SENSORY PROCESSING PATTERNS IN CHILDREN AND ADULTS ON THE AUTISM SPECTRUM

A Thesis

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Abstract

Introduction: Autism is a neurodevelopmental condition that manifests with differences in social-emotional reciprocity, nonverbal communication, and relationship development, along with restricted and repetitive behaviors and sensory processing issues (CDC, 2020). Although sensory atypicality is part of the diagnostic criteria for autism, there is limited research on sensory processing across the lifespan among those on the autism spectrum. This study examines sensory processing patterns in children and adults on the autism spectrum as compared to neurotypical children and adults.

Methods: The Short Sensory Profile (SSP), a parent-reported questionnaire used to measure sensory behaviors, was collected for 48 child participants (autism: n = 24; typically developing [TD]: n = 24). The Adolescent/Adult sensory profile (AASP), a self-report questionnaire about everyday sensory experiences, was completed by 48 adult participants (autism: n = 24; neurotypical [NT]: n = 24). Analysis of Variance (ANOVAs) was used to analyze group differences and Pearson's correlations were used to examine correlations between sensory processing and age.

Results: Children on the autism spectrum showed significant group differences in all SSP domains compared to the control group (p-values < .05). Adults on the autism spectrum had significant group differences in all four sensory quadrants as well as significant group differences in domain scores for activity level, visual, touch, and auditory processing (p-values < .05). For TD children, no domains significantly correlated with age, and in the autism group, taste/smell sensitivity (r = 0.479, p = 0.018) was the only domain that significantly correlated with age. For NT adults, taste/smell processing (r = -0.519, p = 0.009) and touch processing (r =

-0.538, $p = 0.007$) were the only domains that significantly correlated with age, and low registration ($r = -0.557$, $p = 0.005$) was the only quadrant that significantly correlated with age. For autistic adults, no domains or quadrants significantly correlated with age.
Conclusions: The results suggest that both children and adults on the autism spectrum demonstrate greater sensory processing concerns than the control group. Given the continued persistence of sensory concerns in adulthood, there is a need for more research on strategies to support sensory processing across the lifespan.

Problem Statement

Autism is a neurodevelopmental condition that manifests with differences in social-emotional reciprocity, nonverbal communication, and relationship development, along with restricted and repetitive behaviors and sensory processing issues (CDC, 2020). Based on the CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network, as of 2018, one in 44 children has been diagnosed with autism (CDC, 2020). Sensory processing allows individuals to detect, modify, differentiate, and respond to sensory input from one's environment. Sensory processing was added as a symptom of autism as of the DSM-5 (American Psychiatric Association, 2013). Hyper- or hypo-responsivity to sensory input were added as part of four possible criteria, of which two must be met, under the restrictive and repetitive behaviors diagnostic criteria for autism. Research has continuously shown the importance of sensory processing as crucial to a full understanding of autism. Some sensory symptoms have even been recorded in 6-month-olds diagnosed with autism (Estes et al., 2015). Tomchek and Dunn (2007) showed that 95% of autistic children had some amount of sensory processing variance. Although sensory atypicality is now part of the diagnostic criteria for autism, there is limited research on

sensory processing across the lifespan among those on the autism spectrum. Moreover, there is even less research focused on comparing the differences in sensory processing between autistic children and adults.

Existing research on sensory processing in adults on the autism spectrum shows mixed results. Crane et al. (2009) examined sensory processing in 36 adults, 18 on the spectrum (18-65 years old) and 18 neurotypical (NT) adults as a comparison group (19-64 years old). The study showed that autistic adults reported significant sensory issues compared to neurotypical peers, however, they did not find a correlation between age and sensory processing, concluding that unusual sensory processing is lifelong in autism, and does not seem to change with age. On the other hand, Mayer and Heaton (2014) showed a positive correlation between age and sensory processing in their study of 38 participants, 19 autistic adults (23-59 years old) and 19 neurotypical adults (25-52 years old). They showed that increased age and sensory sensitivity predicted issues with perception (Mayer & Heaton, 2014). Compared to the neurotypical group, those on the spectrum were also more affected by age-related processing challenges, like cognitive slowing (Mayer & Heaton, 2014). A larger study by Mayer (2017) focused on the relationship between traits of autism and atypical sensory functioning between 591 neurotypical adults (mean age of 23.56) and 42 autistic adults (mean age of 35.07). The study showed a significant relationship between age and the social skills, communication, and attention-switching subscales of the autism spectrum quotient (AQ), but not for attention to detail or imagination (Mayer, 2017). This study was the first evidence showing that the strength and pattern between sensory functioning and autistic traits are identical for neurotypical and autistic adults (Mayer, 2017). Mayer (2017) also showed that atypical sensory symptoms occur in the neurotypical population as well.

A universal approach to evaluating differences in sensory profiles of those on the autism spectrum does not yet exist (DuBois et al., 2017). Many researchers utilize the Sensory Profile or Short Sensory Profile (Dunn, 1999). The Short Sensory Profile (SSP) is an abridged version of the Sensory Profile for children on the spectrum (Dunn, 1999) and is a parent-report measure. The SSP measures seven domains of sensory behaviors: tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity (Dunn, 1999). The categories of the Sensory Profile are sorted into four quadrants of sensory abnormalities: low registration, sensation seeking, sensory sensitivity, and sensation avoiding (Dunn, 1999). Parents usually complete the survey on behalf of their children, which can cause biases in reporting and has shown only moderate agreement with direct assessments (Tavassoli et al., 2019). The Adolescent/Adult Sensory Profile (AASP) is a self-report questionnaire for ages 11 and above, containing 60 items based upon six categories: taste/smell, movement, visual, touch, activity, and auditory processing (Dunn, 1999). Other researchers recommend direct observation or the Sensory Profile Checklist-Revised (Gonthier et al., 2016).

