Chapter 6
Sensory Subtypes in Autism Spectrum Disorder

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Sensory Features in Autism Spectrum Disorder

Sensory features have been observed and documented since the earliest reports of Autism Spectrum Disorder (ASD). Kanner (1943) described some sensory features in his initial descriptions of childhood ASD including extreme fear of noisy household appliances, fixation on sensory-stimulating activities e.g. spinning, humming to self and rejection of social touch. His case examples also detail evidence of enhanced sensory abilities such as noticing small changes in the physical arrangement of objects in the room. After initial inclusion in the original diagnostic criteria for ASD, sensory features were dropped from subsequent diagnostic manuals until 2013 when they were re-included in the DSM-5 (American Psychiatric Association, 2013). Current estimates of the prevalence of sensory features in ASD range from 60–95% (Lane, Molloy, & Bishop, 2014; Tomchek & Dunn, 2007). In the more than 60 years that have passed since Kanner's initial observations, sensory features have become a commonly observed aspect of the behavioural presentation of ASD and studies regarding the characterisation, mechanisms and treatment of sensory features have increased exponentially (Cascio, Woynaroski, Baranek, & Wallace, 2016; Uljarević et al., 2017).

Sensory features refer to patterns of behaviour that are suggestive of differences in the way daily sensory stimuli are processed, e.g., covering ears in response to an unexpected sound or failure to respond to a painful stimulus (Schaaf & Lane, 2015). In general, sensory features are considered functionally limiting, with individuals with ASD and their families attributing significant restrictions in participation in daily life activities to sensory symptoms (Dunn, Little, Dean, Robertson, & Evans, 2016; Schaaf, Toth-Cohen, Johnson, Outten, & Benevides, 2011). First-hand

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accounts of the impact of sensory features on daily living indicate that sensory sensitivities (e.g. sensitivity to unexpected sounds like a phone ringing, food tastes or smells) can lead to avoidance behaviours and strong emotional reactions to changes in routine or environments (Ashburner, Bennett, Rodger, & Ziviani, 2013; Dickie, Baranek, Schultz, Watson, & McComish, 2009). Further, some daily sensory experiences are reported as distracting (e.g. visual stimulation of moving ceiling fan) resulting in loss of attention and focus, failure to notice more salient stimuli and social difficulties (Ashburner et al., 2013). There are some reports, however, that sensory features may also enhance function, such as a heightened level of awareness to visual detail that may assist in the performance of some learning tasks.

The definition and characterisation of sensory symptoms has been an issue of some debate and controversy in the literature. Discrepancies can be found between descriptions of sensory features found in clinically-oriented versus more experimental literature. In clinical fields, the emphasis in definition has been on behaviours that limit function and some attempts have been made to characterise specific sensory 'sub-disorders' based on the combination of clinically meaningful symptom sets. Several examples of this are found in the occupational therapy literature (Ayres, 1979; Dunn, 2001; Miller, Anzalone, Lane, Cermak, & Osten, 2007). Ayres' work laid the foundation for the recognition of sensory features as clinically important for children with a variety of developmental disorders, including ASD. Ayres proposed a theoretical framework for the understanding of how impairments in the integration of daily environmental sensory stimuli may lead to identifiable patterns of maladaptive behaviour and learning difficulties. These patterns were further described as 'sensory integration disorders' and a model of treatment for each was developed (Ayres, 1979; Bundy & Murray, 2002). Central to Ayres' theory was a distinction between sensory features based on impairments in 'sensory modulation' versus those related to difficulties in processing somatosensory stimuli (vis a vis, tactile, proprioceptive and vestibular) for the purposes of coordinated, goal-directed movement (Bundy & Murray, 2002). More recently, sensory difficulties associated with impairments in sensory modulation have received the greater attention in the clinical literature.

'Sensory modulation' is defined as the ability of the central nervous system to regulate its responses to sensory input (Bundy & Murray, 2002). Dunn (1997) proposed that impairments in sensory modulation present as symptom sets that fall into one of four sensory quadrants – poor registration, sensory sensitivity, sensory avoiding and sensory seeking. Classification into one of the four quadrants is determined by both a hypothesised 'neurological threshold' indicating the level of stimulation (high or low) needed to elicit a behavioural response and the behavioural 'style' of the individual (either passive or active; Dunn, 1997). Individuals with a high neurological threshold and a passive behavioural style are classified as 'poor registration' demonstrated by behaviours that indicate an attenuated or absent response to a sensory stimulus. 'Sensory seeking' encapsulates individuals with a high neurological threshold but an active behavioural style suggesting that behaviours which appear to increase the level of stimulation gained, are the result of inadequate registration of the available sensory stimuli in the environment. The final two quadrants relate to individuals with a low neurological threshold. Sensory avoiders use their active behavioural style to remove themselves from sensory stimuli that may become overwhelming or be perceived as highly intense. Individuals classified in the sensory sensitivity quadrant, however, have a passive behavioural style and may demonstrate less overt signs of distress to sensory stimuli such as withdrawal, anxiety or other internalising symptoms (Dunn, 1997).

