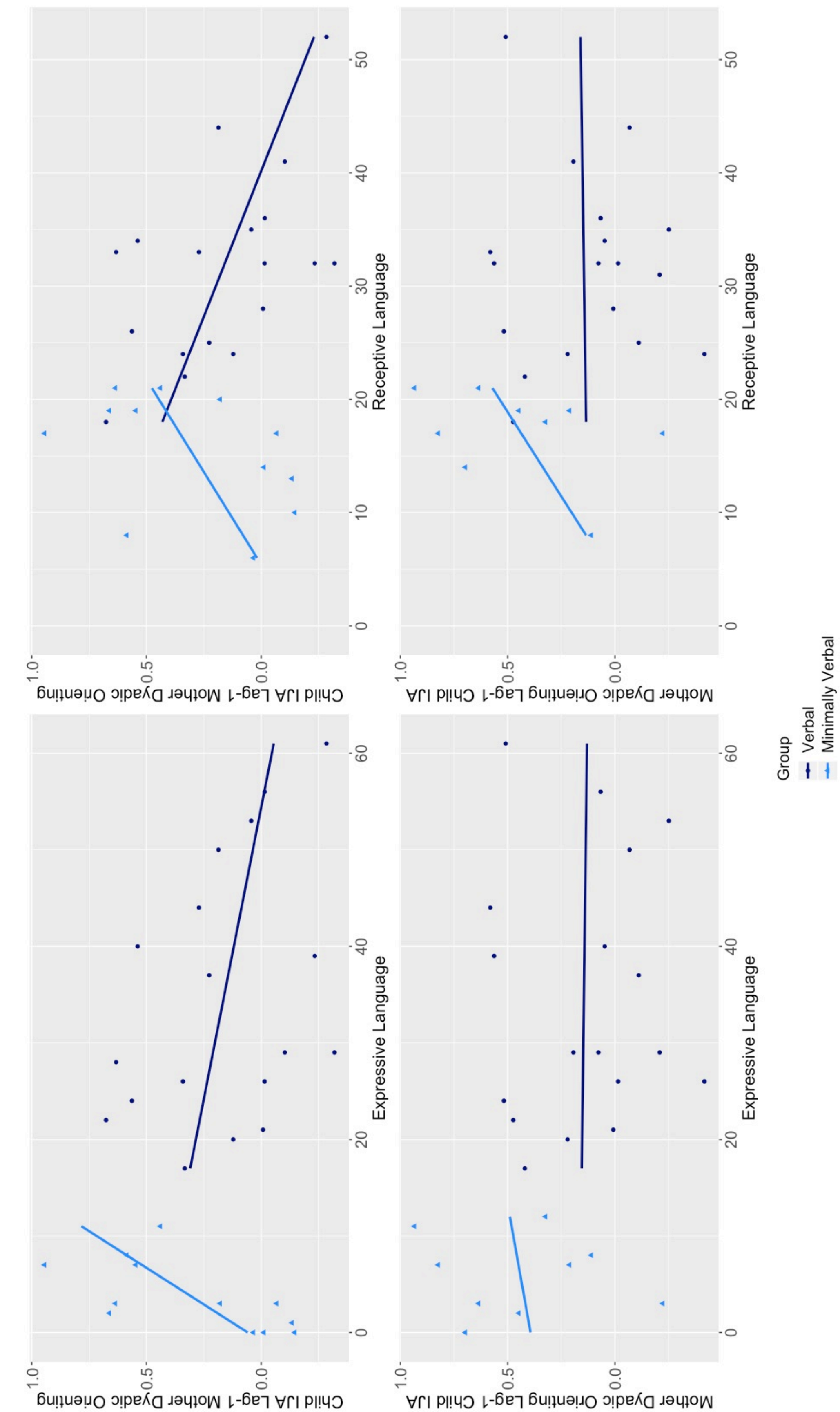
Post-hoc regression models were fit to examine child and parent characteristics that may relate to the two significant contingent relations between initiating joint attention and dyadic orienting. Results of the post-hoc regression models are summarized in Table 9. In each model, Yule's Q scores for child initiating joint attention with lag-1 mother dyadic orienting, and mother dyadic orienting with lag-1 child initiating joint attention were used as dependent variables. Both models included explanatory variables of receptive and expressive language, ADOS-2 score, child age, and mother age. Both models revealed non-significant relations among all independent variables related to each Yule's Q variable (Table 9). Thus, the strength of the contingency between mothers' dyadic orienting and children's initiating joint attention was not related to children's developmental characteristics or mother age.

Table 9. *Contingency analysis post-hoc regression models*

Variable	SS	MSE	*F*	*P*
Initiating joint attention, lag-1 dyadic orienting	-	-	-	-
Receptive language	0.27	0.27	2.300	.14
Expressive language	0.000	0.000	0.000	.99
ADOS-2 score	0.003	0.003	0.025	.88
Child age	0.006	0.006	0.053	.82
Maternal age	0.000	0.000	0.001	.98
Dyadic Orienting, lag-1 initiating joint attention	-	-	-	-
Receptive language	0.140	0.140	1.329	.26
Expressive language	0.216	0.216	2.051	.17
ADOS-2 score	0.053	0.053	0.504	.49
Child age	0.295	0.295	2.798	.11
Maternal age	0.1601	0.161	1.524	.23

To further explore the *direction* of the temporal association between child initiating joint attention and mother dyadic orienting, two models were fit using the Yule's Q score as the dependent variable; the first model used child initiating joint attention with lag-1 mother dyadic orienting, and the second model used mother dyadic orienting with lag-1 child initiating joint attention as dependent variables (see Figure 9). Both models were built hierarchically, first by splitting the children into minimally-verbal (module 1) and verbal (module 2 and 3) groups based on the module of the ADOS-2 they were administered, and fitting the new module grouping variable in the model. Then the child's expressive language and receptive language were added to the model. Finally, the interactions between module group and expressive language, and module group and receptive language were added to the model. Each model utilized type III sums of squares.

Figure 9. *Temporal associations between child initiating joint attention and mother dyadic orienting and their relation to expressive and receptive language for minimally-verbal and verbal groups*



For the first model, using child initiating joint attention with lag-1 mother dyadic orienting as the dependent variable, no significant main effects for module group, expressive language, or receptive language were observed, however significant interactions emerged for module group and receptive language (F (1, 24) = 7.83, p = .009), and module group and expressive language (F (1, 24) = 4.25, p = .050). In both instances, a positive relation existed for the minimally-verbal group, such that greater expressive and receptive language predicted a stronger temporal association between the child's joint attention initiations and subsequent mother dyadic orienting, with mothers *more* likely to attend to their child after a successful joint attention initiation was executed by the child. In comparison, in both instances a negative relation existed for the verbal group, such that greater expressive and receptive language abilities predicted a weaker temporal association between the child's joint attention initiations and subsequent mother dyadic orienting, with mothers *less* likely to attend to their child in an interval after the child initiated joint attention.

When evaluating the converse dependent variable, mother dyadic orienting with lag-1 child initiating joint attention with the same explanatory variables, a module group main effect emerged (F (1, 21) = 4.32, p = .050) indicating that on average, children in the verbal group were more likely that their counterparts in the minimally-verbal group to initiate joint attention in the interval succeeding that which their mother attended to them. There was no main effect for receptive language (F (1, 21) = 0.18, p = .68) or expressive language (F (1, 21) = 0.23, p = .64), nor were either of the interactions significant (module group by expressive language, F (1, 21) = 0.07, p = .79; module group by receptive language, F (1, 21) = 0.84, p = .37).

VI

Study 2 Discussion

The purpose of Study 2 was to examine joint attention behaviors of children with ASD and their mothers in both structured and unstructured contexts (i.e., competing demands, teaching and free play with a parent), and to examine the relation between mother attention (i.e., dyadic orienting) and joint attention behaviors of children with ASD. This study tested three primary research predictions: (a) the rate of children's IJA, children's RJA, and mothers' dyadic orienting differed as a function of context (i.e., competing demands, teaching, and free play contexts); (b) children's joint attention behaviors in the competing demands, teaching, and free play tasks related to children's developmental characteristics and mother's attention, as measured by mothers' successful dyadic orienting in each task; and (c), a temporal association between joint attention and dyadic orienting, such that the more joint attention children with ASD direct toward their mothers, the more attentive mothers are toward their children, and conversely, the more attentive mothers are to their children, the more joint attention children direct toward their mothers.

Several key findings emerged in study 2 that will be of central focus in the forthcoming discussion. First, the study found that the rate of children's joint attention and mother's dyadic orienting differed depending on the context of their interaction. Children exhibited greater frequency of IJA during the competing demands task, and greater frequency of RJA during the free play and teaching tasks. Mothers also attended more to their children during the teaching and free play tasks compared to the competing demands task. Children's receptive and expressive language was related to their IJA across all three tasks, however their ASD severity and chronological age were only related to IJA during the free play task. Child IJA was also related to mother attention, and this relation was moderated by the child's expressive and receptive language in the teaching task. The relation between child IJA and mother attention was also moderated by the number of words spoken by the mother during the competing demands task. In addition to the bivariate association between child IJA and mother attention, this relation was also found to be temporally significant, with a bi-directional contingent association such that child IJA predicted subsequent mother attention, and mother attention predicted subsequent child IJA. When the group was split by children's language ability (i.e., minimally-verbal and verbal groups) there was a group by receptive language, and a group by expressive language interaction on the contingency between child IJA and subsequent mother attention. These results point to the important role that child language has on mother-child social interactions, and how children's verbal ability, as well as the context of the social interaction may influence joint communicative outcomes.

Taken together, these results support the hypothesis proposed in Study 2, that children's joint attention would be related to, and moderated by their mother's attention and contextual factors. The parallel and distributed processing model of joint attention (Mundy & Jarrold, 2010) informs these conclusions given that within this framework, children's skillful integration of joint attention is supported by actions and behaviors of their caregiver, as well as aspects of their environment, which provide opportunities that reinforce and build increasingly effortless coordination of joint attention in children's social communication.

Child Joint Attention

Joint attention is a pivotal skill in child development and serves as a building block for language development and other developmental skills (Adamson et al., 2017; Bottema-Beutel 2016; Mundy, 2016). Joint attention deficits are evident in children with ASD, even for those who have developmentally appropriate language (Dakopolos & Jahromi, 2018) and who do not exhibit intellectual deficits (Mundy & Crowson, 1997). While the sample in the current study did not include a TD or other DD comparison group, the current study's sample of children with ASD demonstrated commensurate joint attention skills to comparable samples of children with ASD in the literature. For example, Van der Paelt, Warreyn, and Roeyers (2015) found in a sample of 87 children with ASD whose mean age was 49 months (*SD* = 14 months), that children with expressive language age < 2 years had an average IJA frequency of 1.37, and those with expressive language age ≥ 2 years had an average IJA frequency of 3.54 as measured by the ESCS (Mundy et al., 1996). Comparatively, in the present study, frequency counts of children's joint attention across contexts indicated that children with ASD initiated joint attention an average of 3.95, 1.43, and 1.57 times in the competing demands, teaching, and free play tasks respectively. As each task was 5 minutes in length, children in the present sample emitted an initiation of joint attention just less than once every two minutes (.46/min). The sample children's RJA was slightly higher, with an average frequency of 1.86, 3.36, and 3.45 in each of the three tasks (competing demands, teaching and free play), or an average of .58 responses per minute. The comparison to past work should be interpreted with caution as the ESCS has standardized procedures, but is not standardized on duration, making frequency comparisons with mother-child interaction observations somewhat difficult.

A large proportion of studies that employ measures of joint attention utilize the ESCS (Mundy et al., 1996) with a trained experimenter as the social partner (e.g. Adamson et al., 2017; Dawson et al., 2004; Nichols, Martin, & Fox, 2005). The present study is unique in that it utilizes the structured ESCS (Mundy et al., 1996) coding scheme during semi-structured interactions – including free play – with the child's mother. While the specific combination of contexts examined in the current study is relatively novel, a few researchers utilize similar schemes.

Yoder and Warren (1999) used a semi-structured play-based parent-child interaction (PCX) to measure maternal responsivity and intentional communication in a sample of typically developing young children. The PCX paradigm has been used in other studies among Yoder's research group (e.g. Fey et al., 2006; Yoder & Warren, 2002), and was broadened by Kasari and colleagues (e.g. Kasari et al., 2006) to code other dimensions of parent-child interactions. The PCX has been used by Kasari and colleagues to code parental responsiveness (e.g. Kasari, Siller, Huynh, Shih, Swanson, Helleman, & Sugar, 2014), symbolic play (e.g. Kasari et al., 2006) and notably, child joint attention (Kasari et al., 2012). Kasari et al. (2012) averaged IJA and RJA frequencies from the ESCS and PCX, and found that children with ASD in their sample (n = 40) who were between the ages of 3 and 4 years had average frequencies of 3.89 (*SD* = 2.72) for IJA, and 9.05 (*SD* = 4.96) for RJA. Although the average IJA and RJA frequencies in the present study were lower than those found in Kasari et al. (2012), Kasari's frequencies reflected the formal ESCS (Mundy et al., 1996) measure of joint attention with an experimenter.

