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Relationship Between Sensory Sensitivities and Cognitive and Adaptive Abilities in Children
with Autism Spectrum Disorders

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Abstract

Sensory sensitivities are widely reported among individuals with ASD. These sensory sensitivities can be classified as over-responsivity, under-responsivity, or seeking of sensory stimulation. Following recent changes in the diagnostic criteria, sensory sensitivities are considered a key feature of the behavioral phenotype of ASDs. Despite their significance, sensory sensitivities have been largely underestimated. Therefore, more research in this area may reveal important information about the influence of sensitivities on functioning, as well as the underlying causes of the symptoms. This study investigated a possible relationship between sensory sensitivities and cognitive and adaptive abilities in children with ASD. The sample included 29 children approximately 23 months old who had been diagnosed with an ASD according to the DSM-IV-TR criteria. Presence of sensory sensitivities was determined using parent report on the Toddler ASD Symptom Interview (TASI). The Mullen Scales of Early Learning (Mullen) and Vineland Adaptive Behavior Scales, Second Edition (Vineland II) were used to measure cognitive and adaptive abilities. The results indicate that there are no differences in cognitive and adaptive abilities between children with ASD who display sensory sensitivities and those who do not display sensory sensitivities. Although not significant, there was a pattern such that children with ASD and sensory sensitivities performed slightly better on measures of cognitive and adaptive ability compared to children with ASD without sensory sensitivities. Given the high variability in manifestation of these sensory sensitivities both within individuals and across the ASD population, it seems plausible that the dichotomous grouping used in this study may have limited the opportunity to find effects.

Introduction

Overview of Autism Spectrum Disorders

Autism spectrum disorders (ASDs) consist of a range of developmental disabilities marked by significant social difficulties, impaired communication, and restricted, repetitive behaviors (APA, 2013). These complex neurological disorders range in severity and symptoms between individuals. As reported by the Center for Disease Control and Prevention, about 1 in 88 children have been diagnosed with an ASD. While common among all racial, ethnic, and socioeconomic stratifications, ASDs are almost five times more common among boys than among girls (CDC, 2012). The earliest reliable ASD diagnosis can be obtained at around two years of age, but final diagnoses are often given when the child is much older (CDC, 2012). In addition to these main diagnostic criteria, sensory sensitivities have been widely reported among individuals with ASD.

A Change in Diagnostic Criteria

Currently, research suggests an average of 69 to 80 percent of individuals with autism experience sensory sensitivities (Caminha & Lampreia, 2012). While reported rates do vary across the literature, they all reveal that sensory sensitivities are common in ASDs. Many researchers, such as Caminha and Lampreia (2012), argue that these sensitivities have been largely underestimated. These investigators insisted that sensory sensitivity be included in the diagnostic criteria, for the prevalence and importance of these symptoms are too great to overlook.

For the first time, sensory sensitivities have been included in the ASD diagnostic criteria detailed in the recently released Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). The DSM-5 characterizes these symptoms as “hypo- or hyperactivity to sensory input or unusual interest in sensory aspects of the environment” (APA, 2013). While not required for diagnosis, sensory sensitivity is amongst four detailed manifestations of restricted, repetitive behaviors, interests, or activities (APA, 2013). Two out of four of these demonstrations must be observed to meet criteria in this domain (APA, 2013). Mahjouri and Lord (2012) discuss that inclusion of these sensory sensitivities will offer important information that is useful in treatment. Presence of these sensitivities will now be noted in those who are diagnosed using these modified criteria, allowing them the opportunity for more comprehensive intervention. Those individuals with ASD display sensory sensitivities will continue to be included under the new criteria and also may benefit from a more inclusive diagnosis. Furthermore, Caminha and Lampreia (2012) highlight that the addition of this criterion could potentially shed new light on the disorder by bringing sensory sensitivity to the forefront of researchers’ attention.

Defining Sensory Sensitivities

Sensory sensitivities can be classified into three categories: over-responsivity, under-responsivity, and seeking of sensory stimulation (Ben-Sasson et al., 2009). Over-responsivity describes exaggerated and extended reactions to sensory input, often responses with rapid onset. Under-responsivity is defined as either lack of awareness or delayed response to sensory stimulation. Sensory seeking includes prolonged or intense interest in sensory experiences (Ben-Sasson et al., 2009).

There is also evidence that these sensitivities are not limited to simply three categories. Autobiographical reports from individuals with ASD revealed that these symptoms may also include fluctuations between hyper- and hyposensitivity, sensory distortions and shutdowns, sensory overload, difficulties processing information from multiple senses simultaneously, and difficulty identifying from which sensory channel the information originated (O'Neill & Jones, 1997, as cited in Ben-Sasson et al., 2009). Another study demonstrated that individuals with autism show patterns of gestalt perception, perception delays, and synesthesia in addition to hyper- and hyposensitivity (Bogdashina, 2003, as cited in Ben-Sasson et al., 2009). Additionally, there is evidence of avoidance of sensory stimulation in individuals with ASD. However, it is suggested that this avoidance is a reaction to over-sensitivity to stimuli (Minshew & Hobson, 2008). Altogether, evidence in the literature indicates that sensory perception is often abnormal in multiple ways in people with ASD.

Among the literature, these symptoms are not referred to with consistent terminology. Although researchers are often referring to the same phenomenon, they use different terms – sensory sensitivities, abnormalities, and dysfunctions, are among the terms used. There is a need for standard terminology for comparison purposes in research within this area. For the purposes of this paper, sensory sensitivities will be defined as any abnormal response to sensory stimulation.

