Sensory Symptoms in Autism Spectrum Disorders

Eric P. Hazen, MD, Jennifer L. Stornelli, MOT, OTR/L, Julia A. O'Rourke, PhD, MS, MMSc, Karmen Koesterer, EdM, and Christopher J. McDougle, MD

The aim of this review is to summarize the recent literature regarding abnormalities in sensory functioning in individuals with autism spectrum disorder (ASD), including evidence regarding the neurobiological basis of these symptoms, their clinical correlates, and their treatment. Abnormalities in responses to sensory stimuli are highly prevalent in individuals with ASD. The underlying neurobiology of these symptoms is unclear, but several theories have been proposed linking possible etiologies of sensory dysfunction with known abnormalities in brain structure and function that are associated with ASD. In addition to the distress that sensory symptoms can cause patients and caregivers, these phenomena have been correlated with several other problematic symptoms and behaviors associated with ASD, including restrictive and repetitive behavior, self-injurious behavior, anxiety, inattention, and gastrointestinal complaints. It is unclear whether these correlations are causative in nature or whether they are due to shared underlying pathophysiology. The best-known treatments for sensory symptoms in ASD involve a program of occupational therapy that is specifically tailored to the needs of the individual and that may include sensory integration therapy, a sensory diet, and environmental modifications. While some empirical evidence supports these treatments, more research is needed to evaluate their efficacy, and other means of alleviating these symptoms, including possible psychopharmacological interventions, need to be explored. Additional research into the sensory symptoms associated with ASD has the potential to shed more light on the nature and pathophysiology of these disorders and to open new avenues of effective treatments.

Keywords: autism spectrum disorder, pervasive developmental delay, sensory integration, sensory overresponsivity, sensory processing

Abnormalities in sensory responsivity have been observed in autism spectrum disorder (ASD) since Kanner’s first characterization of autism in 1943.1 Children with ASD frequently demonstrate significant differences in the ways that they respond to sensory stimuli. Despite the high frequency of sensory symptoms in ASD, in the past these symptoms have been viewed as peripheral to the disorder rather than as a core feature. In recent years, however, the central significance of sensory symptoms in ASD has been increasingly recognized. A growing body of research has demonstrated the frequency of these symptoms and the role that they can play in contributing to the features and functional impairments in ASD.

This newly recognized importance of sensory symptoms in ASD has led some to propose that these symptoms may be more than just a peripheral phenomenon and that they may represent, instead, a fundamental feature of the disorder itself, rooted in the same pathophysiology and contributing to the broader developmental and behavioral issues observed in ASD, including social and linguistic impairments and repetitive behaviors. This shift in thinking is reflected in the inclusion of sensory symptoms as part of the ASD diagnosis in the new edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), in contrast to the DSM-IV, under which they were not considered part of the diagnostic criteria for autism.2 In this article, we will review the recent literature regarding abnormalities in sensory functioning in those with ASD, including recent evidence regarding the neurobiological basis of these symptoms, their clinical correlates, and their treatment.

Journal articles for this systematic review were identified using the electronic databases PubMed and PsycINFO. The databases were searched using the following search terms: sensory AND autism, sensory AND pervasive developmental delay, sensory AND Asperger’s. Abstracts were then reviewed, and articles were included in this review, if they were relevant to the topic of this review and they met the following criteria: (1) publication in a peer-reviewed journal, (2) full-text
article available in English, (3) related to sensory functioning in individuals with an autism spectrum disorder, including autism, pervasive developmental disorder not otherwise specified (PDD-NOS), and Asperger’s disorder. Articles were excluded if they were based on animal models or if their full text was not available in English. A manual review of relevant authors and the bibliographies from selected articles was later performed to identify additional articles for inclusion if they met the above criteria.

**NATURE AND FREQUENCY OF SENSORY SYMPTOMS IN ASD**

Individuals with ASD have been found to have high rates of abnormalities of sensory functioning. Abnormalities in all sensory modalities have been reported in ASD, and a broad range of disturbances may be observed. Published studies using standardized rating scales of sensory symptoms in individuals with ASD have consistently shown a high frequency of sensory symptoms at least one standard deviation from standardized norms, with prevalence estimates varying from 69% to 95%. The broad range of prevalence estimates may be due to differences in methodology and also to differences in the study populations, including differences in age and specific diagnoses.

Among the most common sensory symptoms observed and studied in ASD are disorders of sensory modulation, which can be defined as abnormal responses to sensory stimuli leading to functional impairment. Sensory-modulation disorders fall into three categories. The first is sensory overresponsivity (SOR), in which an individual experiences distress or displays an exaggerated negative response to sensory input, often leading to avoidance and hypervigilance related to the stimulus. For example, a child may be especially sensitive to tactile sensations associated with particular items of clothing or with particular features, such as tags, on clothing. This sensitivity may lead the child to become extremely upset or anxious when wearing such an item, to have an outburst when wearing certain clothes, or to refuse to wear certain clothes.

The second category of sensory-modulation disorder is sensory underresponsivity, in which an individual may seem to be unaware of, or slow to respond to, a stimulus that would normally be expected to elicit a response. Some children, for example, have been found to be underresponsive to pain, which can lead to injury when a child continues to engage in a behavior, such as touching a hot stove, which would normally elicit a strong pain response.