In a validity study, Roos, McDuffie, Weismer and Gernsbacher (2008) showed significant correlations between IJA measures and between RJA measures derived from the ESCS (Mundy et al., 1996) and a free play session using ESCS coding methodology. In their study, 20 children with ASD between the ages of 30 and 38 months were administered the ESCS (mean duration = 16.5 minutes), as well as participated in a 15-minute free play session with an experimenter. Results from the study indicated respective IJA and RJA frequencies were *significantly different* between the standardized ESCS and free play interactions, yet they were *significantly correlated* across the two contexts (Roos et al., 2008). For IJA, children with ASD had frequencies of 9.95 (*SD* = 9.67) for the ESCS and 2.90 (*SD* = 2.59) for the free play session (Roos et al., 2008). The results of Roos et al.'s (2008) study provide evidence that joint attention can be measured with validity in alternative contexts using ESCS coding schemes. Others have also noted that measures of joint attention in different contexts can generate complimentary information about joint attention skills in children with ASD (e.g. Adamson et al., 2017).

Factors Associated with Joint Attention

In the current study children's joint attention was found to be strongly correlated with the child's teacher-rated expressive and receptive language ability, as well as their chronological age, and ADOS-2 severity score, such that children with poorer language skills, younger children, and children with more severe ASD exhibited less frequent IJA, while less frequent RJA was only associated with ASD severity on the ADOS-2. These results align with other researchers who have demonstrated that IJA most strongly relates to children's *current* language ability, while RJA more strongly predicts *later* language ability (e.g. Bottema-Beutel, 2016). These results provide evidence for the important link between language and joint attention, as well as the centrality of joint attention deficits as a primary symptom of ASD.

When the current study's sample was stratified by ADOS-2 module into minimally-verbal (module 1) and verbal (module 2 and 3) groups, significant group differences were observed in IJA during the competing demands and free play task, however no group differences were observed in RJA. It may be that these findings reflect the documented dissociative nature of IJA and RJA (e.g. Mundy & Jarrold, 2010). Even the children in the present sample who had poorer receptive and expressive language were able to respond to joint attention at similar levels to their more verbal peers, yet they did not exhibit the same joint attention initiations as their more verbal counterparts. These results are particularly noteworthy in light of the fact that the groups did not significantly differ in their chronological age, or ASD severity.

While young typically developing children are able to seamlessly integrate joint attention initiations into their pre-verbal repertoire of social skills, it may be that children with ASD benefit from greater language skills in order to access similar levels of joint attention. A meta-regression analysis of 605 effect sizes across more than 40 studies comparing language and joint attention skills in TD and ASD children found that effect sizes were significantly higher in ASD groups for expressive and receptive language compared to other groups, including TD (Bottema-Beutel, 2016). Bottema-Beutel (2016) hypothesized that there may be a joint attention "threshold," in which once a certain level of joint attention is attained, expressive and receptive language is "no longer tethered to variation in joint attention." While this may be true for typically developing children and some highly verbal children with ASD, many children with ASD may fall below such a threshold or never meet it, making their language more contingent on joint attention (Bottema-Beutel, 2016). Children with ASD may experience joint attention and language abilities that remain tethered, developing concurrently instead of disengaging to move beyond joint attention skills onto other skills that could more efficiently facilitate language development. This phenomenon may help explain how language skills of children with ASD promote their joint attention abilities.

Relation between Mother Attention and Child Joint Attention

Children's IJA was related to mother dyadic orienting in the competing demands and free play task. These results are unsurprising given that the behavioral coding scheme necessitated the occurrence of children's initiations prior to their mother's attention. That said, a more nuanced picture of child-mother associations emerged when child and parent language was tested as a moderator of this association.

Child language moderates mother attention and child joint attention. In the teaching task, the relation between child IJA and mother attention was moderated by both the child's expressive and receptive language, such that as the child's language ability increased, the relation between IJA and mother attention was strengthened. When the relation between children's IJA skill and mother's attention are framed within a joint engagement perspective – in which the child and their mother are communicating jointly – the child's language ability significantly predicts better joint engagement. Adamson et al. (2017) posit that as toddlers begin to speak, their joint attention skills facilitate word learning, and this bidirectional relation significantly impacts joint engagement. In their study of at-risk children subsequently diagnosed with ASD, children with ASD who moved from not-talking to talking over a 6-month period during their 3rd year "seemed to kindle a developmental transformation of joint engagement," in which children who were already able to speak did not change in their joint engagement abilities during this period, whereas those who developed speech rapidly and significantly increased joint engagement with their caregiver (Adamson et al., 2017).

Mother language moderates mother attention and child joint attention. The number of words spoken by the mother also moderated the relation between child IJA and mother attention during the competing demands task. The relation between mother attention and child IJA was strengthened as mothers spoke more during the interaction. There is evidence that the *manner* in which mothers respond and direct their attention may make a difference in communication outcomes for children with ASD. For instance, the number of parent utterances that followed their child's focus of attention, as well as the number of parent utterances responding to their child's verbal communication significantly predicted increases in children's spoken vocabulary over a 6-month period (McDuffie & Yoder, 2010). The *number* of words that a mother speaks to her child may not be as important as *what* is said during their interactions, yet the present study provides evidence that mother language more broadly is an important promotive factor related to children's joint attention.

There is a growing body of literature establishing other factors and processes at play during social interactions between children with ASD and their caregiver (e.g. Gulsrud et al., 2016) that may promote child joint attention and language ability. For example, in a joint attention, symbolic play, engagement and regulation (JASPER) intervention among 86 toddlers with ASD and their parents, parent-rated buy-in and parent involvement predicted better joint engagement outcomes for children with ASD (Gulsrud et al., 2016). Additionally, mirrored-pacing – which represents a parent's ability to appropriately time and pace imitative play acts with their child – was found to strengthen the relation between intervention and joint engagement (Gulsrud et al., 2016). There is also evidence that when mothers of children with ASD are tasked with specific intervention strategies that target joint attention (e.g. Kasari et al., 2008) or symbolic play (e.g. Kasari et al., 2015), there are significant positive longitudinal changes in their child's joint attention, joint engagement and social skills (e.g. Kasari et al., 2014).

Contingent child IJA and mother attention. Contingency analyses were used to examine the temporal link between child joint attention and mother attention in both directions (i.e., child behavior predicting mother behavior, and mother behavior predicting child behavior). The present study found that during intervals in which children initiated joint attention, mothers were significantly more likely to attend to their child in the following 15-second interval. Additionally, during intervals in which mothers attended to their child, the child was more likely to initiate joint attention in the subsequent interval. It could be that mothers' attention promotes more initiations of joint attention from their child, which could help explain the relation between initiating joint attention and dyadic orienting. However, because child IJA and attention were contingently related in both directions (i.e. IJA predicted subsequent dyadic orienting, and dyadic orienting predicted subsequent IJA), a more likely explanation is that mother-child bidirectional attention reinforced brief episodes of joint engagement.

From a behavior analytic perspective, the bidirectional contingent relation between IJA and mother attention could be interpreted as a "conversational unit" in which both the speaker (i.e., child IJA) and listener (i.e., mother attention) reinforce one another (Greer, Pohl, Du, & Moschella, 2017). Within the behavioral view, these brief episodes of joint engagement (or conversational units) demonstrate evidence of the child's emerging *naming* (i.e., the ability to learn language incidentally) through their joint stimulus control of speaker and listener. It may be that the social interaction between the mother and child itself is emerging as a behavioral reinforcer for both the mother and child, but in order to fully emerge, the individual must be reinforced as both a listener and speaker during the exchange.

Contingent child RJA and mother attention. Despite the statistically significant contingent relations between child IJA and mother attention, child RJA and mother attention were not contingently associated in either direction. These results suggest that communicative exchanges between the parent and child were not continued or extended by the child. For example, for mother dyadic orienting to be present, the child would have made an attentional bid toward their mother, to which the mother attended. However, these exchanges did not significantly elicit the likelihood that the child would respond to their mother in the subsequent interval. It may be that the child was not reinforced by responding to their mother. Therefore, there is evidence that communicative exchanges between mothers and their children likely did not build upon themselves, but rather, tended to be brief punctuated communicative episodes.

Associations between mother-child contingencies and participant characteristics. Significant contingencies (i.e. IJA predicting dyadic orienting, and dyadic orienting predicting IJA) were followed-up with post-hoc multiple regression analyses and explorations of moderating effects. First, expressive language, receptive language, ASD severity, child age, and maternal age were found to not be related to either contingency scenario between IJA and dyadic orienting. These results were unexpected, especially given the strong correlations found between child language and IJA, as well as the moderating role child language played in the association between IJA and dyadic orienting.

One explanation regarding the lack of associations in these analyses could point toward the joint attention threshold hypothesis (Bottema-Beutel, 2016), discussed above. Children in the more verbal group may have other social skills that more strongly predict their language abilities. Their joint attention skills may not have promoted the contingency between mother attention and IJA, but rather, other social skills outside the scope of the primary research questions may have promoted their mother's attention, and possibly have had a stronger relation to their language abilities.

Another possibility is that the main effects of expressive and receptive language, ADOS severity, child age, and mother age were not significant because mother behavior may be more strongly moderated by their child's level of functioning and language ability. There is evidence that mothers may adapt their behavior based on the diagnosis (e.g. Adamson et al., 2017; Kasari et al., 1988) or severity (e.g. Konstantareas et al., 1988) of their child's ASD. In fact, results of the present study suggest that in order to understand how children's expressive and receptive language relate to the contingency between child joint attention and mother attention, children's verbal status must be accounted for.

Moderating mother-child contingencies. The sample was split into minimally-verbal (ADOS-2 module 1) and verbal (ADOS-2 module 2 and 3) groups. Interaction terms were created between the group variable and expressive language, and the group variable and receptive language. When predicting the contingency between child IJA and subsequent mother attention, there was a significant interaction between both receptive language and group, and expressive language and group, whereas these interaction effects were non-significant in the mother attention predicting subsequent child IJA contingency. For the contingency between IJA and subsequent mother attention, for the minimally verbal group, the better expressive and receptive language abilities the child had, the stronger the contingency was between child IJA and mother attention; however, for the verbal group, the better expressive and receptive language abilities the child had, the weaker the contingency between child joint attention and subsequent mother attention.

Mother-child contingencies for the minimally-verbal group. To a certain extent, mothers may have expectations or assumptions about their child's communicative abilities, and anticipate their child's communication. For children in the minimally verbal group, parents may have been more vigilant and attentive to their child's IJA due to the relative infrequency of their initiations. When their child made an initiation, these mothers were right there to socially capitalize on their child's initiation. Within the minimally verbal group, those children with comparatively better language skills may have had mothers who were more anticipatory of their initiations due to awareness of their child's emerging language capabilities.

In a study of preschool children with ASD and mental-age matched intellectually disabled and TD children and their caregivers, caregivers did not differ in their responsiveness to children's non-verbal communication, so although children with ASD in this sample were on average 31 months older than their typically developing counterparts, caregivers were observed interacting and responding to their children at comparable levels (Kasari, Sigman, Mundy, & Yirmiya, 1988). Additionally, for children with ASD, caregiver responsiveness was also found to be positively related to children's expressive language ability, such that parents were more responsive as children's expressive language improved (Kasari et al., 1988). These results directly support the findings in the present study, and suggest that for minimally-verbal children, as their language abilities increase, mothers are more attentive to their communicative attempts.

For children with ASD with lower expressive and receptive language, mothers may have a sharper focus of attention in anticipation of their child's communication, and as such – although they are not quantitatively more responsive than parents whose children are already speaking – these mothers may modulate qualitative aspects of their responsive behaviors to meet their child's particular communicative needs (Konstantareas et al., 1988).

Mother-child contingencies for the verbal group. For the mothers of verbal children, it is possible that the mere fact their child is able to communicate verbally does not provide any additional motivation to the mother to be more attentive to her child's IJA. According to Hart and Risley (1999), as children develop language, at first parents hang onto their child's every word, but once children reach a certain level of language ability, parents may lose interest in what their child has to say. As children gain language, they develop other, more sophisticated means to obtain a social partner's attention, and do not rely on joint attention as much as those without language (Adamson et al., 2017; Bottema-Beutel, 2016).

In a longitudinal sample of 60 children with ASD or pervasive developmental disability not otherwise specified (PDD-NOS), growth curve modeling revealed that, over a 40-month period, children who experienced the greatest growth in language abilities between the ages of 40- to 80-months, were those children who demonstrated better toy play and deferred imitation skills (Toth, Munson, Meltzoff, & Dawson, 2006). In their study, children at 40-48 months of age who initially began with better language ability were those who also began with superior joint attention skills, however as the children developed, joint attention gave way to deferred imitation and toy play as most predictive of rate of language development (Toth et al., 2006). Toth and colleagues (2006) speculate that joint attention may be a skill that acts as a "starter set," facilitating social communicative interactions in which language can develop, which then gives way to other skills that propel language development further. Thus, mothers of children who have moved beyond the sole use of joint attention may not attend as frequently to their child's joint attention bids because they are accustomed to attending to their child's more sophisticated behaviors.