Overview of Sensory Sensitivities

Sensory sensitivities are not universal in or specific to ASDs, but they are nonetheless common, clinically significant and important to investigate (Caminha & Lampreia, 2012). Numerous researchers have revealed considerable differences in the prevalence of these

sensitivities between children with ASD and typically developing children. Ben-Sasson and colleagues (2009) compared these groups and found a significant difference in the frequency of these sensitivities, with the greatest difference in under-responsivity, followed by over-responsivity, and then sensory seeking behaviors.

Sensory sensitivities may be present in more than one modality, both across the ASD population and within a particular individual. A study of adults with ASD by Crane, Goddard, and Pring (2009) found that, out of the four quadrants included in the Adult/Adolescent Sensory Profile – low registration, sensation seeking, sensory sensitivity, sensation avoiding – individuals with ASD showed extreme levels of sensitivity in at least one quadrant. In addition, they found high within-group variability in their sample, suggesting that individuals with ASD may express these sensitivities in different modalities, but manifestations may be of the same severity (Crane et al., 2009). Kern and colleagues (2007) found further evidence for this, as their results suggest the presence of sensory sensitivities in main sensory areas – audition, vision, oral, and touch – and that each modality is not independent of the others. From this, they also inferred that these sensitivities are global in the ASD population (Kern et al., 2007). It seems that there is variability in the manifestation of these sensory sensitivities both within and between individuals with ASD.

Although an ASD diagnosis is not typically given until a child is two years old, he or she may present symptoms, including sensory sensitivities, before reaching this age. Osterling, Meltzoff, and Kulh (2000 as cited in Caminha & Lampreia, 2012) found that these sensitivities are observable within the first year of life in a child with autism. Baranek (1999) replicated this result by showing that one-year-old infants who were later diagnosed with autism displayed lower orientation toward visual stimuli, put objects in their mouth more often, avoided social touch, and required more attention-getting taps to orient them when their name was called. With

inclusion of sensory sensitivities in the DSM-5 criteria, presentation of these symptoms beginning at such an early age may act as warning signs to parents and pediatricians.

There may be correlations between the age of the individual, the severity of ASD, and the presentation of these sensory sensitivities. Some evidence suggests that sensory sensitivities are more common during childhood and dissipate with age (Caminha & Lampreia, 2012); however, other researchers have found that these sensitivities are maintained throughout the life course (Crane et al., 2009). A correlation between sensory sensitivities and the severity of ASD in children, but not adults, has also been suggested (Kern et al., 2007). Ben-Sasson and colleagues (2009) also found chronological age, mental age, and severity of ASD to be possible contributing factors to the intensity of sensory sensitivities.

Particular sensory sensitivities may be indicative of the severity of the disorder. A cluster analysis of parent report measures for children with ASD found that while being the highest functioning, the overfocusing cluster was the most socially impaired (Liss et al, 2006). This suggests that overfocusing may negatively impact social behavior but may not impede intelligence level or general behavior patterns. These results suggest that overresponsivity to sensory stimuli, resulting from the characteristic overfocusing (Liss et al, 2006), may be detrimental to social behavior rather than intellect or behavior. In the same study, the lowest functioning cluster were generally underreactive, suggested that underreactivity may be related to mental retardation (Liss et al, 2006). This suggest that underresponsivity to sensory stimuli may be indicative of intellectual impairment in individuals with ASD.

Theories of Sensory Sensitivity

The presence of sensory sensitivities in autism spectrum disorders is clear, but the underlying causes remain unknown. Several hypotheses have been suggested to explain these symptoms. Many of these theories also link explanations to the characteristic features of ASDs. While none of the following hypotheses fully explain ASD symptoms, there appears to be consensus that sensory sensitivities contribute to the symptomatology of ASDs (Caminha & Lampreia, 2012).

Several researchers have suggested that there is a deficit in the arousal-modulating system in individuals with ASDs. Ornitz and Ritvo (1968, as cited in Caminha & Lampreia, 2012 and Minshew & Hobson, 2008) argue that people with ASDs experience fluctuations between over- and under-arousal to sensory input. This inconsistency leads to a failure to modulate sensory stimulation and to unstable perception. They contend that in an effort to reduce attention to unexpected and uncomfortable stimuli, individuals with ASD engage in repetitive behaviors (Hutt, Hutt, Lee, & Ounsted, 1964, as cited in in Caminha & Lampreia, 2012). In this way, sensory sensitivity may explain the presence of repetitive behaviors. Marcel Kinsbourne (2011) further explored this theory, concluding that the primary function of repetitive behaviors in individuals with autism is to moderate arousal level when they perceive environmental circumstances to be stressful and overwhelming. When overaroused due to perceived threat or excitement, the individual may feel anxious and restrict sensory input by turning attention inward. The stereotypies apparent in individuals with autism may be behavioral strategies used to reduce overwhelming experiences created by hypersensitivity to the environment. Kinsbourne (2011) also presumes that the restricted range of interests and need for sameness resulting from this overarousal and heightened sensitivity is likely to extend beyond repetitive behavior to also restrain thought.

Another theory posits that individuals with ASD have super-selective attention in which they focus on a minor element of complex stimuli (Lovaas & Newsom, 1976, as cited in Caminha & Lampreia, 2012). They tend to show perceptual biases for details and greater sensitivity to unique stimulus features, which may be connected to characteristic cognitive qualities found in autism – namely, heightened processing of features and exaggerated focus on insignificant details (Happé, 1999, as cited in Minshew & Hobson, 2008). This distinctive and exaggerated selection of attention may contribute to the “need for sameness” (Happé, 1999, as cited in Minshew & Hobson, 2008), as well as the social and communication difficulties characteristic of autism (Lovaas & Newsom, 1976, as cited in Caminha & Lampreia, 2012).