In contrast to the clinical models described above, researchers in more experimental disciplines have attempted to define sensory features in terms of underlying structures, mechanism and impairment (Marco, Hinkley, Hill, & Nagarajan, 2011). This body of work focuses on biological processes related to sensory features and encapsulates studies in neuroscience and cognitive psychology. Psychophysiological and brain imaging techniques have been used to quantify neurophysiologic responses to sensory stimuli, usually under controlled conditions (see Marco et al., 2011 for a review of this work). Until recently, clinical and experimental inquiries into sensory features have been largely conducted independently of each other (Cascio et al., 2016). This has led to some confusion in the terminology used and understanding of sensory features (Cascio et al., 2016). Schaaf and Lane (2015) have attempted to clarify some of this confusion and provided guidance for terminology usage. These authors suggested that the terms *sensory reactivity*, *sensory perception* and *sensory integration* be used to characterise the full extent of sensory symptoms. *Sensory reactivity* refers to behaviours termed as hyper-, over-, hypo- or under-responsivity or sensitivity. Behaviours indicative of sensory reactivity difficulties might include responses to stimuli that are either too strong (e.g. extreme distress to the sound of a vacuum cleaner turning on) or insufficient (e.g. no response to a painful stimulus). In this chapter, we will use ‘sensory reactivity’ synonymously with ‘sensory modulation’. *Sensory perception* refers to the ability to perceive and interpret sensory stimuli (Schaaf & Lane, 2015). In general, sensory perception refers to cognitive and physiological functions that are measured through standardised behavioural tests or psychophysiological procedures. Finally, *sensory integration* refers to the organisation, binding or assimilation of multiple sensory inputs for the purpose of more detailed understanding of the sensory context (Schaaf & Lane, 2015). Sensory integration is considered synonymous with multisensory integration.

Despite this growing understanding of the breadth of sensory symptoms, sensory features as defined in the DSM-5 diagnostic criteria for ASD (Association, 2013) refer only to difficulties in sensory modulation and are based on clinical conventions. The DSM-5 defines sensory features as:

> *Hyper- or hypo-reactivity to sensory input or unusual interests in sensory aspects of the environment (e.g., apparent indifference to pain/temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects, visual fascination with lights or movement).*

Under current diagnostic guidelines for ASD, sensory features are considered a sufficient but not necessary element of the ‘restricted, repetitive patterns of behaviour, interests, or activities (RRBI)’ criterion. As such, the observation of sensory features (as described above) in an individual presenting for ASD diagnosis can be included as one of the two elements required to meet the RRBI criterion.

Relation of Sensory Features to Other RRBI

Investigations into the relation of sensory features to other RRBI in ASD are premised on the assumption that one possible function of RRBI is as a mechanism to manage adverse responses to daily sensory stimuli. In the 'over-arousal' theory, it has been postulated that RRBI including repetitive motor behaviours, adherence to routines, and preoccupations may serve to block sensory input that is perceived as threatening or too intense by individuals who experience sensory hyper-reactivity (Schulz & Stevenson, 2019). Evidence to support this theory is found in the literature reporting that increased sensory hyper-reactivity is associated with increased frequency and intensity of repetitive behaviours of all types (Chen, Rodgers, & McConachie, 2008; Schulz & Stevenson, 2019; Wigham, Rodgers, South, McConachie, & Freeston, 2015; Wolff et al., 2019). Further, this relation has been reported to hold across ASD and typically developing groups, regardless of gender, chronological age and IQ (Schulz & Stevenson, 2019).

In a second theory, authors propose that engagement in RRBI by individuals with ASD may serve to provide additional sensory input to individuals who experience sensory hypo-reactivity and are less able to use sensory stimuli in the environment (Joosten & Bundy, 2010). Clinical sensory theorists such as Dunn (1997) and Miller et al. (2007) propose that sensory seeking behaviours, such as repetitive motor behaviours, provide a hypo-reactive individual with an opportunity to generate sensory experiences, which aid in self-regulation, adaptive behaviour and learning. In support of this proposition, Wigham et al. (2015) observed that increased sensory hypo-reactivity but not hyper-reactivity was significantly associated with increased repetitive motor behaviours in ASD. Further, Gal, Dyck, and Passmore (2010) reported that sensory hypo-reactivity was the strongest correlate of stereotyped movements in children with ASD. Other study findings, however, contradict the 'over-arousal'/'seeking' theories. For example, Wigham et al. (2015) also observed that sensory hypo-reactivity was significantly associated with 'insistence on sameness' behaviours. In the context of sensory features, 'insistence on sameness' behaviours are generally considered to be efforts to control or reduce the level of sensory input in the environment and as such, would be more logically related to sensory hyper-reactivity (Black et al., 2017).