Mother-child contingencies affect mother behavior. Mothers may also anticipate communicative acts that are more typical of their child's chronological development, rather than their current cognitive development, and in doing so, miss joint attention acts of their child that one would expect of younger children. In a study of children with ASD who were either "higher functioning verbal" or "lower functioning non-verbal," and their mothers, groups did not differ in the total number of utterances made by mothers, but did differ in mean utterance length (Konstantares, Zajdeman, Homatidis, & McCabe, 1988). Mothers of children in the non-verbal group asked fewer questions, and made more directives of their child than the verbal group, and mothers of non-verbal children provided significantly less reinforcement for their child's language and significantly less language modeling than did mothers of the verbal group.

It could also be that in the absence of specific intervention strategies, mothers of children with ASD have difficulty managing their expectations of their child's communicative abilities. There may be factors specific to ASD that make it especially difficult for parents to employ attentional and regulation strategies with the same fidelity as parents of TD children. Adamson et al. (2017) found that parent scaffolding and following-in were significantly impacted by their child's subsequent ASD diagnosis. Specifically, for 2-year-old children who were at high risk for ASD and who were later diagnosed, their parents were *less* adept at scaffolding and following-in than parents of children who were typically developing, and were less adept than parents whose children were at high risk for ASD but were not subsequently diagnosed.

There is controversy regarding the extent to which parenting behaviors are moderated by their child's ASD diagnosis. In a different study, Adamson, McArthur, Markov, Dunbar, and Bakeman (2001) showed that parents of children with ASD made as many attention regulating bids as mothers of typically developing children, but the mothers of children with ASD employed bids that differed slightly in commenting contexts, and also took on different forms than the bids of mothers with TD children. Caregivers of children with ASD were also shown to not differ from caregivers of TD and ID children in their responsiveness, as well as their engagement in mutual play (Kasari et al., 1988).

There is also evidence, however, that maternal sensitivity, including positive and negative parenting is moderated by ASD diagnosis (Blacher, Baker, & Kaladjian, 2013). Additionally, mothers of children with ASD have been found to smile less, and be less likely to respond to their child's smiles than mothers of typically developing children (Dawson et al., 1990). Finally, in a 2-part study of children with ASD compared to typically developing children and their mothers (study 1), and children with ASD compared to their typically developing siblings and their mothers (study 2), mothers of children with ASD did not differ in their total frequency of approach behaviors during a free play session, but did differ in the types of approach behaviors employed (Doussard-Roosevelt, Joe, Bazhenova, & Porges, 2003). In this study, mothers of children with ASD exhibited more physical contact, more high intensity behavior, and fewer social verbal approaches than mothers of children with TD, and these results were consistent even for study 2, in which the *same* mother exhibited different control behaviors toward her children based on ASD diagnosis (Doussard-Roosevelt et al., 2003). Given this evidence, there remain important questions regarding dyadic interactions between children with ASD and their parents.

Contributions of Context

An important contribution of the present study is that mother attention and child joint attention varied by the context of their interaction. To our knowledge, there are no published studies that address how contextual factors relate to joint attention outside of free play contexts. There are, however, some studies that look at how context may relate to other dimensions of behaviors among children with ASD.

In a study of Dutch-speaking children with ASD ages 8-18, and age, gender and IQ matched typically developing children, measures of executive function (EF) were categorized based on their degree of structure (from structured to open ended). Children with ASD had greater EF deficits than the typically developing group, with group differences more pronounced when the EF task was more open-ended (Van Eylen, Boets, Steyaert, Wagemans, & Noens, 2015).

In another study, Blacher, Baker, and Kaladjian (2013) rated positive and negative parenting in structured (clean-up and problem solving) and unstructured (free play) settings using the Parent-Child Interaction rating System (PCIRS, Belsky, Crnic, & Woodworth, 1995). Across all groups (TD, ASD, Down Syndrome, and unspecified DD), positive parenting was greatest in unstructured settings, while negative parenting was most salient during structured tasks. Dawson et al. (1990) used three tasks including free play, clean-up, and snack time to probe scenarios with low communicative demand, high communicative demand, and a face-to-face interaction respectively. Across all three tasks, children with ASD did not differ in the frequency or duration of gaze at their mothers' faces. Finally, in elicited vs. spontaneous imitation tasks, children with ASD performed similarly to children with TD in elicited tasks, but performed significantly poorer in spontaneous tasks (Ingersoll, 2008). When imitation was accompanied by coordinated joint attention, the ASD group performed significantly poorer than their TD peers in both tasks (Ingersoll, 2008).

Competing demands, teaching and free play. The three tasks employed in the present study differ conceptually in their communicative demands. During the competing demands task, the onus of communication was largely placed on the child because the mother was instructed to complete a large packet of work, and was often preoccupied in that task. In the teaching task, the onus of communication was placed on the parent. This task required the parent to teach their child to build a developmentally appropriate, but moderately difficult 3-dimensional model based on a 2-dimensional example. In order for the child to be successful building the model, the parent had to provide the child with verbal directions and scaffolds to accomplish the task. In the third, and final task – free play – the onus of communication was neutral. In this task, parents were instructed to play as they normally would at home. There was no indication of who was to take the lead, or how much communication should occur. Each of the three tasks provided vastly different opportunities for parent attention, and child joint attention.

Context and primary study variables. When observing associations between study variables across contexts, IJA, RJA, and dyadic orienting did not relate outside of their respective contexts, that is, IJA in the competing demands task was related to dyadic orienting in the competing demands task, but IJA in the competing demands task did not related to dyadic orienting in the teaching, or free play tasks. These results suggest that joint attention and dyadic orienting can be reliably assessed in different social contexts, and there may be utility in doing so.

In addition, IJA and RJA were related to children's ADOS-2 scores, but only in the free play context. These results are worth further exploration in future studies given that the ADOS-2 is administered within a structured free-play context with an experimenter. Child IJA in the free play task was also related to child chronological age. The ability to play appropriately is a developmental skill, and children who were older, i.e. more developmentally advanced, may have been able to coordinate IJA into free play with their mothers better than younger children. Child IJA in all three tasks was related to their expressive and receptive language, but the effect sizes were largest for expressive and receptive language in the free play task. The free play task may be the most developmentally aligned context in the present study, leading to its strong associations among receptive language, expressive language, ASD severity, and child age.

The utility of assessing child and parent behaviors in different contexts may relate to *functions* of the demands inherent in the tasks. For instance, the competing demands task may tap into children's social motivation, whereas the teaching task may relate to parental stress and performance anxiety – each task exerting their own pressures on the underlying construct being assessed, in this case, child joint attention and maternal attention.

Context and child joint attention. Children had significantly greater frequency of IJA in the competing demands task compared to the teaching or free play tasks after taking into account children's base level of IJA, and their receptive and expressive language ability. Children's frequency of IJA did not differ between the teaching and free play tasks. While the parameters of the competing demands task compelled mothers to offer less attention to their child, children in the sample were still able to coordinate significantly more joint attention initiations during the competing demands task than the other two. These results may point toward children's greater social motivation due to the mother actively paying less attention to the child. When the child had their mother's explicit attention in the teaching and free play tasks, children may have been less motivated to initiate joint attention because those tasks did not require the child to work as hard to gain their mother's attention.

These results may help inform social motivational theories of autism (e.g. Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2013; Dawson, 2008), which look broadly at social impairments such as social orienting and joint attention. These theories hypothesize that social impairments in children with ASD may be explained by differences in neurological reward processing, thus producing social motivational deficits that impact areas of social communication. Various studies have investigated the role of oxytocin (e.g. Starvopolous & Carver, 2013) as well as interventions such as the Early Start Denver Model (e.g. Rogers, Estes, Lord, Vismara, Winter, Fitzpatrick, Guo, & Dawson, 2012) on social motivation in children with

ASD. Differences observed in children's IJA across social contexts may add an important perspective to social motivation theories of autism because these differences could be explained by social-motivational factors inherent in the context, indicating contextual variability in the social motivation of children with ASD.

An opposite pattern of results existed for child RJA. Children had significantly greater frequencies of RJA in the teaching and free play tasks compared to the competing demands task. This result should be interpreted cautiously as RJA has been shown to differ as a function of opportunity to respond (e.g. Dakopolos & Jahromi, 2018), and it may be that due to the parameters of the competing demands task, there were simply fewer opportunities for children to respond to their mothers than in the teaching or free play tasks. There was no significant difference in child RJA between the teaching and free play tasks after controlling for children's base rate of responding and their expressive and receptive language ability.

Context and mother attention. Mother dyadic orienting during the free play context was related to child expressive and receptive language, however mother dyadic orienting in the competing demands and teaching tasks did not relate to child language ability. As opposed to the prospective role of the free play task as it relates to children with ASD, it may be that the free play task taps into the relation between mother attention and child language because the nature of the interaction places few explicit behavioral demands on the mother, therefore allowing her to better attend to her child, especially in a context in which child language is promoted.

Due to violations of statistical assumptions, differences in mother dyadic orienting across contexts could not be empirically assessed. However, when observing rates of mother attention, important contextual differences emerged. During the competing demands task, mothers attended to 61% of their child's bids, compared to 81% in the teaching task and 83% in the free play task. These results suggest that contextual elements may have shaped mothers' behavior. For example, it could be that instructing mothers to fill out the questionnaire during the competing demands task diverted their attention away from their child to a degree that the other tasks did not. With respect to mother attention, it is noteworthy that the competing demands task elicited the greatest amount of child IJA, but the lowest proportion of mother attention. Therefore, during the session children were likely making bids for joint attention that their mothers outright missed. While this was true for all contexts, it was most pronounced in the competing demands task.

Associations Between Mother Attention, Context, and Child Joint Attention

A number of analyses in the present study intersected mother attention, child joint attention, and context. Child IJA was related to mother attention in the competing demands, and free play tasks, but not during the teaching task; yet in the teaching task, child receptive language and child expressive language moderated the relation between child IJA and mother dyadic orienting. One possible explanation of this pattern of results is that there is something uniquely different about the teaching task compared to the free play and competing demands tasks. It could be that by asking the mother to teach her child to complete a construction puzzle in the teaching task, a performance element was introduced into the context that may have strained communication between parent and child. For children with better expressive and receptive language, the challenge of teaching her child to build the structure may have decreased, which in turn may have enabled the mother to be more attentive to communication attempts made by her child.

There is evidence that parent behaviors may be moderated by task demands *and* child development. In a study of typically developing children and children at risk for developmental disability, mothers exhibited increased sensitivity over a 2-year period (from child age of 3 to 5 years) during challenging tasks that required teaching or child regulation, however over this same period, mother sensitivity remained unchanged during free play tasks (Ciciolla, Crnic, &

West, 2013). In another study utilizing a mother-child teaching task, mothers' use of cognitive assistance and questioning increased, while their directiveness decreased over a period of 2 years (from child age of 18 months, to 42 months), and these results were predicted by child effortful control measured in other settings (Eisenberg, Vidmar, Spinrad, Eggum, Edwards, Gaertner, & Kupfer, 2010). These changes observed in parenting behavior as children developmentally improve their communicative and executive functioning skills could support the notion that mothers in our sample may be influenced by their child's language abilities during a task that could also exert mutual behavior regulation and increased child-scaffolding demands.

Children's expressive language ability strengthened the relation between child RJA and mother attention in the free play task. In this task, children with better expressive language had greater frequency of RJA, which in turn allowed parents more opportunities to attend to their child, thus creating more fluid communicative engagement. Without the constraints of explicit task demands, the free play task may have provided an optimal balance of mother and child communicative opportunities to elicit mutual communication in children with better expressive language.

Finally, the number of words spoken by the mother during the competing demands task moderated the relation between child IJA and mother attention. In this task, the number of words spoken by the mother may have served as a dyadic orienting technique. As verbal responding was an element of mother dyadic orienting, it follows that the more mothers spoke during the competing demands task, the stronger the relation between mother attention and child IJA. This relation may have only been detected in the competing demands task because mother language was explicitly embedded in the teaching task, and implied in the free play task. In fact, the average number of words spoken by mothers in the competing demands task was 144, compared to 458 in the teaching task, and 370 in the free play task.

Limitations of Study 2

The conclusions drawn from the present study may be limited due to the absence of a comparison group, small sample size, and generalizability of the sample. Without a typically developing or other developmentally disabled comparison group, it is difficult to extend results of the study to other populations. A typically developing sample would be especially useful when assessing contextual differences in child joint attention as well as mother dyadic orienting. While this study provides strong evidence that contextual factors are important to consider for children with ASD, more research is necessary, including research utilizing comparison groups to help validate the procedure and draw valid conclusions about how behaviors among children with ASD and their parents may differ from those observed in typical development.

Due to the small sample size, the study may have lacked sufficient statistical power to identify significant associations and group differences. Additionally, post-hoc regression analyses and moderator analyses should be interpreted with caution. While significant results were found, many of the effects were non-significant after controlling for multiple comparisons.

The present study also used the same progression of tasks for each participant. This decision was deliberate to allow for consistency in the study variables when assessing individual differences, however there may have been order effects. For instance, because the competing demands task was presented first, children may have been ignored by their mothers, and these effects could have influenced the child's joint attention in the subsequent tasks. In addition, it could be that if mothers became frustrated during the teaching task, their frustration could influence their interaction in the following free play task. Future work on contextual differences would benefit from counterbalancing task presentation across participants to control for some of the potential order effects.