Addressing both of the above theories, Liss and colleagues (2006) suggest that individuals with ASD suffer from overarousal resulting in overreactivity, overfocused attention, and repetitive behavior and interests. Based on cluster analysis of parent report measures of children with ASD, the researchers found that 43 percent of the sample displayed overfocused sensation and attention, along with overreactivity, preservative behavior and interests, and exceptional memory. This pattern was particularly notable in 10 percent of the sample. Within the overfocused cluster, they found sensory seeking behaviors to be prevalent. They took this to suggest that an overreaction to a stimulus in the child’s focus may only occur when that stimulus is unexpected or aversive. Otherwise, the individual may choose to focus on a pleasurable stimulus out of interest or as a soothing mechanism. The researchers also predict that a difficulty in shifting attention may contribute to overfocusing and intensify overarousal.

Those with ASD may also experience neurological thresholds that are either too high or too low for efficient sensory processing and management (Dunn et al, 1999, as cited in Minshew & Hobson, 2008). Based on this model, individuals may show various sensory sensitivities based

on their behavioral self-regulation strategies (Dunn et al, 1999, as cited in Minshew & Hobson, 2008). Further evidence for this reveals that individuals with autism show enhanced perceptual processing for low-level stimuli (Minshew & Hobson, 2008). Dawson and Lewy (1989, as cited in Caminha & Lampreia, 2012) theorize that there is an optimum level of stimulation and many of the key features of autism are reactions to surpassing this level. From this argument, it follows that sensory sensitivities not only are a key feature of ASD, but also are major contributors to the characteristic behavioral phenotype.

Another popular theory suggests that individuals with ASD may possess insufficient cross-modal integration, fragmentation, and processing dyscontrol – what researchers named *canalesthesia* (Waterhouse et al., 1996). There is evidence that each sense operates independently and that the brain of individuals with ASD is incapable of organizing these stimuli meaningfully (Hatch-Rasmussen, 1995, as cited in Caminha & Lampreia, 2012). Minshew and Hobson (2008) suggest that these dysfunctions in higher cortical sensory perception are manifestations of a more broad information processing impairment.

Sensory Sensitivity Connection to Other Characteristic Features of ASD

As discussed above, sensory sensitivities may contribute to the overall behavioral, social, and communication features of ASD. Self-reports from high-functioning individuals with autism reveal that they consider sensory sensitivity to be a predominant characteristic of their lives and see them to be directly related to the social and communication problems they face (Caminha & Lampreia, 2012).

Sensory perception is the lens through which humans learn to interact with the world. A baby's first experiences in this world are sensory in nature, and the baby constructs meaning of

the world using these innate sensory abilities (Stern 1992, as cited in Caminha & Lampreia, 2012). Babies who have ineffective sensory processing are unable to make sense of incoming stimuli, severely limiting their opportunities for learning and growing (Caminha & Lampreia, 2012). Therefore, sensory sensitivities may effectively impede proper development. Given the sensory sensitivities evidenced in individuals with ASD, these may lead to the “triad of impairment” (Caminha & Lampreia, 2012).

In accordance with this theory, Kenet (2011) asserts that dysfunction in early sensory processing will have downstream consequences on higher cognitive functions. This follows that the repetitive behaviors, social and communication deficits typical in individuals with ASD are possible consequences of the sensory sensitivities that they display (Kenet, 2011). These sensory sensitivities may have significant effects on the characteristics of ASD and gaining further understanding of them is essential.

Implications of Sensory Sensitivity

Experiments have drawn connections between sensory sensitivities and participation and performance displays in children with ASD. Sensory sensitivity may affect the activities that children with ASD engage in, thereby further reducing social learning opportunities. Reynolds, Bendixen, Lawrence, and Lane (2011) found significant differences in the types of activities children with ASD participated in compared to typically developing controls. Overall level of competence in the activities, social performance, and school performance were reflected in these differences. The children who scored higher on sensory sensitivity, meaning they displayed severe sensitivities, showed significantly lower competence than others. Effectively, sensory sensitivities impeded children’s ability to participate in meaningfully in activities (Reynolds et

al., 2011). This inference was strengthened by Hochhauser and Engel-Yerger (2010) when they correlated limited participation in leisure activities with the presence of sensory sensitivities in children with high-functioning autism spectrum disorder. This lack of effective engagement in activities limits social learning opportunities available to the child.

Additionally, sensory sensitivities may be linked to school performance. Ashburner, Ziviani and Rodger (2008) found that auditory filtering difficulties, sensory under-responsiveness, and sensory seeking behaviors were significantly associated with academic underachievement. Sensory sensitivity may be among many ASD features associated with poor academic performance, but it is significant nonetheless. In a younger age group, this “underachievement” may be realized in cognitive and adaptive deficits, which makes looking at these relationships interesting.

Sensory sensitivities may also impact the way individuals engage in activities of daily living. Daily living skills require a basic level of fine and gross motor coordination along with cognitive planning. A study by Jasmin and colleagues (2009) revealed that sensory avoiding and fine motor skills were highly correlated with daily living skills in children with ASD. They found many correlations between sensory-motor ability and daily living skills (Jasmin et al., 2009). Sensory seeking and touch processing were associated with gross motor skill performance, suggesting that sensory sensitivities may explain gross motor difficulties seen in children with ASD (Jasmin et al., 2009). With sensory sensitivities potentially impacting these domains, these sensitivities may have a large impact on the autonomy of children with ASD (Jasmin et al., 2009).