Sensory processing abnormalities can have a cascading effect on the lives of those on the spectrum (Thye et al., 2018). Sensory differences can cause problems with foundational abilities like auditory, visual, tactile, and oral sensation (van Heijst & Geurts, 2015), which then can lead to difficulties in tasks of higher-order functioning such as language, communication, academics, and careers. Challenges in these areas can negatively impact the quality of life for the individual, which could explain the poor quality of life reported for some of those on the spectrum compared to NT peers (van Heijst & Geurts, 2015). A better understanding of sensory profile patterns will help researchers better identify their effects on social performance (Hilton et al., 2007), improve

diagnostic accuracy, and symptom management for those of all ages on the autism spectrum. Therapy addressing the sensory needs of autistic children and adults can help with acclimation to social settings and independent living. The goal of this research is to examine sensory processing in autistic children and adults. Findings from this study will potentially contribute to research supporting the development of tailored interventions driven by sensory profiles to enable people to achieve a better quality of life and become more independent.

Identity-First Language Statement

In alignment with a majority of the autistic community (Taboas et al., 2023), this article will be using identity-first language. Many in the autistic community see neurodiversity as a crucial part of their identity and prefer that the language used reflect these views (Taboas et al., 2023).

Literature Review

Background

Autism is a neurodevelopmental condition that manifests with differences in social-emotional reciprocity, nonverbal communication, relationship development, along with restricted and repetitive behaviors and sensory processing issues (CDC, 2020). For someone to receive an autism diagnosis, they must also have at least two of the following characteristics: repetitive movements, inflexible routine, fixated interests, or hyper- or hypoactivity to sensory input (CDC, 2020). Autism is distinguished by difficulties in three domains: social interaction, communication, and repetitive behaviors (Kamp-Becker et al., 2010). Based on the CDC's ADDM Network, as of 2018, one in 44 children has been diagnosed with autism (CDC, 2020). The number of people diagnosed with autism has consistently increased over the past 20 years, and boys have been shown to be diagnosed with autism four times more frequently than girls

(Sharma et al., 2018). Autism is a lifelong condition and has been shown to have an impact on quality of life, but its developmental trajectory is not well-known (van Heijst & Geurts, 2015).

Sensory Processing in Autism

Since the inclusion of sensory processing differences into the DSM-5 (American Psychiatric Association, 2013), research has focused on how sensory processing differs in autism and how it affects daily life. Sensory processing allows individuals to detect, modify, differentiate, and respond to sensory input from one's environment (Miller et al., 2017). Tomchek and Dunn (2007) showed that 95% of children (3 to 6 years old) in their autism sample had some amount of sensory processing variance. A systematic review completed by Dellapiazza et al. (2018) showed atypical sensory processing in 82% to 97% of the participants on the spectrum. Kanner (1943) even included sensory differences in autistic individuals in his original description of autism. Sensory differences have even been recorded in 6-month-olds diagnosed with autism (Estes et al., 2015).

Sensory input affects all parts of daily living and one's environment is impacted consciously and unconsciously by their sensory information (Mayer, 2017). Knowing the sensory processing patterns of autistic children helps their occupational therapists better understand their daily experiences and how the patterns impact their daily activities (Ismael et al., 2018).

Current scales used to assess sensory processing in individuals are the Sensory Profile, with variations including the Short Sensory Profile (SSP) and the Adolescent/Adult Sensory Profile (AASP) to assess sensory processing according to one's age. The AASP is a 60-item questionnaire focused on six categories: taste/smell, movement, visual, touch, activity, and auditory processing (Dunn, 1999). The SSP is an abridged, 38-item parent-reported version of

the Sensory Profile (Dunn, 1999). The SSP measures seven domains of sensory behaviors: tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive/seeks sensation auditory filtering, low energy/weak, and visual/auditory sensitivity (Dunn, 1999). The Sensory Profile categories are sorted into four quadrants of sensory abnormalities: low registration, sensation seeking, sensory sensitivity, and sensation avoiding (Dunn, 1999). Low registration refers to a high neurological threshold and passive behavioral response, while sensation seeking also refers to a high neurological threshold, but an active behavioral response. Sensory sensitivity refers to a low neurological threshold and passive behavioral response, while sensation avoiding also refers to a low neurological threshold, but an active behavioral response. The reported information helps professionals understand how the person processes sensory stimuli.

Research has continuously shown the importance of sensory processing in understanding autism. Robertson and Baron-Cohen (2017) discussed the sensory experiences of those on the autism spectrum as 'seeing the trees, but not the forest,' meaning there is a focus on perceptual details instead of global processing. In children on the spectrum (ages 6 – 10 years), Hilton et al. (2007) showed that Dunn's quadrant scores discriminated well against the Social Responsiveness Scale (SRS) in autistic children, suggesting that sensory processing is a function of autism severity. This means that children's ability to process their environment's sensory information may impact their ability to socialize (Hilton et al., 2007). Atypical sensory processing may manifest differently among autistic individuals, however, those on the spectrum often have severe sensory processing compared to NT peers (Crane et al., 2009). Kern et al. (2007) completed a study with 104 participants on the spectrum (3-56 years old) and showed that auditory, visual, touch, oral, and multisensory processing are affected in autism, suggesting

global sensory processing issues. Although sensory atypicality is now part of the diagnostic criteria for autism, there is limited research on sensory processing across the lifespan among those on the autism spectrum. Moreover, there is even less research focused on the associations between age and sensory processing for autistic children and adults.