Study participants were recruited from a self-selected sample of children diagnosed with ASD who attended a therapeutic preschool that provides effective early intervention embedded in nearly all aspects of the child's school day (Selinske, Greer, & Lodhi, 1991). Despite all eligible children in the school receiving a recruitment flyer, most mother participants agreed to participate *after* direct inquiries by school staff members. Children in the sample received related services such as speech and language services, occupational therapy and interventions for ASD at an earlier stage than other children with ASD (e.g. Zablotsky, Colpe, Pringle, Kogan, Rice, & Blumberg, 2017; n= 1287; mean age of diagnosis = 5.23; mean age of first services = 3.90). Thus, families in the sample may be more proactive in their attempts to decrease social and adaptive behaviors related to ASD symptoms in their children, and children in the sample may exhibit better behaviors than other ASD populations.

Given the composition of the sample being limited to children with ASD who attended a specialized therapeutic school, several implications are worthy of consideration. First, parents who seek such intensive early services may be more resourceful and motivated to address their child's developmental delays. Many of these parents may also have resources and means to pursue an intensive therapeutic preschool that may not be financially or otherwise available to other parents. Thus, there may be selection bias toward more competent, socioeconomically advantaged mothers in the present study. Second, children with ASD who are identified at earlier ages tend to present with more significant developmental, behavioral, and communicative delays related to the disorder. Given the fact that children in the present sample attended an intensive applied behavior analysis preschool, the specific targets of intervention at their school – including verbal behavior development, and maladaptive behavioral intervention – may influence the observed joint attention and language abilities of children in the sample, therefore children in the sample may not reflect the full spectrum of ASD.

One strength of this study was its ability to assess for many demographic, child, and mother characteristics, however there were limits to the data collected. Omitted data that may have contributed to the conclusions drawn in the present study include (a) the number and ages of other children in the family; (b) mother's current employment status and occupation; (c) other interventions the child received at school (e.g. speech and language therapy); (d) the target(s) of child intervention at their preschool.

Future Directions

Study 2 informs a number of future directions for research and intervention. First, the study should be expanded to include two typically developing samples, the first matched on chronological age and sex, and the second matched on expressive and receptive language ability and sex. When expanding this research to typically developing samples, it is important to acknowledge the challenges involved in controlling for expressive and receptive language in a typically developing sample as the younger chronological ages necessary to achieve developmental matching may undermine researchers' abilities to rely on the tasks used in the present study. However, important conclusions within the present study could be bolstered with the inclusion of a typically developing sample.

Future studies should more closely examine relations assessed in the present study split by ADOS-2 module groups. Future studies should also continue to explore the role of context on child joint attention, parent-child joint engagement, and parenting behaviors. The present study provides evidence that context matters, but more research is needed to develop this hypothesis. Contextual differences could be utilized to facilitate parent-mediated interventions on child communication and social skills, and possibly offer utility in a variety of other targets of intervention, including play interventions. Future research should compare validated measures of joint attention such as the ESCS (Mundy et al., 1996) alongside joint attention in other contexts to ensure the validity of child behavior. Future research could also identify contexts that require children with ASD to employ effortful control or emotion regulation. For instance, there is evidence that joint attention is related to children's effortful control (e.g. Jahromi, Chen, Dakopolos, & Chorneau, 2019), but assessing how child joint attention is employed within a context that taps on other developmental skills could provide us with a better understanding of development in ASD and TD. Future studies could also parse out joint attention behaviors and focus on how specific aspects of joint attention such as eye contact or pointing relate to mother attention and contextual factors.

Another area of potential future inquiry could identify parent and social partner characteristics that are related to communicative contexts. Differences in parental stress, anxiety and efficacy, for instance, could provide researchers with a better understanding of factors that may promote or impede social communication with children with ASD. In addition, while the number of words spoken by the mother emerged as a meaningful variable, the present study did not address the *quality* of the mother's language, which could be an important dimension of inquiry in future work. Future interventions focusing on child communication and parenting behavior should also consider the social context of interactions when developing their intervention frameworks. Finally, mother age was found to be significantly negatively related to their child's ASD severity, and while it is difficult to speculate on why this association was found, it warrants further investigation.

Conclusion

As the rate of ASD diagnosis in the general population continues to climb, it is imperative that researchers, clinicians, and educators work together to help explain the cognitive and neurological processes at play in ASD symptomology. It is equally, if not more important that we use this knowledge to inform interventions and tools to help children with ASD succeed socially and educationally, and help construct processes and programs that lead to improved quality of life. While many of the deficits observed in individuals with ASD are cognitively based, it is clear that caregivers also play an important role when designing interventions and considering implications on developmental outcomes of children with ASD.

This dissertation sought to extend our understanding of joint attention in ASD relative to child-specific (e.g. sensory responsivity and social attention) and external (e.g. mother behaviors and social context) factors. The results of both Study 1 and Study 2 confirmed their respective hypotheses, that regulation – particularly sensory responsiveness – adversely affects the social attention and social skills of children with ASD compared to their typically developing peers (Study 1), and that children's joint attention would be related to, and moderated by their mother's attention and contextual factors (Study 2). These two studies integrated theoretical perspectives on joint attention, namely the affective model of joint attention (Adamson & Russell, 1999), and the parallel and distributed processing model of joint attention (Mundy & Jarrold, 2010).

Study 1 speaks to the affective model of joint attention (Adamson & Russell, 1999), in that children's regulatory abilities have a strong impact on their joint attention development. Sensory responsiveness may play a role in children's regulation broadly, and the evidence presented in study 1 indicates that sensory responsiveness is related to joint attention, and this relation differs for children with ASD compared to their typically developing peers. Study 2 aligns more closely with the parallel and distributed processing model (Mundy & Jarrold, 2010), which posits that children build their joint attention skill through experience and practice. In Study 2, both mother behavior and contextual factors were related to children's joint attention. It may be that specific behaviors of children's caregivers and contextual factors could promote or discourage children's joint attention development depending on how well those behaviors or contexts nurture opportunities for children to practice joint attention.

Taken as a whole, joint attention development and its skillful use involves complex interactions between individual child factors such as language, effortful control, and emotion regulation, caregiver characteristics and parenting strategies, as well as influences due to demands of the interactive context. While there exists an already strong body of research that addresses many of these topics, the two studies that comprise this dissertation add to the literature by examining how sensory responsiveness and joint attention work together to promote social competence in children with ASD, and by examining how mothers' behaviors may be related to their child's joint attention, and how this relation is moderated by task demands.

Results of the present study indicate that sensory responsiveness may influence the social communication of children with ASD differently than for children with TD; that the language ability of children with ASD may moderate their mother's attentional approaches to social communication with their child; and these social communicative interactions are further moderated by contextual demands exerted upon the dyad. More research is justified to further disentangle how and why joint attention deficits are so pervasive in autism spectrum disorder.

References

Adamson, L. B., & Bakeman, R. (1985). Affect and Attention: Infants Observed with Mothers and Peers. *Child Development*, 56, 582-593.

Adamson, L. B., & Bakeman, R. (1999). Viewing variations in language development: The communication play protocol. *Perspectives on Augmentative and Alternative Communication.* 8, 2–4.

Adamson, L. B., & Bakeman, R. (2006). Development of Displaced Speech in Early Mother-Child Conversations. *Child Development*, 77(1), 186-200.

Adamson, L. B., Bakeman, R. & Deckner, D. F. (2004). The Development of Symbol-Infused Joint Engagement. *Child Development*, 75(4), 1171-1187.

Adamson, L. B., Bakeman, R., Deckner, D. F., & Romski, M. (2009). Joint Engagement and the Emergence of Language in Children with Autism and Down Syndrome. *Journal of Autism and Developmental Disorders*, 39, 84-96.

Adamson, L. B., Bakeman, R., Suma, K., & Robins, D. L. (2017). An Expanded View of Joint Attention: Skill, Engagement, and Language in Typical Development and Autism. *Child Development*, 1-18.

Adamson, L. B., McArthur, D., Markov, Y., Dunbar, B., & Bakeman, R. (2001). Autism and joint attention: Young children's responses top maternal bids. *Applied Developmental Psychology*, 22, 439-453.

Adamson, L. B., & Russell, C. L. (1999). Emotion Regulation and the Emergence of Joint Attention. In P. Rochat (Ed), Early Social Cognition: Understanding Others in the First Months of Life, (281-297), Mahwa, NJ: Psychology Press.

Aldred, C., Green, J., Emsley, R., & McConachie, H. (2012). Brief Report: Mediation of Treatment Effect in a Communication Intervention for Pre-School Children with Autism. *Journal of Autism and Developmental Disorders*, 42, 447-454.

Amarel, C. P., Simones, M. A., Mouga, S., Andrade, J., & Castelo-Branco, M. (2017). A Novel Brain Computer Interface for Classification of Social Joint Attention in Autism and Comparison of 3 Experimental Setups: A Feasibility Study. *Journal of Neuroscience Methods*, 290, 105-115.

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders (DSM-V). American Psychiatric Publishing, Arlington, VA.

Anagnostou, E., Jones, N., Huerta, M., Halladay, A. K., Wang, P., Scahill, L., Horrigan, J. P., Kasari, C., Lord, C., Choi, D., Sullivan, K., & Dawson, G. (2015). Measuring Social Communication Behaviors as a Treatment Endpoint in Individuals with Autism Spectrum Disorder. *Autism*, 19(5), 622-636.

Apicella, F., Chericoni, N., Costanzo, V., Baldini, S., Billeci, L., Cohen, D., & Muratori, F. (2013). Reciprocity in Interactions: A Window on The First Year of Life in Autism. *Autism Research and Treatment*, 1-12.

Bakeman, R. & Adamson, L. (1984) Coordinating attention to people and objects in mother-infant and peer-infant interactions. *Child Development,* 55, 1278– 89.

Baker, A. E. Z., Lane, A., Angley, A. T., & Young R. L. (2008). The Relationship Between Sensory Processing Patterns, and Behavioural Responsiveness in Autistic Disorder: A Pilot Study. *Journal of Autism and Developmental Disorders*, 38, 867-875.

Baldwin, D. A. (1995). Understanding the Link Between Joint Attention and Language. In C. Moore, & P. Dunham (Eds), *Joint Attention: Its Origins and Role in Development* (131-158), New York: Psychology Press.

Baranek, G. T. (1999). Autism During Infancy: A Retrospective Video Analysis of Sensory-Motor and Social Behaviors at 9-12 Months of Age. *Journal of Autism and Developmental Disorders*, 29(3), 213-224.

Baranek, G. T. (1999b). *Sensory Processing Assessment for Young Children (SPA)*. Unpublished manuscript, University of North Carolina at Chapel Hill.

Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive Sensory Patterns in Young Children with Autism, Developmental Delay, and Typical Development. *American Journal on Mental Retardation*, 112(4), 233-245.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory feature in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, 47, 591-601.*

Baranek, G. T., Watson, L. R., Boyd, B. A., Poe, M. D., David, F. J., & McGuire L. (2013). Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. *Development and Psychopathology*, 25, 307-320.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High Functioning Autism, Males, and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders*, 31(1), 5-17.

Baum, S. H., Stevenson, R. A., & Wallace, M. T. (2015). Behavioral, Perceptual, and Neural Alterations in Sensory and Multisensory Function in Autism Spectrum Disorder. *Progress in Neurobiology*, 134, 140-160.

Bayliss, A. P., & Kritikos, A. (2011). Brief Report: Perceptual Load and the Autism Spectrum in Typically Developed Individuals. *Journal of Autism and Developmental Disorders*, 41, 1573-1578.

Bekele, E., Crittendon, J. A., Swanson, A, Sarkar, N., & Warren, Z. E. (2014). Pilot Clinical Application of an Adaptive Robotic System for Young Children with Autism. *Autism*, 18(5), 598-608.

Bekele, E., Lahiri, U., Swanson, A. R., Crittendon, J. A., Warren, Z. E., & Sarkar, N. (2013). A Step Towards Developing Adaptive Robot-Mediated Intervention Architecture (ARIA) for Children with Autism. *IEEE Trans Neural System Rehabilitation Engineering*, 21(2), 1-31.

Belmonte, M.K., Cook, E.H., Anderson, G.M., Rubenstein, J. R.L., Greenough, W.T., Beckel-Mitchener, A., Courchesne, E., Boulander, L.M., Powell, S.B., Levitt, P.R., Perry, E.K., Jiang, Y.H., DeLorey, T.M., & Tierney, E. (2004). Autism as a disorder of neural information processing: Directions for research and targets for therapy. *Molecular Psychiatry*, 9, 646-663.

Belmonte, M., & Yurgelun-Todd, D. (2003). Functional anatomy of impaired selective attention and compensatory processing in autism. *Cognitive Brain Research*, 17(3), 651–664.

Belsky, J., Crnic, K. A., & Woodworth, S. (1995). Personality and Parenting: Exploring the Mediating Role of Transient Mood and Daily Hassles. *Journal of Personality*, 63, 905-929.

Ben-Sasson, A., Carter, A. S., & Briggs-Gowan, M. J. (2010). The Development of Sensory Over-Responsivity from Infancy to Elementary School. *Journal of Abnormal Child Psychology*, 38(8), 1193-1202.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society*, 57(1), 289-300.