Need for Further Research

Sensory sensitivities have been largely underestimated and under-researched in the ASD literature. As evidenced, these sensitivities may play a major role in the symptomatology of these disorders. The dearth of current research in this domain makes it essential to further investigate this area. Given the lack of research and ambiguity of existing findings, it is difficult to determine how sensory sensitivities may affect individuals with ASD.

Gaining a clearer understanding of sensory sensitivities may yield greater insight into the causes and presentation of ASD (Kenet, 2011). Given the evidence that sensory sensitivities are correlated with the triad of impairment in ASD, more knowledge in this area may reveal significant information about the underlying causes of these symptoms. There is a great need to study the implications of sensory sensitivities in order to gain a better understanding of ASD in general as well as to understand the lives of the individuals with these disorders. In addition, understanding sensory sensitivities may lead to the discovery of neural or behavioral markers that could be useful in risk assessment, early diagnosis, and potential treatment of ASD (Kenet, 2011).

Present Study

This study will investigate a possible relationship between sensory sensitivities and cognitive and adaptive abilities in children with ASD. We will use a sample of children approximately 23 months old who have been diagnosed with an ASD according to the DSM-IV-TR criteria. Presence of sensory sensitivities will be determined using parent report on the Toddler ASD Symptom Interview (TASI), a semi-structured parent interview of ASD symptomatology. The Mullen Scales of Early Learning (Mullen) and Vineland Adaptive Behavior Scales, Second Edition (Vineland II) will be used to measure cognitive and adaptive

abilities. Group differences on cognitive and adaptive abilities between sensory sensitivities present (SS Present) and sensory sensitivities absent (SS Absent) groups will be explored. This study attempts to address some of the gaps in the literature surrounding sensory sensitivities, as well as highlight their importance in ASD and their need to be further addressed in intervention strategies.

Given that sensory sensitivities may have an impact on the diagnostic triad of ASD and that they are associated with abilities such as daily living skills and academic achievement, we hypothesize that the presence of sensory sensitivities in children with ASD will be negatively associated with their cognitive and adaptive abilities. Specifically, we predict that having sensory sensitivities, as indicated by parent report on the TASI, will be associated with lower scores on the Mullen and Vineland.

Methods

Participants

Participants were drawn from a sample of children involved in an ongoing study examining the effectiveness of a 20-item, ASD-specific toddler screening questionnaire called the Modified Checklist for Autism in Toddlers, Revised (M-CHAT-R; Robins, Fein, Barton, & Green, 2001). Participants were recruited for the study by a pediatrician during a well-child visit at 18 or 24 months of age or through the child's early intervention services.

Once enrolled in the study, children received several measures of ASD symptomatology, cognitive and adaptive functioning. Children were included in the current study if they received an ASD diagnosis, and if caregivers had indicated the presence of sensory sensitivities on the

Toddler ASD Symptom Interview (TASI; Barton, Boorstein, Dumont-Mathieu, Herlihy, & Fein, 2012).

Participants for the current study included 29 children ages 18 to 24 months, diagnosed with ASD. The sample was 72.4% male (n = 21) and 27.6% female (n = 8). The mean age was 23.52 (SD = 3.086). Caregivers identified the majority of these children as White (62.1%, n=18), with fewer reported as Black or African American (10.3%, n=3), Asian or Pacific Islander (17.2%, n=5), and Hispanic/Latino (10.3%, n=3). 86.2% of mothers reported having achieved a high school diploma or higher at the time of the evaluation.

Procedure

Caregivers filled out the M-CHAT-R at their child's pediatrician's office or early intervention site. The completed screener was then sent to the University of Connecticut Early Detection laboratory and scored. If the child failed the screener, caregivers were called to clarify missed items and confirm answers. If the child continued to fail the M-CHAT-R after this follow-up phone interview, they were invited to the University of Connecticut for a free diagnostic evaluation.

A licensed clinical psychologist and a graduate student in the University of Connecticut Clinical Psychology Ph.D. Program conducted the evaluations. The assessments included a battery of measures to assess the developmental level, the adaptive skills, and the ASD-specific symptomatology of each child. Parent-report measures included the Autism Diagnostic Interview- Revised (ADI-R), Vineland Adaptive Behavior Scales, Second Edition (Vineland II), and Toddler ASD Symptom Interview (TASI). Children were administered the Mullen Scales of Early Learning (Mullen) and Autism Diagnostic Observation Schedules (ADOS). Based upon

caregiver interview and direct observation of the child, the clinician and graduate student each completed the Childhood Autism Rating Scale (CARS). Testing results were shared with the families at the time of the evaluation and, within six to eight weeks, a comprehensive report, including an explanation of test results and recommendations was sent to the family. Participants who received an evaluation at approximately two years of age were invited to return for a reevaluation two years later to assess diagnostic stability and make recommendations for additional interventions needed.

Diagnoses were based upon the clinical judgment of a licensed clinical psychologist using scores from various ASD-specific measures, developmental and adaptive assessments, and the DSM-IV-TR criteria for ASD or PDD-NOS diagnosis. Designating ASD diagnosis based on the judgment of experienced clinical psychologists has been shown to have high inter-rater reliability (Klin, Lang, Cicchetti, & Volkmar, 2000). ASD diagnoses in this study included Autistic Disorder, Autistic Disorder with Low Mental Age (low MA), and Pervasive Developmental Disorder - Not Otherwise Specified (PDD-NOS).

Measures

Each child in the study received a series of measures to be used for clinical evaluation and diagnosis. The following measures were used in the current study.