The third category of sensory-modulation disorder is sensory-seeking behavior in which an individual exhibits an unusual craving for, or preoccupation with, certain sensory experiences. For example, a child may repeatedly sniff his fingers or put nonfood items in his mouth.

Much of the research related to sensory symptoms in individuals with ASD has focused on SOR. One likely reason for this focus is that these symptoms are often the most noticeable to caregivers. Another is that recent evidence suggests that SOR in ASD is connected with anxiety and other difficulties, which we will discuss later in this article. Indeed, SOR is highly prevalent in individuals with ASD, with estimates from studies in children ranging from 56% to 70%. However, a 2009 meta-analysis that looked at 14 studies of sensory-modulation symptoms in individuals with ASD suggested that sensory underresponsivity may be the most common symptom type in this population. Many individuals with ASD suffer from a combination of underresponsive and overresponsive symptoms.

With regard to sensory modality, while it is clear from numerous studies that any sensory modality may be affected, some evidence suggests that individuals with ASD appear to have a greater frequency of sensory impairments in the domains of taste and smell, as well as tactile sensitivity, when compared to others with sensory dysfunction.

**MEASURES OF SENSORY SYMPTOMS**

Several standardized assessment instruments are available for evaluating suspected sensory-processing difficulties. One of the most commonly used instruments in both research and clinical settings is the Sensory Profile, which is designed for children 3 to 10 years of age. One of the advantages of this instrument is ease of use, as it consists of a straightforward checklist filled out by a child’s caregivers. The measure yields a report that compares the child’s score across various domains, including sensory modality, to normative data. These norms come from a sample of 1200 children; no published norms are available for children with autism. Other variations of the measure have been developed including the more abbreviated Short Sensory Profile, the Sensory Profile for Infants and Toddlers, and the Adolescent/Adult Sensory Profile.

Perhaps the gold standard of standardized assessments for sensory dysfunction is the Sensory Integration and Praxis Test (SIPT). This tool provides a comprehensive assessment of sensory functioning for children ages 4 years to 8 years, 11 months old. The SIPT involves direct observation of a child’s behavior rather than relying on checklists. This process provides a significant advantage, as checklists may miss more subtle symptoms and may be affected by the caregiver’s biases and observational abilities. The SIPT requires administration by a trained, certified occupational or physical therapist, however, and is more time-consuming than other measures, with the full battery taking approximately two hours. Since the SIPT also requires that the child understand and follow directions, it may not be valid for children with intellectual impairments.

Several other standardized sensory-assessment instruments have been developed, including the Sensory Processing Measure and the DeGangi-Berk Test of Sensory Integration. In addition, many standardized measures of autism-spectrum symptomatology, including the Childhood
Autism Rating Scale,20 Autism Behavior Checklist,21 and Gilliam Autism Rating Scale,22 feature items related to sensory-processing dysfunction. All of these instruments have been developed and standardized, however, with populations of typically developing children. While many of these tools have been used in studies of children with ASD, no published instruments have been developed for, and standardized with, this particular population of children. Indeed, the heterogeneity of the ASD population presents a challenge to standardizing such a tool. Nonetheless, the absence of an instrument that is tailored specifically to the ASD population presents a limitation to current research in sensory dysfunction in this population.

DEMOGRAPHICS: RELATIONSHIP OF DIAGNOSIS, AGE, IQ, AND SYMPTOM SEVERITY

Diagnosis
High rates of sensory-processing problems have been identified not only in individuals with autistic disorder but in those with other diagnoses subsumed under the ASD umbrella—in particular, Asperger's disorder4,23–25 and PDD-NOS.4

A study by Baranek and colleagues4 compared rates of sensory symptoms among children with an autism diagnosis to those in an “other developmental delay” group, including individuals with Asperger's disorder and PDD-NOS. In that study, children with autism had the highest rates of sensory symptoms, while the “other developmental delay” group had a significantly greater frequency of sensory symptoms than a control group of typically developing children. Similarly, Leekham and colleagues12 found higher rates of sensory symptoms in children with autism compared to age- and IQ-matched controls with developmental delay due to other causes.

This finding that individuals with an autism diagnosis may have higher rates of sensory symptoms than those with other ASDs, such as Asperger's disorder and PDD-NOS, is indirectly supported by a meta-analysis of sensory-modulation symptoms in ASD, which showed that studies with a higher percentage of subjects with the specific diagnosis of autism showed higher rates of reported sensory symptoms than studies with relatively higher percentages of other ASDs in the study group.10

Studies have shown that patients with other neurodevelopmental disorders, including fragile X26 and Williams27,28 syndromes, also have high rates of sensory symptoms, though no studies have directly compared the frequency and nature of these symptoms to patients with autism.