It is likely, therefore, that the relations between sensory features and other RRBI cannot be completely explained by the 'over-arousal' and 'seeking' theories and additional factors might be at play (Wolff et al., 2019). For example, several commentators have postulated that there may be an important role for 'intolerance of uncertainty' and anxiety in the interplay between RRBI and sensory features (Joosten & Bundy, 2010; Neil, Olsson, & Pellicano, 2016; Wigham et al., 2015). Wigham reported that these factors in combination at least partially mediated the relations among sensory hypo- and hyper-reactivity and both repetitive motor behaviours and insistence on sameness. Neil et al. (2016) reported that 'intolerance of uncertainty' explained half the variance in sensory sensitivities in children with ASD but that a portion of this was mediated by anxiety. A further study observed that sensory avoiding (thought to be one manifestation of sensory hyper-reactivity) mediated the relationship between 'insistence on sameness' and anxiety (Lidstone et al., 2014) and Black et al. (2017) observed that sensory hyper-reactivity mediated the relation between 'insistence on sameness' and specific phobias and separation anxiety in ASD only. There are also emerging reports of a role for sensory perception in the manifestation of RRBI. Kargas et al. (2015) found that auditory discrimination impairments (vis a vis intensity and frequency discrimination) in adults with ASD were associated with more severe RRBI as measured by the Autism Diagnostic Observation Schedule and including preoccupations in play, restricted interests, adherence to routines and repetitive motor patterns. Similarly, Kanakri et al. (2017) observed that increased ambient noise levels in classrooms were associated with increased repetitive motor and speech behaviours in ASD.

The findings from the available literature suggest that the relation between sensory features and RRBI is complex and likely to be multifactorial. Interventions targeting sensory features, however, could be hypothesised to reduce the frequency and severity of other RRBI although this has yet to be confirmed in controlled trials. The mechanism by which sensory directed therapies may impact other RRBI is still unknown although a potential common neural circuity between RRBI and sensory features has been identified (Wolff et al., 2017). Further complicating our understanding of this relationship is the fact that many individuals with ASD present with concurrent sensory hyper-, hypo- and seeking behaviours. Further exploration, therefore, of the relation between RRBI and sensory features is warranted considering patterns of sensory features and RRBI within individuals rather than an exclusive focus on specific sensory behaviours and their RRBI correlates in isolation.

Sensory Subtyping

In further efforts to understand the manifestation and impact of sensory features in ASD, recent investigations have attempted to identify specific patterns of sensory symptoms within individuals with ASD. These patterns or 'subtypes' identify homogenous sub-groups of individuals with ASD with similar sensory features. This approach varies substantially from previous sensory research which has focussed more on the identification of discrete sensory behaviours or features but less on the pattern of co-existence of those behaviours within individuals (Hand, Dennis, & Lane, 2017). Efforts to identify subgroups of individuals with ASD with similar sensory features have implications for our understanding of the basis of sensory disturbance in ASD, and also provide a framework for the provision of customised and targeted therapies. To date, there have been seven proposed sensory subtype models in ASD. All subtype models have focussed on identifying distinct patterns of sensory features within toddlers, children and adolescents. There are no current sensory subtype models for adults with ASD. Further, all subtype models are based on observations made by parents or caregivers of individuals with ASD. Objective measures of sensory features (vis a vis neurophysiological data) have not yet been included in subtype models.

Toddler Models

To date, there have been two published reports of sensory subtype studies in toddlers with or with risk for ASD (Ben-Sasson et al., 2008; Philpott-Robinson, Lane, & Harpster, 2016). Utilising hierarchical cluster analysis, Ben-Sasson et al. (2008) reported that toddlers with confirmed diagnoses of ASD were rated by their parents on the Infant-Toddler Sensory Profile (Dunn & Daniels, 2002), to fall into one of three sensory clusters – low frequency of sensory symptoms (26%), high frequency of sensory symptoms (29%) and mixed (45%). Toddlers in the low frequency cluster displayed few sensory symptoms whereas those in the high frequency cluster showed a high number of sensory hyper-, hypo- and seeking behaviours. The mixed sensory cluster demonstrated high levels of both sensory hyper- and hypo-reactivity but less sensory seeking. Further, members of the high frequency cluster showed the highest levels of depression/withdrawal, whereas the high frequency and mixed clusters displayed more negative emotionality than the low frequency group (Ben-Sasson et al., 2008).

Philpott-Robinson et al. investigated sensory features in 12–24 month old toddlers with risk factors for ASD (n = 46). Sensory features were measured using the Infant-Toddler Sensory Profile (Dunn & Daniels, 2002) completed by parents or caregivers. Model-based cluster analysis was used to interrogate responses and identify homogenous subsets of toddlers. Philpott-Robinson et al. identified two primary sensory subtypes in this group: (1) Sensory Adaptive (59%) and (2) Sensory Reactive (41%). The sensory features of members of the Sensory Adaptive subtype were characterised by typical function across sensory domains. Members of the Sensory Reactive subtype, however, displayed symptoms of sensory hyper-reactivity across sensory domains. Whereas sensory subtype membership in this sample was not associated with early ASD risk, toddlers in the Sensory Reactive subtype demonstrated less mature expressive and receptive language abilities.