Patterns of Sensory Processing in Children

Studies examining patterns of sensory processing in autistic children have shown specific differences between those on the spectrum as compared to typically developing (TD) peers. Crasta et al. (2020) assessed sensory processing and attention profiles in autistic children (ages 6 – 13 years) and showed that 95.8% of the children on the autism spectrum had a probable or definite difference in their sensory processing. Most children on the spectrum scored in the "probable difference" or "definite difference" range in all levels of the quadrants: low registration, sensation seeking, sensory sensitivity, and sensation avoiding (Hilton et al., 2007). Hilton et al. (2007) showed that the sensory sensitivity and sensation avoiding quadrants were the most strongly correlated with the SRS. Tomchek and Dunn (2007) found significant differences in sensory processing in autistic children in eight of the ten factors on the Short Sensory Profile: Sensory Seeking, Emotionally Reactive, Low Endurance/Tone, Oral Sensitivity, Inattention/Distractibility, Poor Registration, Fine-Motor/Perceptual, and Other. Lane et al. (2010) completed a study with 54 autistic children (33 to 115 months) and showed a majority of the children had definite differences in under responsiveness/seeks sensation and auditory filtering compared to the TD group. Lane et al. (2010) showed 92.6% of the children presented dysfunction in auditory filtering. Lane et al. (2010) suggested that auditory filtering, taste/smell sensitivity, and low energy/weak may be especially important in understanding autistic children's sensory profiles.

Robertson and Baron-Cohen (2017) took a neurobiological approach that indicated reduced GABAergic signaling inhibition, shown in two magnetic resonance spectroscopy (MRS) studies, may explain various sensory symptoms in autism. Robertson and Baron-Cohen (2017) also completed auditory tone tests with participants on the autism spectrum and showed that a delay in the response to auditory stimulation predicted the severity of autism. Robertson and Baron-Cohen (2017) mentioned the canonical micro-circuitry view, which is based on genetic studies that suggest differences in synaptic connectivity, signaling, and plasticity in those on the autism spectrum. Currently, there is limited research examining causal factors associated with sensory processing issues in autism and further research is warranted in this area.

Impacts of Sensory Processing Challenges

Abnormalities of sensory processing can impact children's abilities to develop age-appropriate social skills as well as inhibit their academic success. Ashburner et al. (2008) analyzed the effect of sensory processing on classroom and educational outcomes for 51 autistic children (6-10 years). The results showed that sensory seeking, sensory under-responsiveness, and issues with auditory filtering were correlated with academic underachievement. Students who struggled to process verbal instructions in loud environments and showed significantly high sensory seeking behaviors were predicted to underachieve in school settings (Ashburner et al., 2008).

Children on the autism spectrum also have difficulties with certain activities of daily living (ADL) and struggle with communication, especially language. Baranek et al. (2013) studied hyporesponsiveness to sensory stimuli in 127 children, 63 on the spectrum, and showed significant negative correlations between sensory hyporesponsiveness and both expressive and receptive language. These correlations may explain the cascading impact of sensory

hyporesponsiveness and behavioral difficulties with those on the spectrum. Hilton et al. (2007) also noted that low registration behaviors may explain the challenges children on the autism spectrum face during social communication. Understanding autistic children's sensory subtypes can help to identify autism and create specific interventions to improve functioning and quality of life (Simpson et al., 2019). Hilton et al. (2007) hypothesized that each of the four sensory profile quadrants impact an autistic child in a specific way, which changes the way they communicate socially. Sensory processing challenges are important to address because of the diverse effect they may have on autistic children's daily life.

Patterns of Sensory Processing in Adults on the Spectrum

Research has evaluated patterns of sensory processing in autistic adults, but the results correlating sensory symptoms and age are mixed. Crane et al. (2009) examined sensory processing in 36 adults, 18 on the spectrum (18-65 years old) and 18 neurotypical adults as a comparison group. The study showed that adults on the spectrum reported significant sensory differences, however, they did not find an association between age and sensory processing. However, Mayer and Heaton (2014) showed a correlation between age and sensory processing in their study of 38 participants, 19 autistic adults (23-59 years old) and 19 neurotypical adults (2552 years old). Their results revealed that increased age and sensory sensitivity predicted issues with perception (Mayer & Heaton, 2014). Mayer and Heaton (2014) showed speech processing difficulties were most common in older adults on the spectrum as well as those with more self-reported sensory symptoms. The study by Mayer (2017) involved 591 neurotypical adults (mean age of 23.56) and 42 autistic adults (mean age of 35.07) and aimed to further understand the relationship between autistic traits and atypical sensory functioning. The study showed a significant relationship between the subscales of the autism spectrum quotient (AQ)

except for increased attention to detail and challenges with the imagination (Mayer, 2017). The study completed by Mayer (2017) is the first evidence that shows that the strength and correlation between sensory functioning and autistic traits are identical for neurotypical and autistic adults. Mayer (2017) also provided evidence that atypical sensory symptoms occur in the neurotypical population as well.