Chronological Age, Mental Age, and ASD Symptom Severity
Studies examining the relationship of age and sensory symptoms in ASD have produced conflicting results, with some suggesting that symptoms improve somewhat with age29 and others showing no relationship with age.4 The different findings may, in part, be related to significant variation in the age ranges examined in different studies. In their meta-analysis of studies of sensory modulation symptoms in ASD, Ben-Sasson and colleagues10 found that the frequency of sensory symptoms increased until reaching a peak at 6–9 years of age and gradually declined thereafter. The authors suggest that symptoms may peak at this time in response to the stresses and environmental changes associated with entering a school setting. It has been suggested that improvements seen after this age may be related to children learning coping strategies for managing their symptoms.29 Nonetheless, the available evidence indicates that many sensory symptoms continue to occur commonly and cause significant impairment into adulthood.12,29–31

Most evidence suggests that individuals with lower IQ or mental age and more severe ASD symptoms have a higher frequency of sensory symptoms.4,5,10,12,29,32,33 The evidence is conflicting, however, concerning the relationship between IQ and sensory symptoms.23,34

NEUROBIOLOGY OF SENSORY SYMPTOMS IN ASD

Psychophysical Studies of Sensory Symptoms in ASD
Studies of physiologic responses to sensory stimuli in individuals with ASD support the findings from clinical studies that these individuals frequently have abnormalities in their processing of, and response to, sensory input.

Multiple studies using electroencephalography (EEG) and magnetoencephalography have shown that significantly different patterns of activity occur in primary auditory and associative cortical areas in response to various auditory stimuli,35–39

The findings from studies of visual processing in ASD are conflicting. Some have shown no differences in spatial contrast sensitivity and in motion and form perception in subjects with ASD.40,41 Several psychophysical studies, however, have shown subtle visual-processing abnormalities, including impairments in object boundary detection,42 contrast boundary detection,43 and coherent motion discrimination44 in individuals with ASD.

Despite the frequency of symptoms related to tactile sensitivity in the ASD population, relatively few studies have been conducted in this area compared to those of auditory and visual processing.3 Nonetheless, some studies have shown perceptual differences to certain kinds of tactile stimuli in individuals with ASD, including increased sensitivity to vibrotactile stimuli.45,46 A recent magnetoencephalography study showed differential responses to various sensory stimuli in the primary somatosensory cortex of children with autism compared to matched controls, including smaller-amplitude left hemisphere response.47 Similarly, a functional magnetic resonance imaging study comparing responses to sensory stimuli in adults with ASD to controls.
found that the ASD group showed diminished responses to textures in the parietal somatosensory and association areas. Interestingly, however, the ASD group in this study showed increased activity in limbic areas in response to unpleasant textures relative to controls, including increased activity in the insula, an area associated with the processing of pain and disgust.

In addition to studies of individual sensory modalities, some studies have demonstrated deficits in the integration of stimuli from more than one modality, including difficulties integrating auditory and visual input. Congruently, electroencephalography and high-density electrical mapping studies have demonstrated different response patterns to tasks requiring audiovisual integration, auditory-somatosensory integration, and concurrently presented auditory and visual stimuli in individuals with ASD.

**Theories Regarding Pathophysiology**

Just as the underlying pathophysiology of ASD remains unclear, the neurological mechanism responsible for abnormal sensory processing in this population is not known. Several theories have been proposed. Given the abnormalities observed in the integration and higher-level processing of sensory input, abnormal functioning in cortical areas known to play a role in these tasks would be a logical hypothesis. Indeed, neuropathological studies have shown abnormalities in cellular density in the neocortex in individuals with autism, but these findings are not specific to areas involved in sensory processing and are also inconsistent across studies. Disruptions in connectivity between discrete cortical and subcortical regions have also been proposed, which might explain why integration of multisensory inputs would be disrupted; this hypothesis is supported by findings that show abnormalities in white matter connectivity, corpus callosum volume, and long-range firing synchrony. Hardan and colleagues demonstrated an association between decreases in corpus callosum volume and the severity of several symptom clusters, including sensory symptoms, in children with autism. Among others, has suggested that structural and cellular abnormalities in the cerebellum, which have been associated with ASD in neuroimaging and post-mortem pathological studies, may be responsible for the sensory dysfunction seen in these patients; of relevance here is the role that the cerebellum has relatively recently been found to play in integrating and modulating sensory input. Mazurek and colleagues cited clinical correlations between sensory symptoms, gastrointestinal (GI) symptoms, and anxiety in children with ASD, suggest possible disruptions in the hypothalamic-pituitary-adrenal axis and the amygdala, which they theorize could explain the connections between these symptoms. These authors also posit a role for the immune dysfunction that has recently been observed in many individuals with ASD. Significant structural abnormalities in the amygdala have also been associated with autism.

**CLINICAL CORRELATES OF SENSORY DYSFUNCTION IN ASD**

Sensory symptoms in and of themselves can cause significant distress for individuals with ASD and their caregivers. For example, these symptoms have been shown to contribute significantly to limitations in participation in work, family, and leisure activities in families of children with ASD. Much of the recent literature related to sensory symptoms in ASD has focused on the correlation between these symptoms and other problematic symptoms and behaviors associated with the disorders. While the causative nature of these relationships remains unclear, it is evident that sensory symptoms are closely tied to other features of ASD.

**Repetitive Behaviors**

Restricted and repetitive behaviors (RRBs) are part of the diagnostic criteria in both DSM-IV and DSM-5, and thus are present in the vast majority of individuals with ASD. These behaviors comprise a group of heterogeneous behaviors such as hand flapping, body rocking, covering eyes and ears, arranging things in certain order, and insisting on placing items in the same place.