Toddler ASD Symptom Interview (TASI; Barton et al, 2012). The TASI is a semi-structured caregiver interview based upon DSM-IV-TR criteria for ASD that assesses the child's social development, communication abilities, and degree of restricted repetitive and stereotyped behaviors, activities, and interests. Scoring of the TASI involves indicating if a particular ASD symptom is present or absent. Each sub-item is scored to indicate if the specific answer is

consistent with typical development or with atypical development, passing or failing respectively. Answers to the hypo- and hyper-sensitivity questions in the DSM-V Additional Required Questions section were used for the current study. Within this section, the clinician completes a table indicating the presence of hypersensitivity, hyposensitivity, and sensory seeking behaviors in tactile, auditory, taste, smell, movement/pressure, pain, and temperature domains. This information was used to determine the sensory sensitivities of the participants. The psychometric properties of the TASI have not yet been analyzed.

Mullen Scales of Early Learning (Mullen; Mullen, 1995). The Mullen Scales of Early Learning is a standardized measure of cognitive and motor development in children from birth to 68 months of age. It measures the child's skills in Gross Motor, Visual Reception, Fine Motor, Receptive Language, and Expressive Language domains. Gross motor skills are not evaluated in this study. The Mullen provides a t-score, percentile rank, and age equivalent for each domain. T-scores for Visual Reception, Fine Motor, Receptive Language, and Expressive Language domains will be analyzed in the current study. The Mullen demonstrates satisfactory internal consistency (.75 to .83), high inter-rater reliability (.91 to .99), and high test-retest reliability, particularly in younger populations (children 1 to 24 months) (Mullen, 1995). Studies have reported sufficient convergent and divergent validity of the five scales and have attested to their usefulness in assessing developmental problems in infants and young children (Mullen, 1995).

Vineland Adaptive Behavior Scales- Second Edition (Vineland II; Sparrow, Cicchetti, & Balla, 2005). The Vineland Adaptive Behavior Scales, Second Edition is a standardized parent interview that evaluates adaptive functioning in children across four domains: Communication,

Daily Living Skills, Socialization, and Motor Skills. Within each domain, there are several subdomains that address more specific developmental areas. Each domain is assigned a score and a standard score. The measure also yields an overall Adaptive Behavior Composite (ABC). Standard scores for Communication, Daily Living Skills, and Motor Skills will be used for the current study. The Vineland is used for individuals across a broad range of ages and with a variety of intellectual and developmental disabilities and other disorders. Subdomain reliability is moderate to high with approximately 75 percent of subdomains having an internal-consistency of .75 or greater, and has been shown to be even higher for children (Sparrow, Cicchetti, & Balla, 2005). The Vineland II also shows very high internal consistency (upper .80s to low .90s) and test-retest reliability (.88 to .92), and inter-interviewer reliability (.75) across domains (Sparrow, Cicchetti, & Balla, 2005). Validity studies have shown that mean domain scores reflect the DSM-IV-TR diagnostic criteria for ASD in individuals with autism who are verbal and nonverbal (Sparrow, Cicchetti, & Balla, 2005).

Results

In the current study we predicted that the presence of sensory sensitivities in children with ASD would be negatively associated with their cognitive and adaptive abilities. Specifically, we hypothesized that children with ASD who displayed sensory sensitivities would have significantly lower scores on the Mullen and Vineland compared to children with ASD who did not display sensory sensitivities. An alpha level of .05 was used as the criterion for significance for all statistical tests.

Characterization of Samples

Participants were grouped by presence ($n = 18$) or absence ($n = 11$) of sensory sensitivities based on answers to sensory questions on the TASI. The sensory sensitivities present (SS Present) and sensory sensitivities absent (SS Absent) groups did not significantly differ in age ($t(27) = .31, p = .759$), gender (Fisher's Exact Test, $p = .671$), evaluation diagnosis (Fisher's Exact Test, $p = .362$), ethnicity (Fisher's Exact Test, $p = .557$), or maternal education (Fisher's Exact Test, $p = .793$). Demographic information by group can be found in Table 1.

Distribution of Sensory Sensitivities

The categories of sensory sensitivities analyzed were hypersensitivity, hyposensitivity, and sensory-seeking, as used in the Toddler ASD Symptom Interview (TASI). The proportion of sampled individuals within each category can be seen in Figure 1. Proportions reflect that most individuals who displayed hypersensitivities had this atypical response to auditory (28%), tactile (24%), and taste (20%) stimuli. Most individuals whom displayed hyposensitivities were underresponsive to pain (43.75%). Most sensory-seeking individuals sought out sensory stimulation in movement (50%) and tactile (30%) modalities.

Cognitive Ability

Independent samples t -tests were conducted using standard scores from the Receptive Language, Expressive Language, Fine Motor, and Visual Reception domains and the Early Learning Composite of the Mullen Scales of Early Learning to determine if any group differences existed. The SS Present group ($M = 60.40, SD = 12.57$) did not differ significantly from the SS Absent group ($M = 58.20, SD = 12.81$) on the Early Learning Composite ($t(18) = .39, p = .703, d = .173$). In the Expressive Language domain, the two groups (SS Present $M =$

26.78, $SD = 8.44$; SS Absent $M = 22.64$, $SD = 3.93$) did not differ significantly, however there was a trend such that the SS Present group showed higher scores than the SS absent group ($t(26) = 1.79$, $p = .086$, $d = .629$). The SS Present ($M = 33.22$, $SD = 8.53$) and SS Absent ($M = 31.27$, $SD = 8.86$) groups additionally did not significantly differ in Fine Motor skills ($t(27) = .59$, $p = .561$, $d = .224$). Moreover, present ($M = 23.00$, $SD = 5.86$) and absent ($M = 20.82$, $SD = 1.40$) groups did showed no significant differences in performance in the Receptive Language domain ($t(20) = 1.51$, $p = .147$, $d = .512$).