Childhood Models

Lane Model

One of the first sensory subtype models was proposed by Lane and colleagues (Lane et al., 2014; Lane, Dennis, & Geraghty, 2011; Lane, Young, Baker, & Angley, 2010). This model is based on parent observations of sensory features in children with ASD aged 2–10 years (n = 312 across 3 studies) using the Short Sensory Profile (McIntosh et al. 1999). Model-based cluster analysis was used to identify homogenous subgroups of children with ASD based on their sensory features. On the basis of their findings, Lane and colleagues proposed that children with ASD can be classified into one of four sensory subtypes – Sensory Adaptive, Taste Smell Sensitive, Postural Inattentive and Generalised Sensory Difference (Lane et al., 2014). Subtypes differ from each other on the basis of the *severity* (mild to severe) and *focus* (auditory, taste, smell, proprioceptive and vestibular) of the sensory symptoms. It is further hypothesised by the authors, that subtype classifications can be understood as relating to difficulties in *sensory reactivity* and/or *multisensory integration* (Hand et al., 2017). In this context, sensory reactivity is considered synonymous with sensory modulation. Difficulties in sensory reactivity manifest as behaviours that are either too intense (hyper-reactive) or insufficiently intense (hypo-reactive) for a given stimulus. For example, crying and extreme upset during hair-cutting may be indicative of sensory hyper-reactivity to tactile stimuli whereas failure to respond to name may be indicative of sensory hypo-reactivity to speech stimuli. Multisensory integration difficulties in Lane's model refer to higher level behaviours that are indicative of potential failures in the assimilation of multiple, concurrent sensory inputs. Such behaviours could include postural and motor coordination difficulties (Hand et al., 2017; Lane et al., 2014). Figure 1 outlines the relation of Lane's four sensory subtypes with their proposed underlying mechanisms.

As can be seen, children with ASD who are classified as Sensory Adaptive, experience no clinically significant difficulties with either sensory reactivity or multisensory integration. Their responses to daily sensory stimuli are reported by their parents to fall within normal limits. Children with ASD who are classified as Taste/Smell Sensitive, however, display behaviours suggestive of difficulties with sensory reactivity. These children do not, however, appear to experience impairment in multisensory integration. Those children with ASD classified as Postural Inattentive display difficulties in postural control, maintenance of body positions against gravity and filtering salient from less salient auditory stimuli. These behaviours are suggestive of impairment in multisensory integration. These children do not, however, appear to experience difficulties in sensory reactivity. Finally, children with ASD classified as Generalised Sensory Difference are reported by their parents to experience difficulties in both sensory reactivity and multisensory integration.

Lane et al. (2014) observed that in a large group of children with ASD presenting for diagnosis of ASD, most were classified into either Sensory Adaptive (37.5%) or Taste/Smell Sensitive (40.2%) subtypes. Patterns of sensory features indicated by Postural Inattentive (10.3%) and Generalised Sensory Difference (12.1%) were less common. As such, this subtype model concludes that significant numbers of

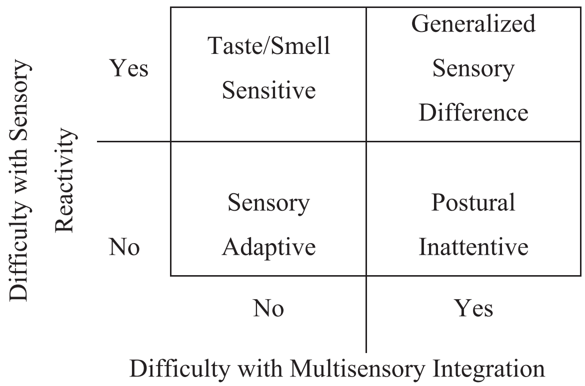

Fig. 1 Lane's sensory subtype model. (From Hand et al., 2017. Reprinted with permission)

children with ASD do not experience clinically significant sensory features. Further, subtype membership was not found to be strongly associated with non-sensory features such as ASD symptom severity, gender or IQ (Lane et al., 2014). Differences between subtypes have been reported, however, in adaptive behaviour with members of subtypes experiencing greatest difficulties with sensory reactivity, being reported to experience the highest levels of challenging behaviours (Lane et al., 2010). Further, members of the Taste/Smell Sensitive subtype displayed the highest levels of communication difficulty and picky eating (Lane et al., 2010, 2011).