Despite the heterogeneity of these behaviors, they can be grouped into several subcategories. Recent factor analysis of 1825 ASD individuals based on the Repetitive Behavior Scale–Revised parent questionnaire identified five subcategories: (1) repetitive sensory-motor/stereotypic behaviors, (2) ritualistic/insistence on sameness behaviors, (3) compulsive behaviors, (4) restricted/circumscribed interests, and (5) self-injurious behaviors. The first two subcategories were previously identified by performing factor analysis of the RRB items from the Autism Diagnostic Interview–Revised. Numerous factor analysis studies found that the repetitive sensory-motor/stereotypic behaviors subgroup consistently includes a sensory component, indicating that sensory processing closely relates to these specific repetitive behaviors. Repetitive sensory-motor/stereotypic behaviors, which include body rocking, repetitive use of objects, and sensory-seeking behaviors, have been shown to be worse in younger individuals with lower cognitive abilities, and they improve with age. By contrast, ritualistic behaviors, insistence on sameness, and difficulties with transitions have been found to be independent of age or cognitive abilities.

Children with ASD are more likely to experience repetitive behaviors if sensory-processing abnormalities are present, and more-severe sensory abnormalities are associated with more RRBs. This association has led some researchers to propose that stereotypic behaviors have an underlying sensory origin, and the available evidence suggests that such behaviors have a self-stimulatory function. Characterizing RRBs as solely sensory-based, however, is likely an oversimplification. Boyd and colleagues investigated how specific RRBs (stereotypy, self-injury, compulsions, rituals, and restricted interests) are associated with the three

---

**Sensory Symptoms in ASD**

---

**Harvard Review of Psychiatry**

---

Copyright @ 2014 President and Fellows of Harvard College. Unauthorized reproduction of this article is prohibited.
types of sensory dysfunctions in 67 children with autism and 42 children with developmental delay. In that study, the hyperresponsive sensory score showed some associations with stereotypy, self-injury, compulsions, and rituals; the sensory-seeking score suggested a potential association with stereotypy, self-injury, and rituals; and the hyporesponsive sensory score was associated with stereotypies. These preliminary findings suggest that stereotypies are associated with all three types of sensory dysfunctions, although the reasons for these co-occurrences are likely different.

A recent review of RRBs in ASD suggests that repetitive behaviors provide coping strategies for children with ASD to regulate arousal level or to manage anxiety. In cases of hyperarousal, repetitive behaviors might be soothing, whereas in cases of hypoarousal, repetitive behaviors may act to increase sensory stimulation. The authors indicated, however, that the experimental evidence is as yet insufficient to fully support this conclusion and that more research is needed—utilizing measures with strong psychometric properties and including assessments of physiological responses, rather than parent-reported measures.

Self-Injurious Behavior
Self-injurious behaviors (SIBs) are among the more clinically challenging features of ASD. These behaviors consistently present as a separate subgroup of repetitive behaviors in factor analysis studies. SIBs are also highly correlated with other subgroups of repetitive behaviors, especially with the repetitive sensory-motor/stereotypic behaviors subgroup. SIBs in individuals with developmental disorders are commonly frequent and repetitive, closely resembling stereotypic movements. Based on these observations, Gal and colleagues hypothesized that SIBs represent a more severe form of stereotypic movements. This hypothesis was, indeed, supported in their own study of 221 children, including 56 children with autism, in which the presence of SIBs was contingent on the presence of other stereotypic movements.

A recent study of 241 individuals with ASD evaluated the influence of seven factors on SIBs: (1) atypical sensory processing, (2) impaired cognitive ability, (3) abnormal functional communication, (4) abnormal social functioning, (5) age, (6) the need for sameness, and (7) rituals and compulsions. Abnormal sensory processing was the strongest single predictor of SIBs, explaining 12% of the variance.

Several studies of SIBs in ASD have implicated impaired cognitive ability as a risk factor. Age is also a factor, with some indications that SIBs increase during childhood, peak in adolescence, and decrease in adulthood. Therefore, SIBs and the repetitive sensory-motor/stereotypic behaviors subcategory of repetitive behaviors are similarly inversely related to age and IQ, further suggesting that SIBs represent a more severe form of stereotypic behaviors.

The preliminary findings from the study by Boyd and colleagues indicate that SIBs are more associated with the hyperresponsive and sensory-seeking sensory types than with the hyporesponsive type. These authors have also reported that only the hyperresponsive and sensory-seeking types have not correlated with each other, suggesting that these two subtypes do not co-occur in the same individual.

Problem Behaviors and Adaptive Functioning
Sensory-processing dysfunction in individuals with ASD is associated with lower levels of adaptive skills and more problem behaviors, especially in individuals with more severe sensory dysfunction. Lane and colleagues found that the Maladaptive Behaviors subscale from Vineland Adaptive Scales was significantly associated with severe sensory dysfunction. The maladaptive or problem behavior subscale includes items describing a wide range of behaviors such as noncompliance, poor mood regulation, withdrawal, impulsivity, aggression, self-injurious behaviors, hyperactivity, restricted interests, and distractive behaviors.