Crane et al. (2009) showed adults on the spectrum had higher scores in low registration, sensory sensitivity, and sensation avoidance, and lower scores in sensation seeking than the neurotypical group. Gonthier et al. (2016) completed a study regarding sensory profiles with 148 participants on the autism spectrum (19-59 years old) and 148 neurotypical participants (19-62 years old). They showed that the autistic participants had significantly more low registration behaviors, as well as significantly less sensation seeking, sensory sensitivity, and sensation avoiding behaviors (Gonthier et al., 2016).

Mayer (2017) showed that hyper-responsiveness to sensory input from the environment may be a more reliable way to differentiate neurotypical and autistic sensory processing. Mayer (2017) suggested that increased hyperresponsiveness and levels of autistic traits could explain a neurological processing style where the sensory channel is too open, causing more stimulation than the brain can handle.

A study by van den Boogert et al. (2021) consisting of 101 adult participants (mean age of 32.9) showed an association between sensory processing differences and aggressive behaviors. The more sensory differences identified, the higher the levels of aggressive behavior (van den Boogert et al., 2021). Autistic adults with more sensory seeking profiles, showed more anger and proactive and reactive aggression, while those with more low registration profiles showed more proactive aggression (van den Boogert et al., 2021). Autistic adults with more sensory sensitives

showed more reactive aggression and anger and had the highest risk of aggressive behavior (van den Boogert et al., 2021).

The research implies that sensory processing abnormalities are common and continue throughout life for those on the autism spectrum. Crane et al. (2009) concluded that 94.4% of the autistic adult participants had extreme levels of sensory symptoms in at least one quadrant of the AASP. Gonthier et al. (2016) concluded that autistic adults who are low functioning are particularly at risk for sensory symptoms because they have few ways to cope with troubling stimuli. However, Kern et al. (2007) did not observe a significant correlation between sensory symptoms and severity of autism, except between the Child Autism Rating Scale (CARS) and visual high threshold processing, suggesting that sensory differences only correlated with severity of autism in children, not adults.

While certain symptoms of autism may diminish with age, others persist, causing difficulties with ADLs and communication. Mayer and Heaton (2014) showed that compared to the NT group, those on the spectrum were more affected by age-related processing decline, which suggests that autistic adults are more likely to experience age-related processing difficulties, like cognitive slowing. Further research analyzing sensory processing patterns is needed to improve the diagnostic criteria for autism, as well as treat its symptoms and holistically understand the spectrum.

Call for Action

In the current study, we aim to identify and compare the sensory processing patterns in children and adults on the autism spectrum. This study is necessary because there is a lack of knowledge about sensory processing patterns between childhood and adulthood. Tomchek and Dunn (2007) note that more clearly defined sensory processing patterns of those on the spectrum

are needed. Different suggestions have been made to improve sensory processing knowledge such as combined "naturalistic and structured observations" (DuBois et al., 2017) or a "systematic scoping review" (Mayer & Heaton, 2014). DuBois et al. (2017) also recommend evaluating sensory symptoms with multiple techniques while diagnosing autism to understand what problematic behaviors are related. They also recommend interdisciplinary collaboration to understand sensory processing (DuBois et al., 2017). Combinations of different approaches may provide more knowledge about the cognitive and neurological bases of sensory symptoms and daily functioning (DuBois et al., 2017).

Additional research needs to be conducted to diminish existing contradictions within the research. Crane et al. (2009) did not find a correlation between age and sensory processing, but others did (Kern et al, 2006; Kern et al, 2007; Mayer & Heaton, 2014). Research also shows that global motion processing in those on the spectrum evolves more slowly over time (Robertson & Baron-Cohen, 2017), but unusual sensory processing does continue across the lifetime (Crane et al., 2009). A better understanding of this relationship can improve and help tailor therapy for different age populations and may help clinicians avoid mistakes in skills assessment, improve therapy progression, and improve outcomes (Thye et al., 2018).

Sensory symptoms differ for each person on the spectrum and affect their ability to socialize and communicate, indicating that therapy must be individualized for each person (Thye et al., 2018). Understanding patterns of sensory processing at all ages could contribute to individualized interventions for a person's unique sensory needs and, ultimately, improve their quality of life. Sensory-based intervention may help care for low-functioning people on the autism spectrum and prevent maladaptive behaviors from forming (Lane et al., 2010). A further understanding of sensory processing may also help prevent and provide care for other

developmental and behavioral disorders with sensory needs (Gonthier et al., 2016). This research has the potential to contribute to future studies focused on other disorders with sensory symptoms, such as schizophrenia and attention deficit hyperactivity disorder (ADHD) because sensory processing can appear differently depending on the condition.

Sensory processing abnormalities can have a cascading effect on the lives of those on the spectrum (Thye et al., 2018). Sensory differences can cause problems with foundational abilities like auditory, visual, tactile, and oral sensation registration, which then can lead to difficulties in higher-order tasks, such as language and communication. This can then cause challenges in academic and career settings. Difficulties in these areas can impact the quality of life for the individual, which explains the large difference in quality of life between autistic and neurotypical individuals (van Heijst & Geurts, 2015). Understanding sensory symptoms and subtypes can help create "autism-considerate" environments that account for environmental challenges faced by those on the spectrum (Simpson et al., 2019). Mayer (2017) recommended taking a global approach when creating these spaces to ensure all sensory differences are accommodated.