Ausderau Model

A second sensory subtype model was proposed by Ausderau et al. (2014). As for the Lane model, this model is based on parent-reported sensory features of children with ASD (2–12 years). In this model, however, the Sensory Experiences Questionnaire (SEQ; (Baranek, Boyd, Poe, David, & Watson, 2007) was utilised. Ausderau et al. (2014) applied Latent Profile Analysis to the SEQ responses of a large sample of participants (n = 1294) to identify homogenous subgroups of children with ASD based on their sensory features. These authors also identified four distinct sensory subtype groupings. The four subtypes were described as: Mild, Extreme-Mixed, Sensitive-Distressed and Attenuated-Preoccupied. As for the Lane model, the subtypes proposed by Ausderau and colleagues differ from each other in terms of the *frequency and intensity* and the *focus* of sensory symptoms. Individuals classified in the Mild subtypes experienced very few sensory symptoms whereas those in the Extreme-Mixed subtype were reported to experience high levels of symptoms across all sensory domains. Individuals classified as Sensitive-Distressed reported more sensory symptoms related to hyper-reactivity and enhanced sensory perception whereas those in Attenuated-Preoccupied reported more symptoms related to hypo-reactivity and sensory interests, repetitions and seeking (Ausderau et al., 2014). Ausderau et al. found that most participants were classified into either the Mild (29%) or Sensitive-Distressed (28%) subtypes with fewer participants in the Extreme-Mixed (17%) or Attenuated-Preoccupied (17%) subtypes.

In follow up work, Ausderau and colleagues have reported that subtype membership was stable after one year (91%) and ASD symptom severity was greater in the Extreme-Mixed subtype relative to the Mild subtype Ausderau et al. (2014). Further, the Attenuated-Preoccupied subtype presented with the lowest proxy IQ and youngest age. Functional outcomes for each subtype also differ. Membership in the Attenuated-Preoccupied subtype was associated with lowest levels of adaptive behaviour whilst Extreme-Mixed was associated with the highest levels of parenting stress (Ausderau et al., 2016). Ausderau et al. (2014) further observe that their subtype groupings provide additional insights into the relations between sensory features and RRBI. In their model, sensory interests, repetitions and seeking behaviours co-occurred with both hyper- (Extreme-Mixed) and hypo-reactive (Attenuated-Preoccupied) symptom sets suggesting the RRBI may serve differing purposes for different subtypes.

Tomchek Model

Recently, a third childhood sensory subtype model has been proposed (Tomchek, Little, Myers, & Dunn, 2018). As for the Lane Model, this model is based on parent reports of sensory features utilising the Short Sensory Profile (McIntosh et al., 1999). Tomchek's model, however, differs from the earlier subtype models in that it is focused only on younger children with ASD (n = 400; aged 3–6 years) and includes developmental features (adaptive and social behaviour, receptive and expressive language and gross and fine motor skills) alongside sensory features within the grouping analysis. Resulting subtypes, therefore, are based on both sensory and developmental features rather than sensory features alone. Further, Tomchek et al. applied an updated factor structure for the Short Sensory Profile to the analysis, based on new data from an ASD-only sample. As in Ausderau et al. (2014), Tomchek et al. utilised Latent Profile Analysis to identify the best subtype model fit to the data.

Tomchek et al. (2018) described four sensory subtypes: Sensorimotor (51%), Selective Complex (15%), Perceptive-Adaptable (25%) and Vigilant-Engaged (10%). Subtypes differed from each other based on age, developmental functioning and sensory features. Specifically, members of the Sensorimotor group were younger, had the lowest developmental functioning and presented with a broad range of sensory symptoms including taste-smell sensitivity, sensory seeking and hypo-responsivity. This contrasted with members of the Perceptive-Adaptable subtype who were also younger but had relatively higher developmental skills particularly in motor, adaptive and social areas, and fewer sensory features. Members of the Selective Complex group were older, showed good motor skills but decreased social and language skills, and demonstrated high levels of sensory hypo-reactivity and sensory seeking. Finally, members of the Vigilant-Engaged subtype were older, had the highest developmental functioning and showed elevated sensory hyper-reactivity and seeking.

Simpson Model

A fourth childhood sensory subtype model was proposed by Simpson, Adams, Alston-Knox, Heussler, and Keen (2019). This model is the first to use the updated Short Sensory Profile-2 (Dunn, 2014) as the basis for subtyping. The Short Sensory Profile-2 (SSP-2) is a substantial revision of the original Short Sensory Profile. Simpson et al. (2019) note that less than 30% of the items between the two measures match. Further, the newer SSP-2 organises items according to Dunn's (1997) quadrant model – sensory sensitivity, sensory avoiding, sensory seeking and poor registration. The original Short Sensory Profile used a seven domain organising structure that incorporated both sensory modality and quadrant descriptor – i.e. tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive/seeking, auditory filtering, low energy/weak and visual/auditory sensitivity. Simpson et al. (2019) conducted their subtyping analysis on SSP-2 reports from caregivers of children with autism (n = 271) aged 4–11 years utilising Dirichelet Process Mixture Modelling (Liverani, Hastie, Papathomas, & Richardson, 2015).