Blachet, J., Baker, B. L., & Kaladjian, A. (2013) Syndrome Specificity and Mother-Child Interactions: Examining Positive and Negative Parenting Across Contexts and Time. *Journal of Autism and Developmental Disorders*, 43, 761-774.

Bottema-Beutel, K. (2016). Associations Between Joint Attention and Language in Autism Spectrum Disorder and Typical Development: A Systematic Review and Meta-Regression Analysis. *Autism Research*, 9, 1021-1035.

Bottema-Beutel, K., Yoder, P., Hochman, J., & Watson, L. (2014). The role of supported joint engagement and parent utterances in language and social communication development in children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders,* 44, 2162-2174.

Boyd, B. A., Baranek, G. T., Sideris, J., Poe, M. D., Watson, L. R., Patten, E., & Miller, H. (2010) Sensory features and repetitive behaviors in children with autism and developmental delays. *Autism Research*, 3(2), 78-87.

Boyd, B. A., McBee, M., Holtzclaw, T., Baranek, G. T., & Bodfish, J. W. (2009). Relationships among repetitive behaviors, sensory features, and executive functions in high functioning autism. *Research in Autism Spectrum Disorders*, 3(4), 959–966.

Brandwein, A. B., Foxe, J. J., Butler, J. S., Frey, H-P., Bates, J. C., Shulman, L. H., & Molholm, S. (2015). Neurophysiological indices of atypical auditory processing and multisensory integration are associated with symptom severity in autism. *Journal of Autism and Developmental Disorders*, 45, 230-244.

Brock, M. E., Frueler, A., Baranek, G. T., Watson, L. R., Poe, M. D., & Sabatino, A. (2012). Temperament and Sensory Features of Children with Autism. *Journal of Autism and Developmental Disorders*, 42, 2271-2284.

Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In R. M. Lerner (Ed.) *Handbook of child development: Vol. 1. Theoretical models of human development* (6th ed., pp. 793 – 828). Hoboken, NJ: Wiley.

Campbell, D. J., Shic, F., Macari, S., & Chawarska, K. (2014). Gaze Response to Dyadic Bids at 2 Years Related to Outcomes at 3 Years in Autism Spectrum Disorders: A Subtype Analysis. *Journal of Autism and Developmental Disorders*, 44(2), 431-442.

Casenhiser, D. M., Binns, A., McGill, F., Morderer, O., & Shanker, S. G. (2014). Measuring and Supporting Language Function for Children with Autism: Evidence from a Randomized Control Trial of a Social-Interaction-Based Therapy. *Journal of Autism and Developmental Disorders*, 45(3), 846-857.

Charman, T. (2003). Why is Joint Attention a Pivotal Skill in Autism? *Philosophical Transactions: Biological Sciences,* 358(1430), 31-324.

Chawarska, K., Klin, A., Paul, R., Macari, S., & Volkmar, F. (2009). A Prospective Study of Toddlers with ASD: Short-Term Diagnostic and Cognitive Outcomes. *Journal of Child Psychology and Psychiatry,* 50(10), 1235-1245.

Chawarska, K., Ye, S., Shic, F., & Chen, L. (2016). Multilevel Differences in Spontaneous Social Attention in Toddlers with Autism Spectrum Disorder. *Child Development*, 87(2), 543-557.

Chen, Y. H., Rodgers, J., & McConachie, H. (2009). Restricted and repetitive behaviours, sensory processing and cognitive style in children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 39, 653-642.

Cheng, Y., & Huang, R. (2012). Using Virtual Reality Environment to Improve Joint Attention Associated with Pervasive Developmental Disorder. *Research in Developmental Disabilities*, 33, 2141-2152.

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Science*, 16(4), 231-239.

Chiang, C., Soong, W., Lin, T., & Rogers, S. J. (2008). Nonverbal Communication Skills in Young Children with Autism. *Journal of Autism and Developmental Disorders*, 38, 1898-1906.

Ciciolla, L., Crnic, K. A., & West, S. G. (2013). Determinants of Change in Maternal Sensitivity: Contributions of Context, Temperament, and Developmental Risk. *Parenting Science and Practice*, 13(3), 178-195.

Clifford, S. M., & Dissanayake, C. (2008). The Early Development of Joint Attention in Infants with Autistic Disorder Using Home Video Observations and Parental Interview. *Journal of Autism and Developmental Disorders*, 38, 791-805.

Constantino, J. N., & Gruber, C. P. (2005). Social Responsiveness Scale (SRS). Western Psychological Services.

Corkum, V., & Moore, C. (1995). Development of Joint Visual Attention in Infants. In C. Moore, & P. Dunham (Eds), *Joint Attention: Its Origins and Role in Development* (61-84), New York: Psychology Press.

Courchesne, E., & Pierce, K. (2005). Why the frontal cortex in autism might be talking only to itself: Local over-connectivity but long- distance disconnection. *Current Opinion in Neurobiology*, 15(2), 225–230.

Courgeon, M., Rautureau, G., Martin, J-C, & Grynszpan, O. (2014). Joint Attention Simulation Using Eye Tracking and Virtual Humans. *IEEE Transactions on Affective Computing*, 5(3), 238-250.

Daglarli, E., Daglarli, S. F., Gunel, G. U., & Kose, H. (2017). Improving Human-Robot Interaction Based on Joint Attention. *Applied Intelligence*, 47, 62-82.

Dawson, G. (2008). Early behavioral intervention, brain plasticity, and the prevention of autism spectrum disorder. *Development and Psychopathology*, 20, 775-803.

Dawson, G., & Bernier, R. (2013). A quarter century of progress on the early detection and treatment of autism spectrum disorder. *Development and Psychopathology*, 25(4), 1455-1472.

Dawson, G., Bernier, R., & Ring, R. H. (2012). Social Attention: A Possible Early Indicator of Efficacy in Autism Clinical Trials. *Journal of Neurodevelopmental Disorders*, 4(11), 1-12.

Dawson, G., Hill, D., Spencer, A., Galpert, L., & Watson, L. (1990). Affective Exchange Between Young Autistic Children and their Mothers. *Journal of Abnormal Child Psychiatry*, 18(3), 335-345.

Dawson, G., Munson, J., Estes, A., Osterling, J., McPartland, J., Toth, K., Carver, L. & Abbott, R. (2002). Neurocognitive Function and Joint Attention Ability in Young Children with Autism Spectrum Disorder Versus Developmental Delay. *Child Development,* 73, 345–58.

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early Social Attention Impairments in Autism: Social Orienting, Joint Attention, and Attention to Distress. *Developmental Psychopathology,* 40(2), 271-283.

Dawson, G., Webb, S. J., Wijsman, E., Schellenberg, G., Estes, A., Munson, J., & Faja, S. (2005). Neurocognitive and Electrophysiological Evidence of Altered Face Processing in Parents of Children with Autism: Implications for a Model of Abnormal Development of Social Brain Circuitry in Autism. *Development and Psychopathology*, 17, 679-697.

DeGangi, G. A., & Greenspan, S. L. (1989). The Development of Sensory Functions in Infants. *Physical and Occupational Therapy in Pediatrics*, 8(4), 21-33.

Doussard-Roosevelt, J. A., Joe, C. M., Bazhenova, O. V., & Porges, S. W. (2003). Mother-child interaction in autistic and non-autistic children: Characteristics of maternal approach behaviors and child social responses. *Development and Psychopathology*, 15, 277-295.

Drew, A., Baird, G., Taylor, E., Milne, E., & Charman, T. (2006). The Social Communication Assessment for Toddlers with Autism (SCATA): An Instrument to Measure the Frequency, Form and Function of Communication in Toddlers with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 37(4), 648-666.

Dunham, P. J., & Dunham, F. (1995). Optimal Social Structures and Adaptive Infant Development. In C. Moore, & P. Dunham (Eds), *Joint Attention: Its Origins and Role in Development* (159-188), New York: Psychology Press.

Dunn, W. (1997). The Impact of Sensory Processing Abilities on the Daily Lives of Young Children and their Families: A Conceptual Model. *Infants and Young Children*, 9(4), 23-35.

Dunn, W. (1999). *The Sensory Profile: User's manual*. San Antonio, TX: Psychological Corporation.

Dunn, W. (2001). The sensations of everyday life: Empirical, theoretical, and pragmatic considerations, 2001 Eleanor Clarke Slagle lecture. *American Journal of Occupational Therapy*, 55, 608-620.

Dunn, W., Little, L., Dean, E., Robertson, S., & Evans, B. (2016). The State of the Science on Sensory Factors and their Impact on Daily Life for Children: A Scoping Review. *OTJR: Occupation, Participation and Health*, 36(2S), 3S-26S.

Eisenberg, N., Vidmar, M., Spinrad, T. L., Eggum, N. D., Edwards, A., Gaertner, B., & Kupfer, A. (2010). Mother's Teaching Strategies and Children's Effortful Control: A Longitudinal Study. *Developmental Psychopathology*, 46(5), 1294-1308.

Ellawadi, A. B., & Weismer, S. E. (2014). Assessing Gestures in Young Children with Autism Spectrum Disorder. *Journal of Speech, Language, and Hearing Research*, 57, 524-531.

Elliott, C. D. (2007). *Differential Ability Scales*. San Antonio, TX: The Psychological Corporation.

Fenson, L,. Marchman, V. A., Thal, D., Dale, P. S., Reznick, J. S., & Bates, E. (2006) MacArthur-Bates Communicative Development Inventories: User's Guide and Technical Manual 2nd Ed., Baltimore, MD: Brookes Publishing.

Ferri, R., Elia, M., Agarwal, N., Lanuzza, B., Musumeci, S.A., & Pennisi, G. (2003). The mismatch negativity and the P3a components of the auditory event-related potentials in autistic low-functioning subjects. *Clinical Neurophysiology*, 114, 1671–1680.

Fey, M. E., Warren, S. F., Brady, N., Finestack, L. H., Bredin-Oja, S. L., Fairchild, M., Sokol, S., & Yoder, P. J. (2006). Early Effects of Responsivity Education/Prelinguistic Milieu Teaching for Children with Developmental Delays and their Parents. *Journal of Speech, Language, and Hearing Research*, 49, 526-547.

Fletcher-Watson, S., Leekam, S. R., Benson V., Frank, M. C., & Findlay, J. M. (2009). Eye-Movements Reveal Attention to Social Information in Autism Spectrum Disorder. *Neuropsychologia*, 47(1), 248-257.

Fogel, A., De Koeyer, I., Bellagamba, F., & Bell, H. (2002). The dialogical self in the first two years of life: Embarking on a journey of discovery. *Special Issue on the Dialogical Self in Theory & Psychology, 12,* 191–205.

Glod, M., Riby, D. M., Honey, E., & Rodgers, J. (2015). Psychological Correlates of Sensory Processing Patterns in Individuals with Autism Spectrum Disorder: A Systematic Review. *Review Journal of Autism and Developmental Disorders*, 2, 199-221.

Green, S. A., Rudie, J. D., Colich, N. L., Wood, J. J., Shirinyan, D., Hernandez, C.L., Tottenham, N., Dapretto, M., & Bookheimer, S. Y. (2013). Overreactive Brain Responses to Sensory Stimuli in Youth with Autism Spectrum Disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 52(11), 1158-1172.

Greer, R. D. (2008). The ontogenetic selection of verbal capabilities: Contributions of Skinner's verbal behavior theory to a more comprehensive understanding of language. *International Journal of Psychology and Psychological Therapy*, 8(3), 363–386.

Greer, R. D., & Longano, J. (2010). A Rose by Naming: How We May Learn How to Do It. *The Analysis of Verbal Behavior*, 26, 73-106.

Greer, R. D., Pohl, P., Du, L., & Moschella, J. L. (2017). The Separate Development of Children's Listener and Speaker Behavior and the Intercept as Behavioral Metamorphosis. *Journal of Behavioral and Brain Science*, 7, 674-704.

Greer, R. D., & Speckman, J. (2009). The integration of speaker and listener responses: A theory of verbal development. *The Psychological Record*, 59, 449–488.

Grzadzinski, R., Huerta, M., & Lord, C. (2013). DSM-5 and Autism Spectrum Disorders (ASDs): an o\Opportunity for Identifying ASD Subtypes. *Molecular Autism,* 4(12), 1-6.

Guillon, Q., Hadjikhani, N., Baduel, S., & Roge, B. (2014). Visual Social Attention in Autism Spectrum Disorder: Insights from Eye Tracking Studies. *Neuroscience & Behavioral Reviews*, 24, 279-297.

Gulsrud, A. C., Helleman, G., Shire, S., & Kasari, K. (2016). Isolating Active Ingredients in a Parent-Mediated Social Communication Intervention for Toddlers with Autism Spectrum Disorder. *Journal of Child Psychology and Psychiatry*, 57(5), 606-613.

Gulsrud, A., Jahromi, L. B., & Kasari, K. (2010). The Co-Regulation if Emotions Between Mothers and their Children with Autism. *Journal of Autism and Developmental Disorders*, 40, 227-237.

Hart, B., & Risley, T. R. (1999). *The Social World of Children Learning to Talk*. Baltimore, MD: Paul H Brooks Publishing.