Goal of Study

Further evaluation of sensory processing across the lifespan of those on the autism spectrum will provide a better understanding of the age correlations that have been identified. A better understanding of sensory symptom patterns will help researchers better identify their effects on social performance (Hilton et al., 2007). The ultimate goal of this research is to develop tailored interventions to enable people to achieve a better quality of life and become more independent. Understanding the trajectory of sensory symptoms in autism can help those on the spectrum make specialized adjustments throughout their lives (van Heijst & Geurts, 2015). It is important to address independence and daily living skills because they are correlated

with higher health-related quality of life (HRQOL) (Kamp-Becker et al., 2010). While having autism seems to lower HRQOL compared to NT individuals, (Kamp-Becker et al., 2010), the age of those on the spectrum does not seem to have an impact on quality of life (van Heijst & Geurts, 2015).

The goal of the study is to examine sensory processing patterns in autistic children and adults compared to neurotypical children and adults.

Objectives of the Study

This study aims to examine sensory processing patterns in children and adults on the spectrum as compared to neurotypical children and adults. The study's primary research questions and hypotheses include:

1. Do sensory processing patterns differ in autistic children compared to typically developing children?

Hypothesis: Autistic children will demonstrate greater sensory processing issues than typically developing children.

2. Do sensory processing patterns differ in autistic adults compared to neurotypical adults?

Hypothesis: Autistic adults will demonstrate greater sensory processing issues than neurotypical adults.

3. Within the autism group, do correlations between age and sensory processing patterns differ between children and adults?

Hypothesis: Correlations between age and sensory processing will remain consistent between autistic children and adults.

Methods

This project includes secondary analyses of a subset of data that were collected as part of a doctoral dissertation (Crasta, 2017). All study procedures were approved by the local university's Institutional Review Board (IRB) prior to data collection. IRB approval was not required at The Ohio State University since this project includes de-identified data.

Participants.

Child participants. This study also included twenty-four children (M = 8.24 years, SD = 1.39; 19 males, 5 females) with a confirmed diagnosis of autism based on the DSM-5 or Asperger's syndrome/autism based on the DSM-IV-TR from a medical or psychological professional. The control group included twenty-four TD children (M = 7.67 years, SD = 0.86; 17 males, 7 females). The control group participants were composed of children from the community who had no known physical, neurological, or behavior disorders and had not previously received any therapy services as reported by their parents.

Adult participants: This study included a total of 48 adult participants recruited via convenience sampling. Twenty-four participants (*M* = 23.31 years, *SD* = 3.77; 17 males, 7 females) had a confirmed diagnosis of autism. The control group consisted of twenty-four age-matched neurotypical individuals (*M* = 23.7 years, *SD* = 3.51; 12 males, 12 females). There was no group difference in age ($t_{(46)} = .41$, $p = .69$). The diagnosis of autism was confirmed using the Autism Diagnostic Observation Schedule 2 (ADOS-2; Lord, Rutter, DiLavore, Risi, Gotham, & Bishop, 2012). All participants in the control group were screened using a self-report questionnaire that they are free of neurological injuries, disabilities, and family histories of psychological disorders.

Experimental Design

Parents of autistic children and TD controls completed the parent-report Sensory Profile. The adult participants with and without autism completed the self-report AASP.

Behavioral Measures

Short Sensory Profile (SSP). The SSP is 38-item parent-reported questionnaire used to measure sensory behaviors. Participants' parents filled out the SSP soon before arriving at the lab for the study. It is the abridged version of the Sensory Profile (Dunn, 1999) and can be used as a standardized assessment tool to evaluate sensory processing. An SSP raw score for those over five is relatively independent of age (Dunn, 1999) and has a reliability coefficient of 0.90, and a discriminant validity over 95% (McIntosh et al., 1999). There are seven subscales being assessed: auditory filtering, low energy/weak, under-responsive/seeks sensation, sensitivity to movement, tactile, taste/smell, and visual/auditory. The SSP utilizes a 5-point Likert scale to score the responses, with higher scores suggesting behaviors that are more functional and adaptive. The questionnaire describes a child's sensory processing ability by using a classification system with cut-off values. A "typical performance" classification implies the child performed better than the lowest 16% of the research sample. A "probable difference" classification means the child performed like children in the lowest 14% of the research sample. A "definite difference" classification indicates the child performed like children in the lowest 2% of the research sample. Typical performance is implied with a total score above 155, a probable difference is implied by a total score ranging from 142 to 154, and a definite difference is indicated by a total score below 141.

Adolescent/Adult sensory profile (AASP). The AASP is a self-report questionnaire consisting of 60 items that relate to everyday sensory experiences. The AASP is validated for individuals 11 or older. Each item is scored on a 5-point Likert scale indicating how frequently

the behavior is performed (from 1 “almost never” to 5 “almost always”). The 60 items are organized into six categories of taste or smell, movement, visual, touch, activity level, and auditory sensitivities. The questionnaire takes about 10-15 minutes to complete. The AASP scores are categorized into 4 quadrants based on Dunn's (1997) model of sensory processing, which classifies sensory behaviors based on neurological thresholds (high or low) and behavioral responses (passive or active). Neurological thresholds refer to the amount of stimuli needed for the nervous system to respond to sensory stimuli, and behavioral responses relate to the way in which a person responds to their sensory thresholds. The four quadrants are, 1) Low registration (passive behavioral responses with a high neurological threshold), 2) Sensation seeking (active behavioral responses with a high neurological threshold), 3) Sensory sensitivity (passive behavioral responses with a low neurological threshold, and 4) Sensation avoiding: refers to active behavioral responses with a low neurological threshold. Quadrant scores are classified as “much less than most people” (-2 SD from mean), “less than most people”, “similar to most people”, “more than most people”, and “much more than most people” (+2 SD from mean). Extreme sensory processing is defined as scores falling in either “much less than most people” or “much more than most people”. The AASP has reported reliability (r = .64 - .78) and validity (Brown & Dunn, 2002).