Simpson et al. (2019) identified a two-cluster model as the best solution in their analysis. Clusters were described as: (1) Uniformly Elevated (67%) – indicating elevated sensory scores across all sensory quadrants on the SSP-2, and (2) Raised Avoiding and Sensitivity (33%) – indicating elevated scores in the avoiding and sensitivity quadrants. The authors found no differences between the subtypes on the basis of age or autism-related social communication characteristics.

Adolescent Model

Uljarević, Lane, Kelly, and Leekam (2016) described a sensory subtype model for adolescents with ASD (n = 57; aged 11–17 years). Using an identical methodology to that of Lane et al. (2014), these authors identified three sensory subtypes: Sensory Adaptive (33%), Sensory Moderate (51%) and Sensory Severe (16%). Unlike the previous models, subtypes differed from each other only regarding the frequency and intensity of sensory symptoms rather than the sensory modality or specific sensory behaviours. No differences were observed between subtypes relative to sensory foci in taste/smell, vestibular, proprioceptive, auditory, movement and/or hyper- versus hypo-reactivity as has been reported in childhood sensory subtype models. Further, no clear evidence emerged in this study of specific patterns of sensory difference between groups beyond the overall number of sensory symptoms reported. Similar to previous findings by Lane et al. (2014), however, adolescent subtypes were not different from each other in terms of age, expressive language function or social communication. Differences were identified between sensory subtypes, however, in levels of anxiety with anxiety increasing in adolescents reporting more sensory symptoms.

Summary

Overall, the work completed to date on sensory subtypes in ASD demonstrates a high degree of congruence despite the varying samples, measures and analytic approaches utilised. In school-aged children with ASD, variation in sensory features appears to be best explained by four subtypes that differ from each other on the basis of the severity (frequency and number of sensory symptoms reported), and on the focus of the sensory symptoms. In adolescence, variation in sensory features appears limited to the severity of sensory symptoms only. Only preliminary subtyping results are available for toddlers with or with risk for ASD, however, initial results indicate that at this age, sensory subtypes are characterised by either adaptive sensory functioning (no sensory symptoms) or generalised sensory difficulties (sensory symptoms across domains). Taken together, these findings suggest that:

1. Coherent patterns of sensory features can be identified within children with ASD and not all children with ASD share the same sensory profile. The implications of this finding are that sensory features should be carefully assessed to identify:

(a) the presence of sensory symptoms for purposes of diagnosis, and (b) the type of sensory features experienced by the individual with ASD for purposes of customised treatment planning;

2. Many children with ASD have mild or no clinically significant sensory symptoms as evidenced by the majority of sensory subtype models identifying a 'Mild' or 'Sensory Adaptive' cluster. This finding supports the current diagnostic approach in which sensory symptoms are a 'sufficient' but not 'necessary' subcriterion within the 'restricted, repetitive patterns of behaviour, interests, or activities' domain.
3. Sensory features emerge early in ASD but their pattern of presentation changes with maturation. Whilst severity of sensory symptoms is a consistent source of variation in sensory features in ASD, the focus of sensory symptoms appears to only be a significant contributor to subtype differences during middle childhood.

The evidence presented in this chapter supports the utility of a subtyping approach to the understanding of function and behaviour in individuals with ASD. Current subtype models, however, are limited by the exclusive use of proxy-report measures to identify and characterise subtype features. Further, the measures used differed between subtype models, no doubt contributing to the variations in results achieved. In particular, the scope of the sensory domains addressed by each measure is reflective of conceptual differences between sensory theorists regarding the construct of sensory features in ASD. As written, the DSM-5 only includes clinical sensory features that can be broadly described as related to sensory modulation difficulties. It is evident, however, that sensory features in ASD also include difficulties in sensory perception and sensory integration. The tools used in the generation of sensory subtype models so far, are comprised largely of items representing sensory modulation difficulties. Lane et al. (2014) propose that some items of the Short Sensory Profile are representative of sensory integration, but this theory requires further testing. Before additional progress can be made to understand the nature of sensory features in ASD, a consensus model of the latent constructs underlying sensory function needs to be developed. In doing so, new measures can be aligned to a single construct framework that will assist in the identification of the source of differences between sensory subtypes, generate intervention models targeted to known sensory targets and provide a platform for the study of the emergence of these features in early childhood.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders-Fifth Edition (DSM-5®)*. Arlington, VA: American Psychiatric Association.

Ashburner, J., Bennett, L., Rodger, S., & Ziviani, J. J. (2013). Understanding the sensory experiences of young people with autism spectrum disorder: A preliminary investigation. *Australian Occupational Therapy Journal, 60*(3), 171–180.

Ausderau, K. K., Furlong, M., Sideris, J., Bulluck, J., Little, L. M., Watson, L. R., . . . Baranek, G. T. (2014). Sensory subtypes in children with autism spectrum disorder: Latent profile transition analysis using a national survey of sensory features. Journal of Child Psychology and Psychiatry, 55(8), 935–944. doi:https://doi.org/10.1111/jcpp.12219.