Hill, E. L. (2004). Evaluating the Theory of Executive Dysfunction in Autism. *Developmental Review,* 24(2), 189-233.

Hilton, C., Graver, K., & La Vesser, P. (2007). Relationship Between Social Competence and Sensory Processing in Children with High Functioning Autism Spectrum Disorders. *Research in Autism Spectrum Disorders*, 1, 164-173.

Hilton, C. L., Harper, J. D., Kueker, R. H., Lang, A. R., Abbacci, A. M., Todorov, A., & LaVesser, P. D. (2010). Sensory Responsiveness as a Predictor of Social Severity in Children with High Functioning Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders,* 40, 937-945.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior*, 65, 185–241.

Ingersoll, B. (2008). The Effect of Context on Imitation Skills in Children with Autism. *Research in Autism Spectrum Disorders*, 2, 332-340.

Jahromi, L.B., Chen, P., Dakopolos, A. J., & Chorneau, A. (2019). Delay of Gratification in Preschoolers with and without Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Emotion Regulation, and Joint Attention. *Autism*, 1-12.

Jahromi, L. B., Green, J., Dakopolos, A. J., & Kirkman, K. (2018) Parental Control and Directiveness within the Play Interactions of Preschoolers with Autism: Links to Child Interest and Child-Directed Play. IN PRESS.

Jahromi, L. B., Kasari, C. L., McCracken, J. T., Lee, L. S-Y., Aman, M. G., McDougle, C. J., Scahill, L., Tierney, E., Arnold, L. E., Vitiello, B., Ritz, L., Witwer, A., Kustan, E., Ghuman, J., & Posey, D. J. (2009). Positive Effects of Methylphenidate on Social Communication and Self-Regulation in Children with Pervasive Developmental Disorders and Hyperactivity. *Journal of Autism and Developmental Disorders*, 39, 395-404.

Jones, E., & Carr, E. G. (2004). Joint attention in children with autism theory and Intervention. *Focus on Autism and Other Developmental Disabilities, 19*(1),13-26.

Kargas, N., Lopez, B., Reddy, V., & Morris, P. (2014). The Relationship Between Auditory Processing and Restricted, Repetitive Behaviors in Adults with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 45, 658-668.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint Attention and Symbolic Play in Young Children with Autism: A Randomized Controlled Intervention Study. *Journal of Child Psychology and Psychiatry*, 47(6), 611-620.

Kasari, C., Freeman, S., Paparella, T., Wong, C., Kwon, S., & Gulsrud, A. (2005). Early Intervention on Core Deficits in Autism. *Clinical Neuropsychiatry*, 2(6), 380-388.

Kasari, C., Gulsrud, A., Freeman, S., Paparella, T., & Hellemann, G. (2012). Longitudinal Follow-Up of Children with Autism Receiving Targeted Interventions on Joint Attention and Play. *Journal of the American Academy of Child and Adolescent Psychiatry*, 51(5), 487-495.

Kasari, C., Gulsrud, A., Paparella, T., Hellemann, G., & Berry, K. (2015). Randomized Comparative Efficacy Study of Parent-Mediated Interventions for Toddlers with Autism. *Journal of Consulting and Clinical Psychology*, 83(3), 554-563.

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. B. (2008). Language Outcome in Autism: Comparison of Joint Attention and Play Interventions. *Journal of Consulting and Clinical Psychology*, 76(1), 125-137.

Kasari, C., Rotheram-Fuller, E., Locke, J., & Gulsrud, A. (2011). Making the Connection: Randomized Control Trail of Social Skills at School for Children with Autism Spectrum Disorders. *The Journal of Child Psychology and Psychiatry*, 53(4), 431-439.

Kasari, C., Sigman, M., Mundy, P., & Yirmiya, N. (1988). Caregiver Interactions with Autistic Children. *Journal of Abnormal Child Psychology*, 16(1), 45-56.

Kasari, C., Sigman, M., Mundy, P., & Yirmiya, N. (1990). Affective Sharing in the Context of Joint Attention Interactions of Normal, Autistic, and Mentally Retarded Children. *Journal of Autism and Developmental Disorders*, 20(1), 87-100.

Kasari, C., Siller, M., Huynh, L. N., Shih, W., Swanson, M., Hellemann, G. S., & Sugar, C. A. (2014). Randomized controlled trial of parental responsiveness intervention for toddlers at high risk for autism. *Infant Behavior Development*, 37(4), 711-721.

Kenworthy, L., Yerey, B. E., Anthony, L. G., & Wallace, G. L. (2008). Understanding Executive Control in Autism Spectrum Disorders in the Lab and in the Real World. *Neuropsychologic Review*, 18(4), 320-338.

Kern, J. K., Trivedi, M. H., Garver, C. R., Grannemann, B. D., Andrews, A. A., Salva, J. S., Johnson, D. G., Mehta, J. A., & Schroeder, J. L. (2006). The pattern of sensory processing abnormalities in autism. *Autism*, 10(5), 480-494.

Konstantareas, M. M., Zajdeman, H., Homatidis, S., & McCabe, A. (1988). Maternal Speech to Verbal and Higher Functioning Versus Nonverbal and Lower Functioning Autistic Children. *Journal of Autism and Developmental Disorders*, 18(4), 647-656.

Krug, D. A., Arick, J., & Almond, P. (1980). Behavior Checklist for Identifying Severely Handicapped Individuals with High Levels of Autistic Behavior. *Journal of Child Psychology and Psychiatry*, 21, 221–229.

Ladd, G. W. (2005). *Children's Peer Relations and Social Competence: A Century of Progress*, New Haven, CT: Yale University Press.

Ladd, G. W., & Profilet, S. (1996). The child behavior scale: A teacher-report measure of young children's aggressive, withdrawn, and prosocial behavior. *Developmental Psychology*, 32, 1008–1024.

Laird, N. M., & Ware, J. H. (1982). Random Effects Models for Longitudinal Data. *Biometrics*, 38(4), 963-974.

Leekam, S. R., Lopez, B., & Moore, C. (2000). Attention and Joint Attention in Preschool Children with Autism. *Developmental Psychology*, 36(2), 261-273.

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2006). Describing the Sensory Abnormalities of Children and Adults with Autism. *Journal of Autism and Developmental Disorders*, 37, 894-910.

Leekam, S. R., Prior, M. R., & Uljarevic, M. (2011). Restricted and Repetitive Behaviors in Autism Spectrum Disorders: A review of research in the past decade. *Psychological Bulletin*, 137(4), 562-593.

Leekam, S. R., & Ramsden, C. A.H. (2006). Dyadic Orienting and Joint Attention in Preschool Children with Autism. *Journal of Autism and Developmental Disorders*, 36(2), 185-197.

Liss, M., Sauliner, C., Fein, D., & Kinsbourne, M. (2006). Sensory and attention abnormalities in autistic spectrum disorders. *Autism*, 10(2), 155-172.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (2002). *The Autism Diagnostic Observation Scale (ADOS)*. Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism Diagnostic Observation Schedule: ADOS-2*. Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 24, 659–685.

MacDonald, R., Anderson, J., Dube, W. V., Geckeler, A., Green, G., Holcomb, W., Mansfeld, R., & Sanchez, J. (2006). Behavioral Assessment of Joint Attention: A Methodological Report. *Research in Developmental Disabilities*, 27, 138-150.

Marco, E. J., Hinkley, L. B.N., Hill, S. S., & Nagarajan, S. S. (2011). Sensory Processing in Autism: A Review of Neuropsychologic Findings. *Pediatric Research*, 69(5), 48-54.

Mazefsky, C. A., Herrington, J., Siegel, M., Scarpa, A., Maddox, B. B., Scahill, L., & White, S, W. (2013). The Role of Emotion Regulation in Autism Spectrum Disorder. *Journal of American Academy of Child and Adolescent Psychiatry*, 52(7), 679-688.

McDuffie, A., & Yoder, P. (2010). Types of Parental Verbal Responsiveness that Predict Language in Young Children with Autism Spectrum Disorder. *Journal of Speech, Language, and Hearing Research*, 53, 1026-1039.

McEvoy, R. E., Rogers, S. J., & Pennington, B. F. (1993). Executive Function and Social Communication Deficits in Young Autistic Children. *Journal of Child Psychology & Psychiatry & Allied Disciplines*, 34, 563–578.

Meek, S. E., Robinson, L, T., & Jahromi, L. B. (2012). Parent-child predictors of social competence with peers in children with and without autism. *Research in Autism Spectrum Disorders*, 6(2012), 815-823.

Meltzoff, A. N., & Brooks, R. (2008). Self-experience as a mechanism for learning about others: A training study in social cognition. *Developmental Psychology, 44*(5), 1257-1265.

Miller, C. A. (2006). Developmental Relationships Between Language and Theory of Mind. *American Journal of Speech-Language Pathology*, 15, 142-154.

Miller, S. E., & Marcovitch, S. (2015). Examining Executive Function in the Second Year of Life: Coherence, Stability, and Relations to Joint Attention and Language. *Developmental Psychology*, 51, 101-114.

Minshew, N. J., & Hobson, J. A. (2008). Sensory sensitivities and performance on sensory perceptual tasks in high-functioning individuals with autism. *Journal of Autism and Developmental Disorders*, 38(8), 1485-1498.

Morales, M., Mundy, P., Crowsen, M. M., Neal, R. A., & Delgado, C. E. F. (2005). Individual differences in infant attention skills, joint attention, and emotion regulation behaviour. *International Journal of Behavior Development*, 29(3), 259-263.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., & Burack, J. (2006). Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception. *Journal of Autism and Developmental Disorders*, 36(1), 27-43.

Mundy, P. (1995). Joint Attention and Social Emotional Approach Behavior in Children with Autism. *Development and Psychopathology*, 7, 63-82.

Mundy, P. (2016). *Autism and Joint Attention*, New York: The Guilford Press.

Mundy, P., Block, J., Delgado, C., Pomares, Y., Vaughan Van Hecke, A., & Parlade, M. V. (2007). Individual Differences and the Development of Joint Attention in Infancy. *Child Development*, 78(3), 938-954.

Mundy, P., & Crowson, M. Joint attention and early social communication: Implications for research on intervention with autism. *Journal of Autism and Developmental Disorders*, 27(6), 653-676.

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *A manual for the abridged early social communication scales (ESCS).*

Mundy, P., & Gomes, A. (1997). A Skill Approach to Early Language Development: Lessons from Research on Developmental Disabilities. In L. Adamson & M. Romski (Eds.), *Research on communication and language disorders: Contributions to theories of language development* (107–132). New York: Paul Brooks Publishing.

Mundy, P., & Gomes, A. (1998). Individual Differences in Joint Attention Skill Development in the Second Year. *Infant Behavior and Development*, 21(3), 469-482.

Mundy P., Hogan A., & Doehring, P. (1996) Early social communication scales (ESCS): A preliminary manual for the abridged.

Mundy, P, & Jarrold, W. Infant Joint Attention, Neural Networks, and Social Cognition. *Neural Networks,* 23, 985-997.

Mundy, P., & Newell, L. (2007). Attention, Joint Attention, and Social Cognition. *Current Directions in Psychological Science*, 16(5), 269-274.

Mundy, P., Sigman, M., & Kasari, C. (1990). A Longitudinal Study of Joint Attention and Language Development in Autistic Children. *Journal of Autism and Developmental Disorders*, 20(1), 115-128.

Mundy, P., Sigman, M., & Kasari, C. (1994). Joint Attention, Developmental Level, and Symptom Presentation in Autism. *Development and Psychopathology,* 6, 389-401.

Mundy, P., Sigman, M., Kasari, C., & Baron-Cohen, S. (Ed); Tager-Flusberg, H. (Ed), Cohen, D.J. (Ed). (1994). Understanding other minds: Perspectives from autism, (pp. 181-203). New York, NY, US: Oxford University Press.

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the Social Deficits of Autism: The Contribution of Non-Verbal Communication Measures. *The Journal of Child Psychology and Psychiatry*, 27(5), 657-669.

Mundy, P. & Willoughby, J. (1996). Nonverbal communication, joint attention, and early-socioemotional development. In M. Lewis & M. Sullivan (Eds.), *Emotional Development in Atypical Children*, (pp 65 – 87). New York, New York: Wiley Publications.

Naber, F. B.A., Bakermans-Kranenburg, M. J., van Ijzendoorn, M. H., Dietz, C., van Daalen, E., Swinkels, S. H.N., Buitelaar, J. K., & van Engeland, H. (2008). Joint Attention Development in Toddlers with Autism. *European Child and Adolescent Psychiatry*, 17, 143-152.

Nelson, P. B., Adamson, L. B., & Bakeman, R. (2008). Toddlers' Joint Engagement Experience Facilitates Preschoolers' Acquisition of Theory of Mind. *Developmental Science*, 11(6), 847-852.

Nichols, K. E., Martin, J. E., & Fox, N. A. (2005). Individual Differences in the Development of Social Communication: Joint Attention and Temperament. *Cognition, Brain, Behavior*, IX (3), 317-328.

O'Connor, K., & Kirk, I. (2008). Brief Report: Atypical Social Cognition and Social Behaviours in Autism Spectrum Disorder: A Different Way of Processing Rather than an Impairment. *Journal of Autism and Developmental Disorders*, 38, 1989-1997.