Statistical analyses. Group differences on the SSP for children with and without autism and on the AASP for adults with and without autism were examined using analysis of variance (ANOVAs). We used Pearson’s correlations to examine if age correlates with sensory processing across all participants and within the neurotypical and autistic groups.

Results

Participant Characteristics

Child Participants: There were no group differences on age, $F_{(38.54)}$ -1.69, $p = 0.099$).

Adult Participants: There were no group differences on age, $F_{(46)} = 0.658$, $p = 0.514$).

Sensory Profile Differences in Autistic Children

Children on the autism spectrum had significant group differences in all domains with the largest effect size for auditory filtering ($\eta^2 = 0.52$), followed by under-responsive/seeks sensation ($\eta^2 = 0.43$), tactile sensitivity ($\eta^2 =0.37$), low energy ($\eta^2 = 0.33$), taste/smell sensitivity ($\eta^2 = 0.19$), visual/auditory ($\eta^2 = 0.19$), and movement sensitivity ($\eta^2 = 0.15$). Children on the autism spectrum had significant group differences for the total score ($\eta^2 = 0.44$). See Table 1.

The results support our first hypothesis that children on the autism spectrum will demonstrate greater sensory processing concerns than the control group.

Sensory Profile Differences in Autistic Adults

Adults on the autism spectrum had significant group differences in all quadrants with the largest effect size for low registration ($\eta^2 = 0.32$), followed by sensation avoiding ($\eta^2 = 0.27$), sensation seeking ($\eta^2 = 0.24$), and sensory sensitivity ($\eta^2 = 0.18$).

Adults on the autism spectrum had significantly different group differences in domain scores for visual processing, touch processing, auditory processing, and activity level. Adults on the spectrum showed no group differences in domain scores for movement processing or taste/smell processing. The largest effect size was for activity level ($\eta^2 = 0.32$), followed by auditory processing ($\eta^2 = 0.29$), touch processing ($\eta^2 = 0.17$), visual processing ($\eta^2 = 0.11$), taste/smell processing ($\eta^2 = 0.02$), and movement processing ($\eta^2 = 0.00$).

The results support our second hypothesis that adults on the autism spectrum will demonstrate greater sensory processing concerns than the control group.

Sensory Processing Correlations with Age

Child Domains: In the TD group, no domains significantly changed with age. Auditory filtering ($r = 0.126$), low energy/weak ($r = 0.216$), tactile sensitivity ($r = 0.176$), under-responsive/seeks sensation ($r = 0.104$) movement sensitivity ($r = 0.135$), and taste/smell sensitivity ($r = -0.211$) showed no correlation with age.

In the autism group, taste/smell sensitivity ($r = 0.479$, $p = 0.018$) was the only domain that significantly changed with age. As age increased, autistic children's taste/smell sensitivity improved, meaning sensitivity decreased. No other domains significantly changed with age for children on the spectrum, however, tactile sensitivity ($r = 0.309$) and age were moderately correlated, while auditory filtering ($r = 0.195$) under-responsive/seeks sensation ($r = 0.254$), low energy/weak ($r = -0.249$) and movement sensitivity ($r = -0.239$) were not correlated with age.

Across both groups, no domains significantly changed with age. Auditory filtering ($r = 0.068$), low energy/weak ($r = -0.260$), under-responsive/seeks sensation ($r = -0.006$), movement sensitivity ($r = -0.137$), taste/smell sensitivity ($r = 0.129$) and tactile sensitivity ($r = 0.086$) were not correlated with age.

The total sensory profile score for the typically developing group ($r = 0.135$, $p = 0.529$) and the autism group ($r = 0.241$, $p = 0.257$) did not significantly change with age.
Across both groups the total sensory profile score ($r = -0.023$, $p = 0.879$) did not significantly change with age.

Adult Domains: In the neurotypical group, taste/smell processing ($r = -0.519$, $p = 0.009$) and touch processing ($r = -0.538$, $p = 0.007$) were the only domains that significantly changed with

age. As age increased, neurotypical adults' taste/smell processing and touch processing improved. No other domains significantly changed with age for neurotypical adults, however there was a moderate correlation between activity level (r = -0.322) and age, while movement processing (r = -0.127), visual processing (r = -0.013), and auditory processing (r = -0.273) were not correlated with age.

In the autism group, no domains significantly changed with age. Although not significant, taste/smell processing moderately improved (r = 0.310) with age, while movement processing (r = 0.004), visual processing (r = 0.251), touch processing (r = 0.129), activity level (r = 0.024), and auditory processing (r = -0.037) were not correlated with age.

Across both groups, no domains significantly changed with age. Taste/smell processing (r = -0.156), movement processing (r = -0.044), activity level (r = -0.135), auditory processing (r = -0.177), touch processing (r = -0.153), and visual processing (r = 0.110) were not correlated with age.

Adult Quadrants: In the neurotypical group, low registration (r = -0.557, p = 0.005) was the only quadrant that significantly changed with age. As age increased in neurotypical adults, low registration decreased. No other quadrants significantly changed with age for neurotypical adults, however, sensory sensitivity moderately decreased with age (r = -0.351), while sensation seeking (r = -0.158) and sensation avoiding (r = -0.092) were not correlated with age.

In the autism group, no quadrants significantly changed with age. Low registration (r = 0.103) and sensation seeking (r = -0.042), sensory sensitivity (r = 0.195) and sensation avoiding (r = 0.185) were not correlated with age.