Ausderau, K. K., Sideris, J., Little, L. M., Furlong, M., Bulluck, J. C., & Baranek, G. T. (2016). Sensory subtypes and associated outcomes in children with autism spectrum disorders. *Autism Research, 9*(12), 1316–1327. https://doi.org/10.1002/aur.1626.

Ayres, A. (1979). *Sensory integration and the child*. Los Angeles: Western Psychological Services.

Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. *American Journal on Mental Retardation, 112*(4), 233–245.

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Kadlec, M. B., & Carter, A. S. (2008). Sensory clusters of toddlers with autism spectrum disorders: Differences in affective symptoms. *Journal of Child Psychology and Psychiatry, 49*(8), 817–825. https://doi.org/10.1111/j.1469-7610.2008.01899.x.

Black, K. R., Stevenson, R. A., Segers, M., Ncube, B. L., Sun, S. Z., Philipp-Muller, A., et al. (2017). Linking anxiety and insistence on sameness in autistic children: The role of sensory hypersensitivity. *Journal of Autism and Developmental Disorders, 47*(8), 2459–2470. https://doi.org/10.1007/s10803-017-3161-x.

Bundy, A. C., & Murray, E. A. (2002). Sensory integration: A. Jean Ayres' theory revisited. In A. C. Bundy, S. J. Lane, & E. A. Murray (Eds.), *Sensory integration: Theory and practice* (2nd ed.). Philadelphia: F.A. Davis Company.

Cascio, C. J., Woynaroski, T., Baranek, G. T., & Wallace, M. T. (2016). Toward an interdisciplinary approach to understanding sensory function in autism spectrum disorder. *Autism Research, 9*(9), 920–925. https://doi.org/10.1002/aur.1612.

Chen, Y.-H., Rodgers, J., & McConachie, H. (2008). Restricted and repetitive behaviours, sensory processing and cognitive style in children with Autism Spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(4), 635–642. https://doi.org/10.1007/s10803-008-0663-6.

Dickie, V. A., Baranek, G. T., Schultz, B., Watson, L. R., & McComish, C. S. (2009). Parent reports of sensory experiences of preschool children with and without autism: A qualitative study. *American Journal of Occupational Therapy, 63*(2), 172–181. https://doi.org/10.5014/ajot.63.2.172.

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants & Young Children: An Interdisciplinary Journal of Special Care Practices, 9*(4), 23–35.

Dunn, W. (2001). The sensations of everyday life: Empirical, theoretical, and pragmatic considerations. *The American Journal of Occupational Therapy, 55*(6), 608–620.

Dunn, W. (2014). *Sensory Profile 2*. Pearson: San Antonio, TX.

Dunn, W., & Daniels, D. B. (2002). Initial development of the infant/toddler sensory profile. *Journal of Early Intervention, 25*(1), 27–41. https://doi.org/10.1177/105381510202500104.

Dunn, W., Little, L., Dean, E., Robertson, S., & Evans, B. (2016). The State of the Science on sensory factors and their impact on daily life for children: A scoping review. *OTJR: Occupation, Participation and Health, 36*(2_suppl), 3S–26S. https://doi.org/10.1177/1539449215617923.

Gal, E., Dyck, M. J., & Passmore, A. (2010). Relationships between stereotyped movements and sensory processing disorders in children with and without developmental or sensory disorders. *American Journal of Occupational Therapy, 64*, 453–461. https://doi.org/10.5014/ajot.2010.09075.

Hand, B. N., Dennis, S., & Lane, A. E. (2017). Latent constructs underlying sensory subtypes in children with autism: A preliminary study. *Autism Research, 10*(8), 1364–1371. https://doi.org/10.1002/aur.1787.

Joosten, A. V., & Bundy, A. C. (2010). Sensory processing and stereotypical and repetitive behaviour in children with autism and intellectual disability. *American Journal of Occupational Therapy, 57*(6), 366–372.

Kanner, L. J. (1943). Autistic disturbances of affective contact. *The Nervous Child, 2*(3), 217–250.

Kanakri, S. M., Shepley, M., Tassinary, L. G., Varni, J. W., & Fawaz, H. M. (2017). An observational study of classroom acoustical design and repetitive behaviors in children with autism. *Environment and Behavior, 49*(8), 847–873.

Kargas, N., López, B., Reddy, V., & Morris, P. (2015). The relationship between auditory processing and restricted, repetitive behaviors in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 45*(3), 658–668.

Lane, A., Dennis, S., & Geraghty, M. (2011). Brief report: Further evidence of sensory subtypes in autism. *Journal of Autism and Developmental Disorders, 41*(6), 826–831. https://doi.org/10.1007/s10803-010-1103-y.

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of children with autism Spectrum disorder by sensory subtype: A case for sensory-based phenotypes. *Autism Research, 7*(3), 322–333. https://doi.org/10.1002/aur.1368.