Osterling, J., & Dawson, G. (1994). Early Recognition of Children with Autism: A Study of First Birthday Home Videotapes. *Journal of Autism and Developmental Disorders*, 24, 247–257.

Osterling, J. A., Dawson, G., & Munson, J. A. (2002) Early Recognition of 1-year-old Infants with Autism Spectrum Disorder Versus Mental Retardation. *Developmental Psychopathology*, 14, 239–251.

Parrinello, R. M., & Ruff, H. A. (1988). The Influence of Adult Intervention on Infant's Level of Attention. *Child Development*, 59, 1125-1135.

Patten, E., Ausderau, K.K., Watson, L., & Baranek, G.T. (2013). Sensory Response Patterns in Nonverbal Children With ASD. *Autism Research and Treatment*, (2013), 1-9.

Raver, C. C. (1996). Relations between Social Contingency in Mother-Child Interaction and 2-Year-Old's Social Competence. *Developmental Psychology*, 32(2), 850-859.

Robertson, A. E., & Simmons, D. R. (2013). The Relationship Between Sensory Sensitivity and Autistic Traits in the General Population. *Journal of Autism and Developmental Disorders*, 43(4), 775-784.

Rogers, S. J., Estes, A., Lord, C,. Vismara, L., Winter, J., Fitzpatrik, A., Guo, M., & Dawson, G. (2012). Effects of a Brief Early Start Denver Model (EDSM)-Based Parent Intervention on Toddlers at Risk for Autism Spectrum Disorders: A Randomized Controlled Trial. *Journal of American Academy of Child and Adolescent Psychiatry*, 51(10), 1052-1065.

Roos, E. M., McDuffie, A. S., Weissmer, S. E., & Gernsbacher, M. A. (2008). A comparison of contexts for assessing joint attention in toddlers on the autism spectrum. *Autism*, 12(3), 275-291.

Sanchez-Marin F. J., & Padilla-Medina J. A. (2008). A psychophysical test of the visual pathway of children with autism. *Journal of Autism and Developmental Disorders*, 38:1270–1277.

Schietecatte, I., Roeyers, H., & Warreyn, P. (2012). Exploring the nature of joint attention impairments in young children with spectrum disorder: associated social and cognitive skills. *Journal of Autism and Developmental Disorders*, *42*(1), 1-12.

Selinske, J. E., Greer, R. D., & Lodhi, S. (1991). A functional analysis of the comprehensive application of behavior analysis to schooling. *Journal of Applied Behavior Analysis*, *24*(1), 107-117.

Sheinkopf, S. J., Mundy, P., Claussen, A. H., & Willoughby, J. (2004). Infant joint attention skill and preschool behavioral outcomes in at-risk children. *Development and Psychopathology*, 16(2004), 273-291.

Siller, M., & Sigman, M. (2002). The Behaviors of Parents of Children with Autism Predict the Subsequent Development of their Children's Communication. *Journal of Autism and Developmental Disorders*, 32(2), 77-89.

Siller, M., & Sigman, M. (2008). Modeling Longitudinal Change in the Language Abilities of Children with Autism: Parent Behaviors and Child Characteristics as Predictors of Change. *Developmental Psychology*, 44(6), 1691-1704.

Sigman, M., & Kasari, C. (1995). Joint Attention Across Contexts in Normal and Autistic Children. In C. Moore, & P. Dunham (Eds), *Joint Attention: Its Origins and Role in Development* (189-203), New York: Psychology Press.

Sigman, M., Kasari, K., Kwon, J., & Yirmiya, N. (1992) Responses to the Negative Emotions of Others by Autistic, Mentally Retarded, and Normal Children. *Child Development*, 63(4), 796-807.

Skinner, B. F. (1957). Verbal behavior. Acton, MA: Copley.

Smith, L. B., & Thelen, E. (1993). Can Dynamic Systems Theory Be Usefully Applied in Areas Other than Motor Development? In E. Smith, & LB Thelen (Eds), *A Dynamic Systems Approach to Development: Applications*, Cambridge, MA: MIT Press.

Sparrow, S. S., Cicchetti, D., & Saulnier, C.A. (2016). *Vineland Adaptive Behavior Scales- Third edition manual.* Minneapolis: NCS Pearson Inc.

Starvopoulos, K. K. M., & Carver, L. J. (2013). Research Review: Social motivation and oxytocin in autism – Implications for joint attention development and intervention. *Journal of Child Psychology and Psychiatry*, 54(6), 603-618.

Stone, W. L., Coonrod, E. E., & Ousley, O. Y. (2000). Brief Report: Screening Tool for Autism in Two-Year-Olds (STAT): Development and Preliminary Data. *Journal of Autism and Developmental Disorders*, 30(6), 607-612.

Sullivan, L., Mundy, P., & Mastergeorge, A. M. (2015). Joint Attention in Preschool Children: Is it a Meaningful Measure? *International Journal of School and Cognitive Psychology*, 2(1), 1-8.

Taylay-Ongan, A., & Wood, K. (2000). Unusual Sensory Sensitivities in Autism: A Possible Crossroads. *International Journal of Disability, Development, and Education*, 47(2), 201-212.

Thelen, E., & Smith, L. B. (1994). A Dynamic Systems Approach to the Development of Perception and Action. Cambridge, MA: MIT Press.

Tomasello, M. (1995). Joint Attention as Social Cognition. In C. Moore, & P. Dunham (Eds), *Joint Attention: Its Origins and Role in Development* (103-130), New York: Psychology Press.

Tomasello, M. (2010). A Focus on Infrastructure. *Origins of Human Communication.* Cambridge, MA: MIT Press.

Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders*, 36, 993-1005.

Travis, L., Sigman, M., & Ruskin, E. (2001). Links between social understanding and social behavior in verbally able children with autism. Journal of Autism and Developmental Disorders, 31(2), 119–130.

Tronick, E. Z. (1989). Emotions and Emotional Communications in Infants. *American Psychologist*, 44(2), 112-119.

Ungerer, J. A., & Sigman, M. (1981). Symbolic Play and Language Comprehension in Autistic Children. *Journal of the American Academy of Child Psychiatry*, 20(2), 318-337.

Van der Paelt, S., Warreyn, P., & Roeyers, H. (2014). Social-communicative abilities and language in preschoolers with autism spectrum disorders: Associations differ depending on language age. *Research in Autism Spectrum Disorders*, 8, 518–528.

Van Eylen, L., Boets, B., Steyaert, J., Wagemans, J., & Hoens, I. (2015). Executive functioning in autism spectrum disorders: Influence of task and sample characteristics and relation to symptom severity. *European Child and Adolescent Psychiatry*, 24, 1339-1417.

Vaughan, A., Mundy, P. C., Acra, C. F., Block, J. J., Delgado, C. E. F., Parlade, M. V., Meyer, J, A., Neal, R. A., & Pomares, Y B. (2007). Infant Joint Attention, Temperament, and Social Competence in Preschool Children. *Child Development*, 78(1), 53-69.

Vaughan, A., Mundy, P., Block, J., Burnette, C., Delgado, C., Gomez, Y., Meyer, J., Neal, Y., & Pomares, Y. (2003). Child, Caregiver, and Temperament Contributions to Infant Joint Attention. *Infancy*, 4(4), 603-616.

Vaughan van Hacke, A., Mundy, P., Block, J. J., Delgado, C. E.F., Parlade, M. V., Pomares, Y. B., & Hobson, J. A. (2012). Infant Responding to Joint Attention, Executive Processes, and Self-Regulation in Preschool Children. *Infant Behavior and Development*, 35, 303-311.

Watson, L. R., Patten, E., Baranek, G. T., Poe, M., Boyd, B. A., Freuler, A., & Lorenzi, J. (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. *Journal of Speech, Language, and Hearing Research*, 54, 1562-1576.

Watt, N., Wetherby, A. M., Barber A., & Morgan, L. (2008). Repetitive and stereotyped behaviors in children with autism spectrum disorders in the second year of life. *Journal of Autism and Developmental Disabilities*, 38, 1518-1533.

Werner, E., Dawson, G., Osterling, J., & Dinno, N. (2000). Brief Report: Recognition of Autism Spectrum Disorder Before One Year of Age: A Retrospective Study Based on Home Videotapes. *Journal of Autism and Developmental Disorders*, 30, 157-162.

Wetherby, A. M., & Prizant, B. M. (1993). *Communication and symbolic behavior scales: Manual*. Riverside Publishing.

Wiggins, L. D., Robins, D. L., Bakeman, R., & Adamson, L. B. (2009). Brief Report: Sensory Abnormalities as Distinguishing Symptoms of Autism Spectrum Disorders in Young Children. *Journal of Autism and Developmental* Disorders, 39, 1087-1091.

Yoder, P. j., & Warren S. F. (1999). Maternal responsivity mediates the relationship between prelinguistic intentional communication and later language. *Journal of Early Intervention*, 22(6),126-136.

Zablotsky, B., Colpe, L. J., Pringle, B. A., Kogan, M. D., Rice, C., & Blumberg, S. J. (2017). Age of parental concern, diagnosis, and service initiation among children with autism spectrum disorder. *American Journal on Intellectual and Developmental Disabilities, 122*(1), 49-61,93-96.

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2002). Preschool language scale (PLS). The Psychological Corporation.

Appendix A: IRB Approval

TEACHERS COLLEGE
COLUMBIA UNIVERSITY

Teachers College IRB — *Exempt Study Approval*

To: Andrew Dakopolos
From: Myra Luna-Lucero, Research Compliance Manager
Subject: IRB Approval: 18-348 Protocol
Date: 05/13/2018

Thank you for submitting your study entitled, "*Child and Contextual Factors Related to Joint Attention in Children with Autism*;" the IRB has determined that your study is **Exempt** from committee review (Category **4**) on 05/13/2018.

Please keep in mind that the IRB Committee must be contacted if there are any changes to your research protocol. The number assigned to your protocol is **18-348**. Feel free to contact the IRB Office by using the "Messages" option in the electronic Mentor IRB system if you have any questions about this protocol.

You can retrieve a PDF copy of this approval letter from the Mentor site.

Best wishes for your research work.

Sincerely,
Dr. Myra Luna-Lucero
Research Compliance Manager
irb@tc.edu

Appendix B: Copyright Approval for Study 1

JOHN WILEY AND SONS LICENSE
TERMS AND CONDITIONS

Apr 23, 2019

This Agreement between Teachers College, Columbia University -- Andrew Dakopolos ("You") and John Wiley and Sons ("John Wiley and Sons") consists of your license details and the terms and conditions provided by John Wiley and Sons and Copyright Clearance Center.

License Number	4574800320565
License date	Apr 23, 2019
Licensed Content Publisher	John Wiley and Sons
Licensed Content Publication	Infant and Child Development
Licensed Content Title	Differences in sensory responses among children with autism spectrum disorder and typical development: Links to joint attention and social competence
Licensed Content Author	Andrew J. Dakopolos, Laudan B. Jahromi
Licensed Content Date	Oct 30, 2018
Licensed Content Volume	28
Licensed Content Issue	1
Licensed Content Pages	19
Type of use	Dissertation/Thesis
Requestor type	Author of this Wiley article
Format	Print and electronic
Portion	Full article
Will you be translating?	No
Title of your thesis / dissertation	Aspects of Joint Attention in Autism Spectrum Disorder: Links to Sensory Processing, Social Competence, Maternal Attention, and Contextual Factors
Expected completion date	Apr 2019
Expected size (number of pages)	175
Requestor Location	Teachers College, Columbia University 36 Heather Ave SAN FRANCISCO, CA 94118 United States Attn: Teachers College, Columbia University
Publisher Tax ID	EU826007151
Total	0.00 USD
Terms and Conditions	

TERMS AND CONDITIONS

granting such waiver or consent. The waiver by or consent of a party to a breach of any provision of this Agreement shall not operate or be construed as a waiver of or consent to any other or subsequent breach by such other party.

- This Agreement may not be assigned (including by operation of law or otherwise) by you without WILEY's prior written consent.

- Any fee required for this permission shall be non-refundable after thirty (30) days from receipt by the CCC.

- These terms and conditions together with CCC's Billing and Payment terms and conditions (which are incorporated herein) form the entire agreement between you and WILEY concerning this licensing transaction and (in the absence of fraud) supersedes all prior agreements and representations of the parties, oral or written. This Agreement may not be amended except in writing signed by both parties. This Agreement shall be binding upon and inure to the benefit of the parties' successors, legal representatives, and authorized assigns.

- In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall prevail.

- WILEY expressly reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions.

- This Agreement will be void if the Type of Use, Format, Circulation, or Requestor Type was misrepresented during the licensing process.

- This Agreement shall be governed by and construed in accordance with the laws of the State of New York, USA, without regards to such state's conflict of law rules. Any legal action, suit or proceeding arising out of or relating to these Terms and Conditions or the breach thereof shall be instituted in a court of competent jurisdiction in New York County in the State of New York in the United States of America and each party hereby consents and submits to the personal jurisdiction of such court, waives any objection to venue in such court and consents to service of process by registered or certified mail, return receipt requested, at the last known address of such party.