Across both groups, low registration (r = -0.280, p = 0.054) significantly decreased with age. Sensation seeking (r = -0.027) sensory sensitivity (r = -0.030) and sensation avoiding (r = 0.027) were not correlated with age.

The results support our third hypothesis that correlations between age and sensory processing will remain consistent between autistic children and adults.

Table 1. Means, standard deviations (SD), and group differences in behavioral measures.

Assessment	Autism Mean (SD)	Typically Developing Mean (SD)	*F*	*p*	Effect Size (η^2)
Short Sensory Profile (SSP) Variables					
Auditory filtering	14.58 (4.45)	23.42 (3.70)	36.15	**<.001**	0.52
Low energy/weak	21.29 (7.44)	28.54 (2.84)	16.22	**<.001**	0.33
Movement sensitivity	12.13 (2.49)	12.83 (2.22)	5.80	**.005**	0.15
Tactile sensitivity	26.25 (5.97)	32.50 (2.96)	19.08	**<.001**	0.37
Taste/smell sensitivity	12.83 (5.19)	17.46 (3.19)	7.52	**.001**	0.19
Underresponsive/Seeks sensation	19.46 (5.53)	27.71 (4.30)	24.73	**<.001**	0.43
Visual/auditory sensitivity	17.04 (4.23)	19.88 (3.19)	7.93	**<.001**	0.19
Total	162.33 (15.20)	102.14 (41.56)	26.18	**<.001**	0.44

Note: Group differences are examined using analysis of variance. Effect sizes for η2 are interpreted as follows, .01 – small, .06 – medium, and .14 – large (Richardson, 2011).

Table 2. Means, standard deviations (SD), and group differences in behavioral measures.

Assessment	Autism Mean (SD)	Neurotypical Mean (SD)	*F*	*p*	Effect Size (η^2)
Adolescent and Adult Sensory Profile (AASP) Quadrants and Domains					
Low Registration	39.38 (8.73)	29.46 (5.90)	21.32	**<.001**	0.32
Sensation Seeking	41.21 (8.80)	49.63 (6.10)	14.86	**<.001**	0.24
Sensory Sensitivity	40.96 (11.85)	32.33 (6.42)	9.83	**.003**	0.18
Sensation Avoiding	46.08 (11.97)	34.67 (6.32)	17.08	**<.001**	0.27
Taste/Smell Processing	21.33 (2.91)	20.38 (3.83)	.95	.34	.02
Movement Processing	19.33 (3.76)	19.33 (2.44)	.00	1.0	.00
Visual Processing	27.83 (6.37)	24.25 (4.06)	5.40	**.025**	.11
Touch Processing	34.00 (6.45)	29.08 (4.29)	9.67	**.003**	.17
Auditory Processing	33.79 (5.59)	27.00 (5.40)	18.35	**<.001**	.29
Activity Level	31.33 (4.80)	26.04 (2.90)	21.40	**<.001**	.32

Note: Group differences are examined using analysis of variance. Effect sizes for η2 are interpreted as follows, .01 – small, .06 – medium, and .14 – large (Richardson, 2011).

Discussion

The purpose of the study was to examine sensory processing patterns in children and adults on the autism spectrum as compared to neurotypical children and adults. This study is necessary because there is a lack of knowledge about sensory processing patterns between childhood and adulthood in autism. Overall, we showed significant differences in sensory profile scores between the autistic group and the control group for both the child and adult groups. Children on the autism spectrum had significant group differences in all domains. Adults on the autism spectrum had significant group differences in all quadrants. Autistic adults also had significant group differences in domain scores for visual processing, touch processing, auditory processing, and activity level. These results support our first and second hypotheses that children and adults on the autism spectrum will demonstrate greater sensory processing concerns than the control group. We did not show correlations with age for the autism group. In the child autism group, taste/smell sensitivity was the only domain that significantly changed with age. In the adult autism group, no domains or quadrants significantly changed with age. These results support our third hypothesis that correlations between age and sensory processing will remain consistent between autistic children and adults.

Sensory Processing in Children on the Autism Spectrum

The results of the present study support the hypothesis that children on the autism spectrum will demonstrate greater sensory processing differences than the control group. Children on the autism spectrum had significant group differences in all domains of the SSP: auditory filtering, under-responsive/seeks sensation, tactile sensitivity, low energy/weak,

taste/smell sensitivity, visual/auditory, and movement sensitivity. The largest effect size was seen in auditory filtering, under-responsive/seeks sensation, and tactile sensitivity. The present results are consistent with Tomchek and Dunn (2007) who similarly showed the greatest differences in under-responsive/seeks sensation, auditory filtering, and tactile sensitivity. Kojovic et al. (2019) also completed a study with 64 autistic and 36 TD participants, ages 3-6, and showed significant group differences in all SSP domains and the largest effect size in auditory filtering and under-responsive/seeks sensation. Lane et al. (2010) also reported that a majority of the children on the spectrum had differences in under-responsive/seeks sensation and auditory filtering compared to the control group. However, Lane et al. (2010) suggested that low energy/weak may be the third factor that is important in understanding autistic children's sensory profiles, not tactile sensitivity. This difference in results could be due to the use of the SSP, which is parent-reported and may leave room for slightly different interpretations of sensory symptoms. These results are partially consistent with the research completed by McCormick et al. (2016). The study included 29 autistic and 24 TD participants and showed that children on the spectrum had significant group differences in auditory filtering, tactile sensitivity, low energy/weak, and taste/smell sensitivity. In contrast to our results, McCormick et al. (2016) did not show significant group differences in under-responsive/seeks sensation, visual/auditory, or movement sensitivity. The difference in results could be due to differences in study design and age range of the children. McCormick et al. (2016) completed a longitudinal study following the participants, ages 2-8 years old, across three time points.