Attention Problems
About a third of children with ASD have symptoms that support the diagnosis of ADHD (though under DSM-IV, but not DSM-5, diagnostic criteria, a child could be diagnosed only with either ASD or ADHD and not both concurrently). The attention difficulties that are observed in children with ASD tend to be quite different from those with ADHD. Generally, whereas children with ADHD have difficulties staying on task, children with ASD have trouble shifting attention.

The cognitive process of attention consists of selecting items for further processing from an array of sensory stimuli, thoughts, or courses of action. This selection of items for further processing might enhance some items while filtering out others. As such, this selection process requires operations such as attention switching and sustained attention over time. The difficulty in attention shifting in individuals with ASD could be attributed to hypersensitivity to external stimuli coupled with low levels of arousal. Although arousal and the sensory reaction to external stimuli are physiologically different, under-reactivity often co-occurs with under-arousal. Liss and colleagues found that the overresponsivity observed in individuals with ASD was associated with over-focusing attention.

Other studies have found that hypersensory, sensation seeking, and auditory filtering were commonly associated with attention difficulties. A low level of arousal can lead to difficulty in allocating attention resources for processing environmental stimuli. Several neurophysiologic studies indicate that auditory-processing deficits are likely to arise due to cognitive factors such as reduced attention and are not due to impaired acoustic encoding or sound discrimination.

In addition to difficulties in attention shifting, some children with ASD have difficulties in selective attention,
which dictates what information in the environment should be focused on and what information should be ignored. Individuals with ASD have demonstrated difficulties in selective attention when exposed to a stimulating sensory environment. \(^3\) This difficulty may be apparent when a child with ASD functions well in a controlled setting but has a meltdown or runs away in a situation that is sensory challenging, like a playground or a grocery store. Neurophysiologic studies have demonstrated that individuals with ASD perform well on simple visual or auditory tasks, but as the complexity of these tasks increases, their performance degrades, indicating a deficit in the automatic processing of information. This degradation in performance may also indicate that individuals are experiencing an overloading of the attention and working-memory networks.\(^3\)

## Anxiety

Anxiety disorders are highly comorbid in individuals with ASD, with prevalence rates ranging from 11% to 84%.\(^{96}\) Considering the high rates of anxiety and sensory-processing difficulties in ASD and the theoretical links between these two clinical correlates, emerging research has been investigating this relationship.\(^{23,97–100}\) While sensory processing and anxiety hold distinct clinical definitions, studying their relationship has more than a few challenges.\(^{101}\) The aspects of anxiety and sensory-processing difficulties that lend well to theoretical comparisons also create difficulties when attempting to distinguish these two constructs. The characteristic behaviors (e.g., avoidance and dysregulation) overlap, and clinical interpretations are biased by the orientation of the clinician.\(^{101}\) Also, anxiety and sensory-processing difficulties may share similar physiological pathways.\(^{98}\) Specific to the ASD population, communication impairments in certain cases prevent accurate self-report of symptoms, and the behavioral overlaps in ASD phenomenology, anxiety, and sensory processing are difficult to differentiate on behavior checklists.

Sensory overresponsivity is the most often cited sensory correlate to increased anxiety in both general\(^{102–104}\) and ASD populations.\(^{23,97,99,100}\) Green and Ben-Sasson\(^ {98}\) propose three theories supporting the link between sensory overresponsivity and anxiety: (1) SOR is caused by, or is a symptom of, anxiety (e.g., hypervigilence or hyperarousal focused on sensory input); (2) anxiety is caused by, or is a symptom of, SOR (e.g., overreactions to sensory input creates conditioned behavioral responses); and (3) SOR and anxiety are associated through a third variable such as a common risk factor (e.g., common neurophysiological pathways) or overlapping diagnostic criteria (common symptoms across disorders).

Two studies present results supporting Green & Ben-Sasson’s primary SOR theory—namely, (2) above, that SOR precedes anxiety.\(^ {98}\) In a sample including children with ASD, ADHD, and typical development who were presented with a sensory challenge, the intensity of the physical response measured with skin conductance mediated the relationship between baseline arousal and anxiety. The findings suggest that those with greater sensory response also had higher levels of anxiety after challenging sensory stimuli were presented.\(^ {97}\) In another study, toddlers with an ASD diagnosis were assessed over the course of one year to explore the relationship between SOR and anxiety. Although SOR remained stable over time, the researchers found that anxiety increased. Further analysis revealed that SOR at time 1 predicted anxiety level at time 2, but that anxiety at time 1 did not predict SOR at time 2. The findings suggest that SOR may be a precursor to the development of anxiety.\(^ {99}\)

Other investigations offer conflicting results on the general association of SOR and anxiety. In an older sample of children and adolescents with Asperger’s disorder, researchers found significant associations between sensory defensiveness, which is a manifestation of overresponsivity, and anxiety.\(^ {23}\) The association between SOR and anxiety was not replicated in a sample of Japanese children with ASD. The group characterized as having hypersensitivities did not differ significantly on the anxiety measure compared to the group with no hypersensitivities.\(^ {105}\) Further, the anxiety and sensory link appears to weaken slightly with the inclusion of a range of sensory-processing difficulties. Using cluster analysis, three sensory-processing groups were determined for a sample of toddlers with ASD. Groups were defined as low frequency (no to mild sensory abnormalities), high frequency (under- or overresponsivity, and seeking), and mixed frequency (high under- or overresponsivity, and low seeking) of sensory processing difficulties. Toddlers in the high-frequency group had higher rates of parent-reported anxiety than the low-frequency group. Differences in anxiety did not emerge among all of the groups, however, possibly because the overall rate of clinically significant anxiety was low in this sample of young children (5%).\(^ {100}\)