Overall, individual comparisons were not significant; however, there was a pattern such that the SS Present group had higher scores in the Early Learning Composite, Expressive Language, Fine Motor, and Receptive Language domains of the Mullen. This was contrary to our hypothesis. The only domain in which the pattern was consistent with our hypothesis was in the Visual Reception domain ($t(27) = -.75$, $p = .238$, $d = .284$), as the SS Present group ($M = 28.61$, $SD = 8.64$) showed a lower mean score than the SS Absent group ($M = 31.18$, $SD = 9.44$), but the comparison was not significant. Figure 2 displays the mean scores on each domain of the Mullen Scales of Early Learning.

Adaptive Functioning

Independent samples t -tests were conducted to compare standard scores of both groups on the Daily Living, Social, Communication, and Motor domains and the Adaptive Behavior Composite of the Vineland Adaptive Behavior Scales, Second Edition. The sensory sensitivities present ($M = 70.00$, $SD = 15.02$) and absent ($M = 63.00$, $SD = 11.84$) groups did not significantly differ in the Communication domain ($t(27) = 1.31$, $p = .2$, $d = .518$). SS Present ($M = 83.72$, $SD = 16.91$) and SS Absent ($M = 77.91$, $SD = 15.44$) groups also showed no significant differences

in Daily Living Skills ($t(27) = .93, p = .362, d = .359$). The group that displayed sensory sensitivities ($M = 84.77, SD = 8.81$) and the group that did not ($M = 84.18, SD = 11.71$) did not perform differently in Motor Skills ($t(26) = .15, p = .882, d = .056$). Additionally, the SS Present ($M = 75.28, SD = 11.40$) and SS Absent ($M = 74.36, SD = 7.55$) groups did not significantly differ in the Social domain ($t(27) = .24, p = .816, d = .095$). Overall, the SS Present group ($M = 75.69, SD = 11.10$) and SS Absent group ($M = 71.27, SD = 10.384$) demonstrated no significant differences in the Adaptive Behavior Composite ($t(25) = 1.04, p = .307, d = .411$). Again, the results were not significant but exhibited a pattern in the opposite direction than was predicted. Mean differences between groups are shown on Figure 3.

Discussion

The goal of the current study was to examine the relationship between sensory sensitivities and cognitive and adaptive abilities in children with Autism Spectrum Disorders. Based on previous research, it was hypothesized that the presence of these sensory sensitivities would have a negative effect on these abilities, and in turn, that children with sensory sensitivities would have lower scores than peers without sensory sensitivities on measures of cognitive and adaptive skills. Contrary to this hypothesis, our results suggest that there are no differences in cognitive and adaptive abilities between children with ASD displaying sensory sensitivities and those who do not display sensory sensitivities. The pattern suggests that those who display sensory sensitivities may in fact perform slightly better on measures of cognitive and adaptive abilities compared to those who do not display sensory sensitivities.

Given the high variability in manifestation of these sensory sensitivities both within individuals and across the ASD population, it seems plausible that the dichotomous grouping used in this study limited the opportunities to find effects. Hypersensitive, hyposensitive, and sensory-seeking behaviors constitute very different reactions to sensory stimuli, and it therefore seems likely that they would have differential effects on cognitive and adaptive abilities. Splitting the sample into three separate groups based on their specific type of sensitivity (e.g., hypersensitive, hyposensitive, or sensory-seeking) may have yielded effects more consistent with the hypothesis.

As discussed, a cluster analysis of individuals with ASD performed by Liss and colleagues (2006) confirmed their hypothesis that overreactivity (analogous to “hypersensitivity” in the current study) is related to overselective or overfocused attention. They also found the overfocusing cluster to be the most socially impaired while the low-functioning cluster was the most underreactive (Liss et al, 2006). The researchers inferred from this that overfocusing may impede social interaction but not affect intellect or behavior (Liss et al, 2006). In contrast, they suggested that underreactivity (analogous to “hyposensitivity” in the current study) may be related to mental retardation (Liss et al, 2006). Among the overfocused cluster, sensory-seeking behaviors were prevalent (Liss et al, 2006). This research suggests a difference in cognitive and adaptive abilities among individuals with different types of sensory sensitivities. From this research, we would expect hypersensitive and sensory-seeking behavior to be associated with lower scores on social domains and hyposensitive behavior to be related to lower cognitive abilities. Therefore, it appears that our hypothesis would have to be made more specific in order to encompass these differences.

It also seems that sensory sensitivities may exist along a continuum, and therefore, by making dichotomous groups we may have lost important information. As previously stated, sensory sensitivities may not be limited to strictly hypersensitive, hyposensitive, and sensory-seeking categorization (O'Neill & Jones, 1997, as cited in Ben-Sasson et al., 2009). Individuals with ASD may experience fluctuations between hyper- and hyposensitivity, sensory distortions and shutdowns, sensory overloads, perceptual delays, synesthesia, among many other manifestations (Ben-Sasson et al., 2009). The sensory sensitivities also vary in modality both across individuals and across the ASD population (Crane et al., 2009). It also appears plausible that sensory sensitivities may vary in severity between individuals. This postulated continuum was not captured by the measure used in the current study.