Sensory Processing in Adults on the Autism Spectrum

The results of the present study support the hypothesis that adults on the autism spectrum will demonstrate greater sensory processing concerns than the control group. Adults on the

autism spectrum showed significant group differences in four of the six domains of the AASP: visual processing, touch processing, auditory processing, and activity level. The current results are fairly consistent with the previous literature. Kern et al. (2006) reported that there were significant main effects for the autism group in visual processing, touch processing, auditory processing, and oral processing, suggesting greater sensory concerns. This study did not evaluate activity level, movement processing, or taste/smell processing. These differences could be due to these studies having a larger sample size of 104 participants across a larger age range, from 3 to 56 years old, as well as having a slightly different focus on specific sensory processing instead of all 6 domains of the AASP.

Adults on the autism spectrum had significant group differences in all four quadrants: low registration, sensation seeking, sensory sensitivity, and sensation avoiding. This pattern of results is consistent with the previous literature showing significant differences between the autistic and neurotypical group. However, the differences in mean scores are not the same across studies. This study's group differences show more low registration, more sensation seeking, less sensory sensitivity, and more sensation avoiding behaviors than the neurotypical group. However, Crane et al. (2009) show adults on the spectrum have less sensation seeking and more sensory sensitivity behaviors than the neurotypical group. While Gonthier et al. (2016) show adults on the spectrum have less sensation seeking and less sensation avoiding behaviors than the neurotypical group. Clince et al. (2016) showed slightly different results showing significant group differences in all domains, but the autism group had higher mean scores in low registration, sensory sensitivity, and sensation avoiding, and lower mean scores in sensation seeking than the standardization group. These differences in results could be from differing recruitment strategies for autistic participants. Crane et al. (2009) used participants involved in

the National Autistic Society (UK) and other social groups for adults on the spectrum. Gonthier et al. (2016) recruited participants who were permanent residents in inpatient care facilities in France and had profound to severe intellectual disabilities. Clince et al. (2016) collected data from 27 autistic students in higher education and used an AASP standardization group for comparison.

Sensory Processing and Age

The results of the present study support the hypothesis that correlations between age and sensory processing will remain consistent between autistic children and adults. The only domain that shows significant differences with age is taste/smell sensitivity for children on the autism spectrum. As age increased from 6-13 years, taste/smell sensitivity improved, meaning sensitivity decreased. When looking at the adult scores, no domains or quadrants significantly change with age for the autistic group. The child control group showed no significant changes with age, but the adult control group showed significant improvement with age in the taste/smell processing and touch processing domains and the low registration quadrant. The small sample size of the study may have prevented us from finding significant relationships due to a lack of power. The current research regarding sensory processing correlations with age shows mixed results, so the present results are consistent with some of the literature. Crane et al. (2009) similarly show that there was no significant correlation between age and sensory symptoms in 36 adults, ages 18 to 65. In a study completed by Dwyer et al. (2020) autistic and TD children were tested at two points in time, between the ages of 2-5 and later 4-10, to compare sensory behaviors. The researchers showed that most children on the spectrum were placed in the “Stable Intense” class, meaning their sensory symptoms were stable over time, but more severe (Dwyer et al., 2020). For the TD group, more participants were placed in the “Stable Mild” class,

meaning their sensory symptoms did not change over time and they did not experience difficulties with sensory behaviors (Dwyer et al., 2020). However, Lane et al., 2022) showed for the first time in a sample of 919 participants (2-17 years old) that only sensory hyper-reactivity symptoms, specifically sensory sensitivity and avoidance, were correlated with age. Lane et al. (2022) did not show correlations with age for hypo-reactivity. Kern et al. (2007) show that sensory symptoms become less abnormal as age increases in a sample of 104 participants (3-56 years old). In a previous study, Kern et al. (2006) also show that as age increases, the autistic group became more similar in auditory, visual, oral, and touch processing to the control group (n = 104, 3-56 years old). These differences could be due to these studies having a larger sample size of 104 participants across a larger age range, from 3 to 56 years old (Kern et al., 2006; Kern et al., 2007). Lane et al. (2022) also had a larger sample size consisting of 919 participants between the ages of 2-17.

Limitations and Future Directions

Certain limitations of this study could be addressed in future research. This study has a relatively small sample size, and studies with a larger sample size may improve the accuracy and generalizability of the results. The current study also does not include non-verbal participants, those with more severe symptoms, or those with co-morbidities, thus, a study including participants across the entire spectrum will be more representative of the autism population. This study is a cross-sectional design, and using a different study design, such as a longitudinal study may provide a more accurate interpretation of changes with age.

Conclusions

Despite these limitations, the present study has enhanced our understanding of the relationship between sensory processing in adults and children on the spectrum compared to NT individuals, as well as our understanding of how sensory processing changes with age. The study indicates that children and adults on the autism spectrum have significantly different sensory profiles than their NT peers. The results also suggest that sensory processing does not significantly change with age for both the autistic and NT groups. The implications of these results may help design therapy addressing the sensory needs of individuals on the autism spectrum to help acclimate them to social settings and independent living. We hope that the current research will stimulate further investigation of the sensory processing profiles of those on the spectrum.

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