## Other Correlates

Sensory-processing dysfunction has been implicated in other temperamental presentations, including negative affect, withdrawal/depression, and social impairment. In a sample of children and adolescents with Asperger’s disorder, sensory hyporesponsivity was found to correlate with depressive symptoms.\(^ {23}\) By contrast, in a sample of Japanese children with ASD, the hypersensitive group, compared to the nonhypersensitive group, had more depressive symptoms.\(^ {105}\) In another study, elevations in hypersensitivity, hyposensitivity, and sensory seeking combined were associated with higher levels of withdrawal and negative mood.\(^ {106}\) Similarly, overall sensory dysfunction was associated with increased problems on the Aberrant Behavior Checklist, including irritability and lethargy/social withdrawal.\(^ {99}\) In Ben-Sasson and colleagues’ cluster analysis mentioned earlier,\(^ {100}\) the toddlers in the high-frequency (elevated problems in all areas) group had higher rates of parent-reported negative emotionality.
separation distress, and depression/withdrawal symptoms than the low-frequency group. Compared to the mixed group (elevated hyper- and hyposensitivity), the high-frequency group had higher rates of negative emotionality and depression/withdrawal, and the mixed group had higher levels of negative emotionality and depression/withdrawal, than the low-frequency group.

The relationship between gastrointestinal dysfunction and sensory processing in ASD is an area that has garnered attention recently. High rates of GI problems are reported in the ASD population, and those with abdominal pain are more likely to show exaggerated startle reflexes to sensory stimuli. Recently, Mazurek and colleagues explored the intersection of chronic GI problems, anxiety, and sensory processing in a large sample of children and adolescents with ASD. The authors demonstrated that both anxiety and sensory overresponsivity predict the presence of chronic constipation, abdominal pain, bloating, and nausea.

TREATMENT OF SENSORY ISSUES ASSOCIATED WITH ASD

Occupational therapy is currently the mainstay of treatment for sensory disorders associated with ASD. Every individual has a unique sensory profile existing within an ever-changing environment. Thus, the approach that occupational therapists take must be tailored to the specific needs and challenges of each individual. Before treatment can begin, a thorough assessment must take place. The occupational therapist must look at a person’s unique sensory profile and determine through direct observation and assessment, as well as by caregiver interview, how these sensory issues are affecting that individual’s ability to participate fully and safely in his or her daily activities and routines. The therapist also needs to consider how these factors play out across the contexts of home, school, work, and community settings, as well as to the interplay between task, environment, and social context.

Sensory Integration Therapy

Sensory integration therapy is based upon a theory that describes how the nervous system translates sensory information into action. Individuals with sensory integration dysfunction misinterpret everyday sensory information (touch, sound, movement, etc.), are unable to discriminate between sensations, or have such unusual or awkward motor or behavioral responses that it limits participation in daily activities and interactions. Jean Ayres, in explaining the theory of sensory integration, suggested that if a child is engaged in meaningful, individually tailored sensory-motor activities that offer the “just right challenge,” the child’s nervous system will be better able to modulate, organize, and integrate sensory information in order to produce an adaptive response. The premise of providing specific input to a sensory system in order to elicit the reorganization of cortical maps is central to the theory of sensory integration. Lacourse and colleagues found that, although both physical activity and exposure to an enriched sensory environment can affect some aspects of neurogenesis, the importance of active participation is indeed critical to obtain maximal results. Specifically, they found that when presented with a novel (non-habitual) motor task, individuals who engaged in physical performance of the task saw improvement of 121% versus individuals who engaged only in mental practice, who saw an improvement rate of 86%.

Active participation is not the only critical ingredient to sensory integration. Parham and colleagues published a fidelity measure describing the essential components of sensory integration therapy. These components include (1) physical safety, (2) enriched sensory opportunities, (3) strategies to maintain appropriate arousal level/alertness, (4) challenges to postural, ocular, oral, or bilateral motor control, (5) opportunities for higher-level praxis and organization of behavior, (6) collaborating with child in activity choice, (7) tailoring the activity to present the “just right challenge,” (8) facilitating success, (9) tapping into the child’s intrinsic motivation to play/interact, and (10) establishing a therapeutic alliance. Adhering to these principles, sensory integration therapy is carried out by a specially trained occupational therapist with the goals of improving sensory modulation for improved attention and behavioral control and of improving the ability to integrate sensory information across systems as a basis for improved praxis and higher-level skills.