Limitations and Further Directions

This study must be evaluated in light of its limitations. First, the current study had a small sample size. The study consisted of 29 participants, 18 of whom were placed in the SS Present group and 11 of whom were placed in the SS Absent group. Our small sample size may have made it more difficult to detect subtle differences in the cognitive and adaptive abilities of our two groups. It also restricts the reliability of the data and the generalizability of the conclusions. The small sample size also contributed to the heterogeneity of the groups in the current study. In order to make the groups appropriately large for analysis, dichotomous SS Present and SS Absent groups had to be formed. This forced the combination of children with very different sensitivities in the SS Present group. As suggested, the failure to see differences between groups in the current study may be related to a lack of specificity in grouping. Had there been a larger

sample of children, groups based on type of sensory sensitivity (e.g., hypersensitive, hyposensitive, sensory-seeking) could have been formed, thereby creating more specificity in the grouping and possibility for determining group differences. This also becomes problematic, however, given that individuals often express multiple types of sensory sensitivities.

A second limitation of the current study was the inconsistent completion of the TASI sensory information. The portion of the TASI used for this study included three general questions about the presence of hypersensitivity, hyposensitivity, and sensory-seeking behaviors in the child, as well as a table detailing the modality in which the sensory sensitivity was present. Likely as a result of variability in parents' knowledge of their child's sensitivities, some of the questionnaires had the general questions completed, but more specific information was not available. In contrast, for others, the table filled out, but not the general questions, leading to debate over whether clinically significant sensitivities were present. Therefore, the current investigator had to use her judgment when placing individuals into two dichotomous groups. Additionally, visual stimulation information from a different section on the TASI was not used, not lending itself to categorization. The ambiguity further limited opportunities to group participants more specifically and may have resulted in flawed dichotomous grouping.

Data collected on the TASI is qualitative and dichotomous (e.g., present, absent), thereby limiting the statistical techniques available for analysis. Further research in this area should use a quantitative, more detailed measure of sensory sensitivities. A more comprehensive measure of sensory sensitivities, along with a larger sample size, would allow for more specific groupings to be made, possibly revealing group differences that were unable to be determined with the dichotomous grouping in the current study. Utilizing a more continuous, quantitative measure would also allow opportunity to investigate possible effects of severity and manifestation of

sensory sensitivities on cognitive and adaptive abilities. These differences could yield more detailed results, possibly offering more insight into the relationship between sensory sensitivities and cognitive and adaptive abilities.

Conclusions

In conclusion, the data does not appear to support our broad hypothesis that sensory sensitivities have a negative effect on cognitive and adaptive abilities in children with Autism Spectrum Disorders. Although significant differences were not found between the group of children who displayed sensory sensitivities and the group who did not, this may be the result of grouping individuals with a range of sensory sensitivities. Broadly, our results indicate that when grouped together, children with ASD and sensory sensitivities may perform slightly better on measures of cognitive and adaptive ability compared to children with ASD without sensory sensitivities. This suggests not only that there may be a connection between sensory sensitivities and cognitive and adaptive abilities in children with ASDs, but also that the relationship may be positive rather than negative. Further research is necessary to further explore this pattern.

Research should further examine the relationship between sensory sensitivities and cognitive and adaptive abilities in order to shed light on the role of sensory sensitivities in the ASD population. Determining differences, or lack thereof, between individuals with and without these sensitivities would yield a clearer understanding of the mechanisms that underlie the disorders.

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Appendix

Table 1

Sample Demographics

Variable	SS Present	SS Absent	Significance
Age (<i>M, SD</i>)	23.69(2.66)	23.23(5.33)	$t(27) = .310, p=.759$
Gender (N, (%))			Fisher's Exact Test, $p=.671$
Male	12 (41.4%)	9 (31.0%)	
Female	6 (20.7%)	2 (6.9%)	
Eval Dx (N, (%))			Fisher's Exact Test, $p=.362$
Autistic Disorder	7 (24.1%)	5 (17.2%)	
ASD (low MA)	2 (6.9%)	3 (10.3%)	
PDD-NOS	9 (31.0%)	3 (10.3%)	
Ethnicity (N, (%))			Fisher's Exact Test, $p=.557$
White	11 (37.9%)	7 (24.1%)	
Asian or Pacific Islander	1 (3.4%)	2 (6.9%)	
Black or African American	3 (10.3%)	2 (6.9%)	
Hispanic/Latino	3 (10.3%)	0 (0.0%)	
Maternal Education (N, (%))			Fisher's Exact Test, $p=.793$
Did not complete HS or GED	2 (6.9%)	2 (6.9%)	
HS Diploma or GED	3 (10.3%)	1 (3.4%)	
Vocational/Tech	1 (3.4%)	0 (0.0%)	
Some college	11 (37.9%)	6 (20.7%)	
Bachelor's degree	1 (3.4%)	2 (6.8%)	

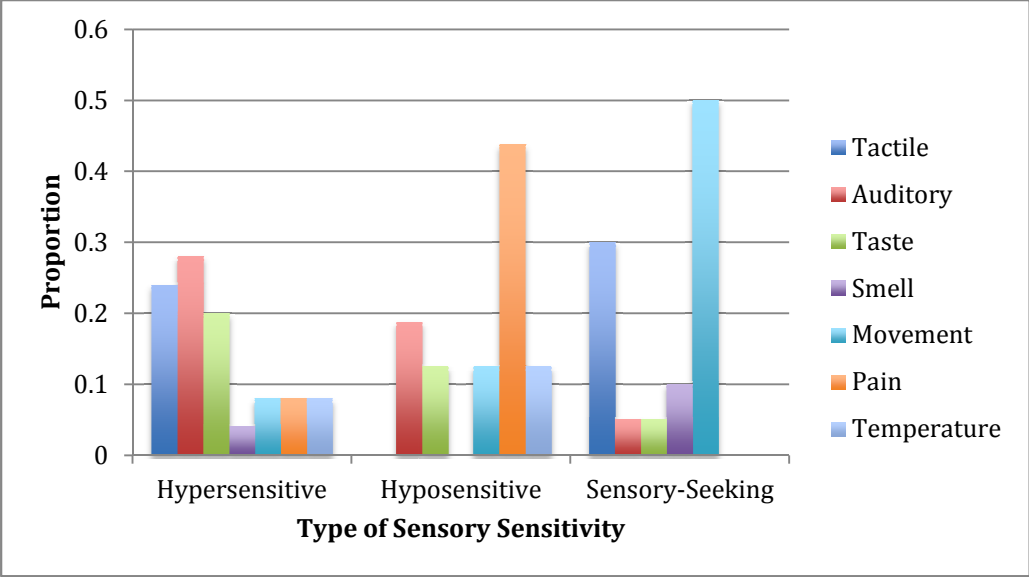


Figure 1. This figure shows the sample proportions of type of sensory sensitivity, broken down by modality.