WILEY OPEN ACCESS TERMS AND CONDITIONS
Wiley Publishes Open Access Articles in fully Open Access Journals and in Subscription journals offering Online Open. Although most of the fully Open Access journals publish open access articles under the terms of the Creative Commons Attribution (CC BY) License only, the subscription journals and a few of the Open Access Journals offer a choice of Creative Commons Licenses. The license type is clearly identified on the article.
The Creative Commons Attribution License
The Creative Commons Attribution License (CC-BY) allows users to copy, distribute and transmit an article, adapt the article and make commercial use of the article. The CC-BY license permits commercial and non-
Creative Commons Attribution Non-Commercial License

Appendix C: Recruitment Letter

Improving Parenting and Enhancing Maternal Wellbeing in Mothers of Preschool Children

Having a preschool child can be stressful. In the past the Keller schools have offered parents training in how to teach a child. We would like to offer more support for parents as new research indicates that additional supports may improve parents and children's lives. We are working with parent coordinator, Barbara Kimmel, and parent educators at the Rockland campus, to collaboratively create a parenting support program with Keller parents. We can't do this without your help! To that end we invite you to participate in our research project on parenting preschool age children and its relationship to the wellbeing of their mothers.

Who is eligible to participate?

Moms who speak English and their 3-5-year-old attending the Fred Keller school.

What is involved?

A one-time 70-minute session that includes the following parent activities:

1. a) 20 minute parent-child interaction task that incorporates some of the routine challenges of parenting – waiting, picking up toys, playing together, teaching your child, helping your child cope when mildly upset;
2. b) 40-50 minutes of questionnaires on child behavior, parenting, and your opinion about supportive programs for parents;

Are there benefits to taking part in the study?

There are no benefits to participation.

Will I be paid for my participation?

We will pay you $35 for your time.

Please consider participating in this study. If you have any questions about the study, please contact co-investigators, Marla Brassard, PhD, at 212 678 3368 or Laudan Jahromi, PhD at 212 678 3821.

Appendix D: Informed Consent

INFORMED CONSENT

Research Title: Improving Parenting and Enhancing Maternal Wellbeing in Mothers of Preschool Children

DESCRIPTION OF THE RESEARCH:

If you speak English and are the mother of a 3-5 year old child attending the Fred Keller schools, you and your child are eligible to participate in a study of how observed parenting is related to mother's wellbeing and child characteristics in order to develop interventions for parents that improve parenting as well as enhance maternal wellbeing.

If you agree to participate you and your child will attend a one-time session that includes the following parent and parent/child activities:

a) 20 minute parent-child interaction task that incorporates some of the routine challenges of parenting – waiting, picking up toys, playing together, teaching your child, helping your child cope when mildly upset;
b) 40-50 minutes of questionnaires on child behavior, parenting, self-care activities such as your sleep, diet, exercise, alcohol use, and your opinion about the questionnaire and supportive programs for parents.

We will also record 4 pieces of information from your child's file at Keller

a) the number of objectives your child met over six months of the school year on the CABAS® International Curriculum and Inventory of Repertoires for Children from Preschool through Kindergarten (C-PIRK);
b) the rate of your child's learning as measured by the ratio of learn units-to-criterion;
c) your child's level of verbal behavior development (e.g., listener); and
d) any educational or psychiatric diagnoses in your child's file (e.g., developmental delay, autistic spectrum disorder).

RISKS AND BENEFITS:

There are no direct benefits to participating in the study. There is no major risk to the research subjects. Minimal risk may include fatigue or boredom or discomfort if your child might get mildly upset. In addition, the questionnaire contains some very sensitive items, some of which may make you feel emotional discomfort. In instances when the researcher finds that you are at risk and in need of support, we have a psychologist present or on call and the researcher may also refer you to Fred S. Keller School social worker, Latasha Gamble, who will help you access resources in the lower Hudson Valley Region.

PAYMENTS:

We will pay you $35 for your time.

DATA STORAGE TO PROTECT CONFIDENTIALITY:

We will ensure your confidentiality by giving a unique identification number (and not name) to you and your child for your video, for your questionnaire, and for the information from the file review. This identification number is how we will record your information in our computer file for analyses. We will keep the identifiable consent forms in a separate, locked filing cabinet in the Co-PI's office, which will be kept separate from the de-identified data. After we record the information from your child's file we will destroy the link between your name and your identification number. No one affiliated with the Fred S. Keller School (FSK) will have access to the key linking your identity or that of your child to the unique identification number.

The videos and the computer file will be kept on a password protected and encrypted files in Professor Marla Brassard's office 529D Thorndike and Professor Laudan Jahromi's office 529I Thorndike. Only authorized members of the research staff will have access to this information. Information will only be used for professional purposes and will not include identifiable information.

TIME INVOLVEMENT:

Participation in this study will last approximately 60-70 minutes and will take place on one day.

HOW WILL RESULTS BE USED:

The results of this study will be used to design a parent support intervention for parents at the Keller Schools starting AY 2017-18, to write articles, and for dissertations. Feedback on overall results may be provided to the Fred S. Keller School. No feedback will be given on individuals.

ROLE OF THE PRINCIPAL INVESTIGATORS:

Co-Principal Investigators Laudan Jahromi, PhD (212 678-3321), and Marla Brassard, PhD, (212 678-3368) will work closely with Barbara Kimmel, Keller School parent coordinator and liaison, to make sure this research study is completed according to Institutional Review Board standards. For questions about the study, please contact the co-principal investigators at any time with questions.

PARTICIPANT'S RIGHTS

Co-Principal Investigators: Marla Brassard, PhD, Laudan Jahromi, PhD

Research Title: Improving Parenting and Enhancing Maternal Wellbeing in Mothers of Preschool Children

I have read and discussed the Research Description with the researcher. I have had the opportunity to ask questions about the purposes and procedures regarding this study.

- My participation in research is voluntary. I may refuse to participate or withdraw from participation at any time without jeopardy to future medical care, employment, student status or other entitlements.

- The researcher may withdraw me from the research at his/her professional discretion.

- If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue to participate, the investigator will provide this information to me.

- Any information derived from the research project that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.

- For questions about the study, I can contact the Co-principal investigators Laudan Jahromi, PhD, 212 678-3821 and Marla Brassard, PhD, 212 678-3368 at any time.

- If at any time I have comments, or concerns regarding the conduct of the research or questions about my rights as a research subject, I should contact the Teachers College, Columbia University Institutional Review Board /IRB.

- The phone number for the IRB is (212) 678-4105. Or, I can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY, 10027, Box 151.

- I should receive a copy of the Research Description and this Participant's Rights document.

- If video and/or audio taping is part of this research, I
  ( ) consent to be audio/video taped.
  ( ) do NOT consent to being video/audio taped. The written, video and/or audio taped

materials will be viewed only by the principal investigator and members of the research team.

- Written, video and/or audio taped materials
( ) may be viewed in an educational setting outside the research (for example, at a research conference presentation or in a graduate level course). This is an optional, additional level of consent that does not affect your participation in the research study.
( ) may NOT be viewed in an educational setting outside the research (for example, at a research conference presentation or in a graduate level course). This is an optional, additional level of consent that does not affect your participation in the research study.

- ( ) I agree to be contacted for possible participation in an hour-long parent-child interaction at FSK within the next year for which I will be offered additional payment and child care

  ( ) I do NOT agree to be contacted for possible participation in an additional parent-child interaction.

- My signature means that I agree to participate in this study.

  Participant's signature: ________________________________ Date:____/____/____

  Name: ________________________________ If necessary:

  Guardian's Signature/consent: ____________________________________

  Date:____/____/____

  Name: ____________________________________

- My signature means that I agree to participate in this study.

  I am the parent /legal guardian of

  ____and I voluntarily approve of

  his /her

  participation and I agree to participate myself.

  Guardian's Signature/consent:

  ____________________________________ Date:____/____/____

  Name: ____________________________________

Appendix E: Script for Parent-Child Interaction

<u>CONSENT MEETING</u>

On the day of the Interaction Task, the parent will sign the consent form. [Prior to the day of the Interaction Task, parents will have received a recruitment letter and a copy of the consent form. A project staff member will speak to the parent by phone to walk through the consent form and address their questions].

<u>PARENT-CHILD INTERACTION</u>

Setup

Empty room – with child table and 3 chairs 3 sitting at table

1) **Start recording video**.

2) **Parent Instructions.** The parent, child, and interviewer are seated at a small (child-sized) table. The interviewer has an iPad from which he/she reads the script. While opening up the script on iPad say, **"Ok, let's get started. What did we ever do before iPads? I have all my work saved on this one! ".** Next, tell the parent about the tasks. "**First you two will build something together. Which type of blocks are best for your child: wooden blocks, Duplos, or Legos?"** [Bring a Ziploc with the three block examples. Be sure to take it out with you when you leave the room for Competing Demands]. **"Then, I will bring in some toys and ask you guys to play for a while. After that, I will come back and hand you this sheet** [show parent the laminated clean-up sheet] **to remind you to ask your child to clean up. When I hand you this sheet, please wait until I leave the room, then ask your child to clean up.** [Hold up the sheet for the mom to read it. Point to the sentence about not cleaning up herself to highlight it for her]. **Finally, please do not use last names on the video"**.

3) **Competing Demands Task (5 minutes).** Tell the child, **"Ok, I'm going to go get some blocks. Your mom really needs to finish filling out these papers before I come back. I'll be right back!"** Hand the clipboard with the demographic questionnaire [including the question about the child's favorite prize for frustration task] to the parent and say, **"It would be really great if you could try to finish this form before I get back".** Leave an iPad on the table with a "work" document (Word or Excel file) open.

4) Go into observation room, start timer, & make notes regarding interactions that may be difficult to see on the camera. Return to the room after 5 minutes of Competing Demands.

5) **Structured Task (5 minutes).** Bring out the appropriate structured task [We will confirm items via piloting; ultimately, we want three bins that each contain appropriate blocks and model picture]:

1. Nonverbal children/very low functioning children and children with fine motor difficulties – use basic (non-interlocking) blocks
2. Children 5-6 with disabilities? – Use Duplo's
3. Children 3-5 typically developing and high functioning ASD? – Use Legos

6) **"Now I'd like you and your mom to build something together. Mom, please teach [child's name] how to build this [picture]. Here are the blocks and a picture of the model".** [Leave out the correct number of blocks to complete the model plus 10-15 additional blocks; no instruction book will be provided].

7) Go into observation room and continue to make notes about interactions that may be

difficult to see on camera. If you see that the chosen blocks are not working for the dyad (too easy, too hard), go back into room with the appropriate alternative and say "Now, we're going to try these blocks instead" and take away the inappropriate block set. After 5 minutes of structured task go in the room. Congratulate child on a job well done (**"You did a nice job building!"**).

8) **Free Play Task (5 minutes).** Move the blocks to the floor during free play. Set up toys for free play [We will confirm items via piloting]:

1. Small basketball
2. Magna Tiles
3. Papers and crayons
4. Brio trains or cars
5. Make-believe play (dr. kit, for younger children use doll house doll props,)

9) Instructions for free play – **"OK, let's move to the floor now. Try to face this way, if possible. Here are some toys I'd like you to play with for a little while".** Name each toy as you take it out of the bin, **"We have a basketball, some magna tiles, some paper and crayons, trains and cars, a doctor's kit..."**. Be sure to take all individual pieces out; spill all the (8) crayons out, all the pieces of the doctor kit, all the magna tiles. Make sure the dyad is sitting facing the camera before you leave.

10) Go into observation room and continue to make notes about interactions that may be difficult to see on camera

11) After 5 minutes, enter the room and say, "**Hey guys, I forgot to give this to your mom**". Hand the parent the laminated sheet indicating that the clean-up session is to start when you leave the room [Wording on sheet: "Please tell your child to clean up. Please don't clean up by yourself"]. When the interviewer closes the door, this marks the beginning of Clean-Up task.

12) **Clean-Up Task (2 minutes).** After the child has fully cleaned up the toys (or 2 minutes of clean-up task, whichever comes first), re-enter the room. If the child has not finished cleaning up, quickly help them finish the clean up.

13) Next, the interviewer enthusiastically tells the child **"You did such a great job today! I'm going to get you a prize!"** When the interviewer returns with the prizes, this marks the beginning of the frustration task.

14) **Frustration Task (3 minutes).** The interviewer enters the room (leaving the door open so that the second interviewer can enter quickly) and presents the child with a small bag of their favorite food snack item (e.g., goldfish, chips) saying, **"Thanks for doing such a great job! For doing such great work, I have some [goldfish] for you! I know how much you love [goldfish]!"** The interviewer hands the item to the child, immediately heads for the door, and as he/she exits, the second experimenter enters, announcing to the first interviewer "**Wait, you can't give him/her that"**. The second interviewer takes the snack from the child, and says directly to the child, **"I'm so sorry, but you can't have that".** The interviewer looks apologetically at both the child and parent and leaves the child and parent in the room for **3 minutes**. Go into observation room and continue to make notes about interactions that may be difficult to see on camera. If mom asks Interviewer 2 what she should be doing next, he/she will say **"Let me go check where [Interviewer 1] went".**

    After 3 minutes, the 1st interviewer re-enters the room and says, **"Guess what? You can have the [goldfish] after all! You did such a super job today!"**

Appendix F: Room layout for parent-child interaction

Diagram not to scale