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders, 40*(1), 112–122. https://doi.org/10.1007/s10803-009-0840-2.

Lidstone, J., Uljarević, M., Sullivan, J., Rodgers, J., McConachie, H., Freeston, M., . . . Leekam, S. (2014). Relations among restricted and repetitive behaviors, anxiety and sensory features in children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 8*(2), 82–92. https://doi.org/10.1016/j.rasd.2013.10.001.

Liverani, S., Hastie, D. I., Papathomas, M., & Richardson, S. (2015). PREeMiuM: An R package for profile regression mixture models using Dirichlet processes. *Journal of Statistical Software, 64*(7), 1–30. https://doi.org/10.18637/jss.v064.i07.

Marco, E. J., Hinkley, L. B. N., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in autism: A review of neurophysiologic findings. *Pediatric Research, 69*(5 Pt 2), 48R–54R. https://doi.org/10.1203/PDR.0b013e3182130c54.

McIntosh, D. N., Miller, L. J., & Shyu, V. (1999). Development and validation of the Short Sensory Profile. . In W. Dunn (Ed.), *Sensory Profile*. San Antonio, TX: The Psychological Corporation.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *The American Journal of Occupational Therapy, 61*(2), 135–140. https://doi.org/10.5014/ajot.61.2.135.

Neil, L., Olsson, N. C., & Pellicano, E. J. (2016). The relationship between intolerance of uncertainty, sensory sensitivities, and anxiety in autistic and typically developing children. *Journal of Autism and Developmental Disorders, 46*(6), 1962–1973. https://doi.org/10.1007/s10803-016-2721-9.

Philpott-Robinson, K., Lane, A. E., & Harpster, K. (2016). Sensory features of toddlers at risk for autism Spectrum disorder. *American Journal of Occupational Therapy, 70*(4), 1–8. https://doi.org/10.5014/ajot.2016.019497.

Schaaf, R. C., & Lane, A. E. (2015). Toward a best-practice protocol for assessment of sensory features in ASD. *Journal of Autism and Developmental Disorders, 45*(5), 1380–1395. https://doi.org/10.1007/s10803-014-2299-z.

Schaaf, R. C., Toth-Cohen, S., Johnson, S. L., Outten, G., & Benevides, T. W. (2011). The everyday routines of families of children with autism: Examining the impact of sensory processing difficulties on the family. *Autism, 15*(3), 373–389. https://doi.org/10.1177/1362361310386505.

Schulz, S. E., & Stevenson, R. A. J. A. (2019). Sensory hypersensitivity predicts repetitive behaviours in autistic and typically-developing children. *Autism, 23*(4), 1028–1041. https://doi.org/10.1177/1362361318774559.

Simpson, K., Adams, D., Alston-Knox, C., Heussler, H. S., & Keen, D. (2019). Exploring the sensory profiles of children on the autism spectrum using the Short Sensory Profile-2 (SSP-2). *Journal of Autism and Developmental Disorders, 49*, 2069–2079.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. *The American Journal of Occupational Therapy, 61*(2), 190–200. https://doi.org/10.5014/ajot.61.2.190.

Tomchek, S. D., Little, L. M., Myers, J., & Dunn, W. (2018). Sensory subtypes in preschool aged children with autism Spectrum disorder. *Journal of Autism and Developmental Disorders, 48*(6), 2139–2147.

Uljarević, M., Baranek, G., Vivanti, G., Hedley, D., Hudry, K., & Lane, A. (2017). Heterogeneity of sensory features in autism spectrum disorder: Challenges and perspectives for future research. *Autism Research, 10*(5), 703–710. https://doi.org/10.1002/aur.1747.

Uljarević, M., Lane, A., Kelly, A., & Leekam, S. (2016). Sensory subtypes and anxiety in older children and adolescents with autism spectrum disorder. *Autism Research, 9*(10), 1073–1078. https://doi.org/10.1002/aur.1602.

Wigham, S., Rodgers, J., South, M., McConachie, H., & Freeston, M. J. (2015). The interplay between sensory processing abnormalities, intolerance of uncertainty, anxiety and restricted and repetitive behaviours in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(4), 943–952.

Wolff, J. J., Dimian, A. F., Botteron, K. N., Dager, S. R., Elison, J. T., Estes, A. M., et al. (2019). A longitudinal study of parent-reported sensory responsiveness in toddlers at-risk for autism. *Journal of Child Psychology and Psychiatry, 60*(3), 314–324. https://doi.org/10.1111/jcpp.12978.

Wolff, J. J., Swanson, M. R., Elison, J. T., Gerig, G., Pruett, J. R., Styner, M. A., et al. (2017). Neural circuitry at age 6 months associated with later repetitive behavior and sensory responsiveness in autism. *Molecular Autism, 8*(1), 8. https://doi.org/10.1186/s13229-017-0126-z.