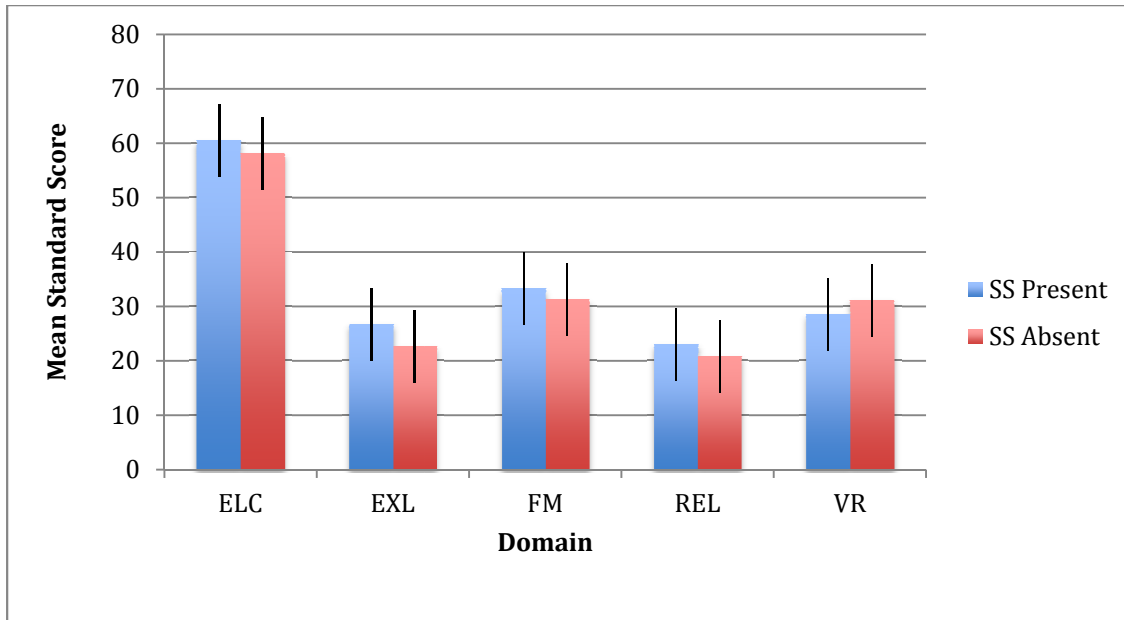


Figure 2. This figure shows group differences on Mullen standard scores. Domains are Early Learning Composite (ELC), Expressive Language (EXL), Fine Motor (FM), Receptive Language (RL), and Visual Reception (VR).

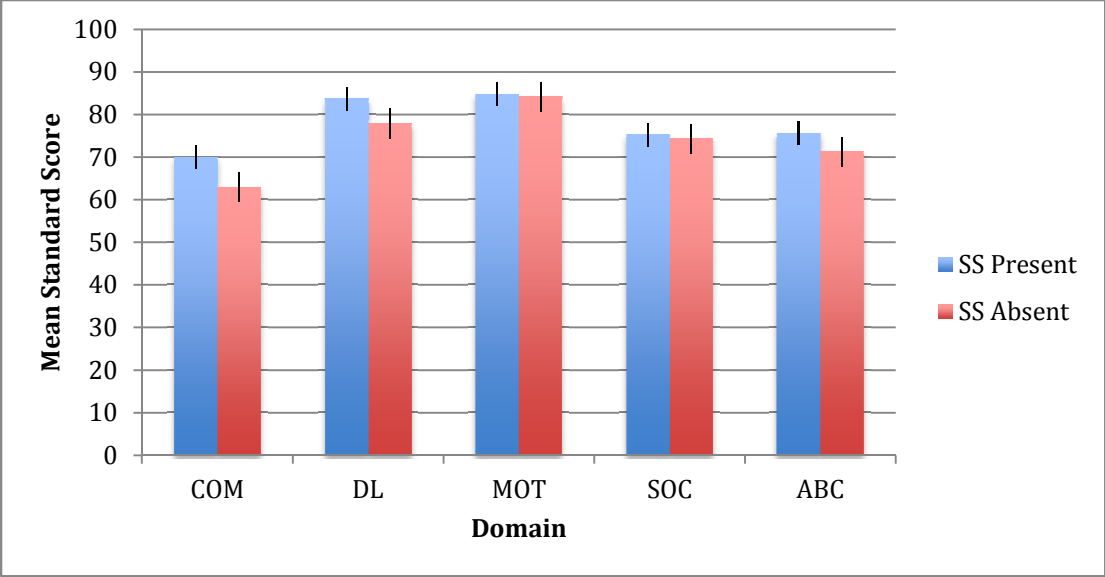


Figure 3. This figure shows group difference on Vineland standard scores. Domains are Communication (COM), Daily Living (DL), Motor (MOT), Social (SOC), and Adaptive Behavior Composite (ABC).