An important study by Miller and colleagues looked at how the benefits occupational therapy–sensory integration (OT-SI) therapy compares to what would be achieved through active participation in play (non-OT). The study used randomized, controlled trials to compare OT-SI intervention with children with sensory modulation disorder to both an active alternative group (e.g., children engaged in a variety of table-top play with a non-OT staff member or student; no parent education provided) and a passive control (children on the waitlist for OT-SI). Children in the OT-SI group made significantly greater improvements toward their goals as measured by a goal-attainment scale, compared to children in the other two groups. Furthermore, the OT-SI group increased significantly more on Attention and the Cognitive/Social Composite of the Leiter International Performance Scale–Revised. These results provide strong evidence for the effectiveness of OT-SI over a non-OT, play-based intervention or no intervention at all.

Pfeiffer and colleagues also found support for sensory integration over other treatments—specifically, OT with a focus on fine-motor skills. Children with ASD ages 6–12 years were randomly assigned to one of the two groups. Although positive outcomes on a goal-attainment scale were achieved for both groups, the changes seen with the sensory integration group were greater.
Despite the findings discussed above, additional research is needed to determine whether sensory integration therapy and related interventions are effective treatments for children with ASD and other developmental disabilities. Lack of strong research in this area has come under scrutiny in recent years, and in May 2012 the American Academy of Pediatrics issued a policy statement on sensory integration therapy, cautioning therapists to communicate this paucity of supportive evidence to patients and families prior to treatment and to encourage the families to determine for themselves if the interventions are reasonable to try for their children.114

**Sensory Diet and Complementary Interventions**

Another key component to an OT intervention with a child with ASD is the implementation of a *sensory diet*—that is, a regimen of regularly scheduled, sensory-based activities provided throughout the day so that the child’s sensory needs are met in a safe, controlled, and socially appropriate manner. This approach can be especially effective with children who are “sensory seekers” who often seek out movement, visual, tactile, or proprioceptive input in ways that interfere with or disrupt daily routines, or that compromise personal safety or the safety of those around them.

A sensory diet needs to be created with the child’s unique sensory profile in mind. In some cases, strategies are imbedded in the child’s regular routine, as in sitting on a small air-filled cushion during meals or using an electric toothbrush instead of a manual one. In other cases, sensory diet activities are implemented as breaks from the child’s routine, as when calming and organizing sensory input is provided in an effort to increase attention, reduce disruptive or impulsive behavior, and improve participation in subsequent activities. Many authors have discussed the calming effects of deep pressure and proprioception, which are frequently incorporated into sensory diets to increase organized behavior.115,116

When helping clients and caregivers create and implement sensory diets, the occupational therapist collaborates with them to identify what challenges exist that may be ameliorated by a sensory diet, what sensory strategies the client seeks, what naturally occurring possibilities exist or may be included, and when to implement the strategies.117 The exact activities depend on the child but may include activities such as bouncing on an exercise ball, jumping on a trampoline, swinging on a swing, getting deep pressure input through massage or other techniques, engaging in heavy work (dragging, pushing, or carrying things to load the muscles), resistive activities (Theraband, Theraputty), oral-sensory inputs (crunchy, chewy, or sour snacks), and a variety of auditory and visual stimuli.

Depending on the child’s cognitive ability and age, strategies for self-regulation may be implemented. The Alert Program’s *How Does your Engine Run?* outlines strategies for children to identify their own arousal levels and to begin to make connections between various activities and sensory inputs and their bodies’ own reactions to those inputs.117 Visual supports such as an “engine wheel” or “engine meter” are helpful in allowing some children with ASD to identify their own “engine” as going “too fast,” “too slow,” or “just right.” Once they identify their engine speeds (with or without adult assistance), they can experiment with methods to change those speeds (e.g., through sensory diets).

Some studies have shown that when a sensory diet is used in conjunction with other complementary interventions, results can be substantial. A study by Hall and Case-Smith118 found measureable improvement in the sensory processing of children with ASD and other developmental disabilities following a 12-week intervention that included the implementation of a sensory diet in conjunction with therapeutic listening. The latter is a sound-based treatment based on the work of a French physician, Alfred Tomatis, who believed that the ear functions as an “integrator” and serves as a critical organ in facilitating organization at all levels of the nervous system.119 The subjects in this study averaged a 71-point increase in their scores on the Sensory Profile (Caregiver Questionnaire), with improvement seen in 9 out of the 14 subsections.118 The parents of these children reported a number of significant behavioral changes following treatment, including increased attention, greater peer interaction, improved sleep patterns, better communication, and easier transitions. The results of this study represent a substantially larger improvement than seen in previous studies utilizing therapeutic listening alone.

**Environmental Adaptation**

Occupational therapists play an important role in environmental adaptation, helping the child to function in various settings. Children who tend to be hyperresponsive to sensory input, for example, may benefit from the use of music (with a faster beat) to increase arousal level or from the use of strong scents (scented candles, foods with strong aromas). Offering these children opportunities to change their seating or positioning during activities or mealtime can also be helpful in keeping them engaged.

By contrast, children who tend to be hyporesponsive to sensory input may need an environment that is calm and predictable. Reducing background noise and using natural light in lieu of fluorescent light, keeping home and classroom well organized with minimal clutter, and selecting bedding and clothing that the child can tolerate well are important considerations.

Many children with ASD rely on an environment that is consistent and on a routine that is predictable. Changes to routine or physical space can be confusing and disorienting to some children with ASD. When change is unavoidable, visual supports can be helpful. Picture schedules depicting the new chain of events or the use of a Social Story (simple vignette about a social situation) are strategies commonly used to facilitate these changes.
Task Modification and Activity Analysis
As stated above, modifying a task or tailoring an activity to present the “just right challenge” is an essential component to OT intervention. Sometimes activities need to be altered to avoid aversive sensory responses, as by decreasing tactile, auditory, or movement input that can lead to overstimulation and withdrawal. In other instances the right type of sensory input needs to be enhanced in order to motivate the child to participate. Another important consideration in activity selection is the child’s overall state of arousal or alertness. Maintaining a state of arousal that supports learning and engagement is an important component to intervention.

Social Considerations
In looking holistically at the impact of children’s sensory impairments on their daily lives, therapists need to look at their social networks across settings, including how the children interact with members of their families at home, how they interact with peers and teachers at school, and how they integrate into the community. Several important adjustments should be made in order to foster social participation in different contexts. Miller120 suggests that identifying playmates who do not overstimulate the child, who are sensitive to the child possibly needing more time to respond, and who make an effort to include the child in activities can help foster more successful peer interactions. Miller also emphasizes the importance of sensitivity training. Educating siblings and classmates about the child’s sensitivities, difficulties with personal space, and unique sensory needs can foster greater understanding and tolerance during daily interactions.

Psychopharmacological Treatment
To date, there is only a single published study related to medication management of sensory symptoms in ASD. This retrospective study by Fung and colleagues121 showed modest improvement in some sensory symptoms following treatment with aripiprazole. The authors speculate that the efficacy of aripiprazole may be related to its modulation of serotonin and dopamine pathways, both of which have been linked to sensory processing, including sensory-gating mechanisms. These results should be interpreted with caution since the study had a retrospective design, did not have a control group, and had a small sample size of only 13 subjects. Nonetheless, it raises the interesting possibility that medications, including others that may affect serotonergic or dopaminergic pathways, may have a role in addressing sensory symptoms in ASD.

DISCUSSION
In summary, abnormalities in responses to sensory stimuli are highly prevalent in individuals with ASD, even when compared to individuals with other forms of developmental delay. These abnormalities can include both hypo- and hypersensitivity to sensory stimuli, and maladaptive and repetitive patterns of seeking particular sensory stimuli. Though the findings are somewhat conflicting, it appears that rates of sensory symptoms are highest in individuals with a diagnosis of autistic disorder relative to Asperger’s disorder and PDD-NOS and that the symptoms may be most frequent and severe in those with lower mental age and more severe overall symptomology. Some evidence suggests that these symptoms diminish in later childhood and adolescence, though they are still common in adults.

The underlying neurobiology of these symptoms is unclear but may be related to other abnormalities in brain structure and function that have been identified in ASD. Proposed mechanisms include local structural abnormalities in cortical areas such as sensory association areas involved in sensory processing and integration, disturbances in long-range connectivity between discrete brain areas (including structural disturbance in the corpus callosum), and structural and functional impairments in the amygdala, cerebellum, and hypothalamic-pituitary-adrenal axis.

In addition to the distress that sensory symptoms can cause for patients and caregivers, these symptoms have been correlated with several other problematic symptoms and behaviors associated with ASD, including restrictive and repetitive behavior, self-injurious behaviors, anxiety, attentional problems, and GI complaints. It is unclear whether these correlations are causative in nature or whether they are due to the same underlying neurological underpinnings. It appears that some of these comorbid symptoms are associated with specific patterns of sensory symptoms. For example, anxiety symptoms are more associated with sensory hyperresponsivity, whereas problems with attention and hyperactivity are closely related to sensory hyporesponsivity and sensory-seeking behaviors. These patterns raise the possibility that endophenotypes in ASD might be elucidated through patterns of sensory symptoms and related comorbidities.

The best-known treatments for sensory symptoms in ASD involve a program of OT that is specifically tailored to the needs of the individual and that may include sensory integration therapy, a sensory diet, and environmental modifications. While further outcomes research is needed to support the efficacy of these interventions, at present they appear to be the most effective treatments available.

The growing recognition of the centrality of sensory symptoms in ASD opens several promising avenues for future investigation. More research is needed on the underlying neurophysiology of those symptoms and on the relationships between them and the symptoms and comorbidities related to ASD. Despite the distress caused by such symptoms, little research has been conducted regarding their treatment. Further research into the efficacy of sensory integration therapies would be useful, and the role of psychiatric medications in treating sensory symptoms has not been adequately explored. A single study showing the
efficacy of aripiprazole raises the possibility that psycho-pharmacology may have an adjunctive role.

In addition to such additional research, greater efforts should be made to train psychiatrists and other mental health professionals working with the ASD population to evaluate patients for sensory symptoms. In addition to helping clinicians better understand their patients’ experiences and enabling them to frame better treatment strategies, the ability to take an effective history of sensory symptoms will become essential to making an accurate diagnosis of ASD under the revised DSM-5 criteria. While much is still unclear about sensory symptoms and their relationship to ASD, it seems that understanding more about these symptoms and their treatment may not only help us improve the quality of life of individuals with ASD; it may shed light on the nature of these disorders.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

REFERENCES

Sensory Symptoms in ASD