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Abstract

The aim of this study was to identify sensory subtypes in children on the autism spectrum using the Short Sensory Profile-2 (SSP-2). Caregivers of children on the autism spectrum aged 4 – 11 years ($n = 271$) completed the SSP-2. Analysis using Dirichlet process mixture model identified a two-cluster model which provided the best solution to subtype sensory responses. Two distinct subtypes were identified: Uniformly elevated (67%) with high scores across all quadrants and Raised avoiding and sensitivity (33%) with raised scores in the avoiding and sensitivity quadrants. There were no differences between subtypes based on chronological age and autism characteristics measured using the social communication questionnaire (total score). Based on the SSP-2, children were reported to experience differences in responses to sensory input, in particular in the area of sensitivity and avoiding.

Introduction

Many children on the autism spectrum display sensory differences and have difficulties processing sensory information (Ben-Sasson et al. 2009). Hyper- and hypo-reactivity to sensory input is now included as a core characteristic of autism in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association 2013). Differences in sensory profiles appear early in young children on the autism spectrum and impact on individuals across their lifespan (see review by Dunn et al. 2016). Children on the autism spectrum may display hypo-responsiveness (under responsiveness) and/or hyper-responsiveness (over responsiveness) to sensory input, with differing profiles occurring across and within sensory modalities (Baranek et al. 2006). These sensory responses can have a profound effect on daily life and have been associated with decreased activity, school and social participation, increased anxiety, challenging behaviours, and poorer cognitive outcomes (see review by Dunn et al. 2016). More specifically, sensory response types have been associated with differing behaviours. Hypo-responsivity has been associated with lower developmental outcomes in young children (Tomchek et al. 2018), while hyper-responsivity has been associated with poorer activity and social competence (Reynolds et al. 2011).

One of the challenges in tailoring support for individuals on the autism spectrum is the extensive heterogeneity among children on the spectrum in relation to sensory differences. One possible approach that may better describe and characterise this heterogeneity is sensory subtyping. Subtyping uses statistical analysis to test the validity of subgroups within a broader group or category and has been explored in autism since the 1970s (Lotter 1974).

However, subtyping of sensory profiles has received limited attention in the research literature. A systematic review of sensory-based subtypes within children on the autism

spectrum identified only eight sensory subtyping studies (DeBoth and Reynolds 2017). Two additional subtyping studies have been published (Tomchek et al. 2018; Uljarevic´ et al. 2016). The summary of these studies provided in Table 1 (with the exclusion of Baranek et al. [2007] who focused only on hyper-responsive sensory patterns), demonstrates the lack of consensus on both the number and nature of sensory subtypes in children on the autism spectrum, with differences based on severity of responses and sensory modality. Studies reported between three and five subtypes. Across the studies, there were two commonly reported subtypes: children who were clinically not significantly different from the normative sample in their sensory responsiveness, and children with significant impairments across all or most sensory domains. However, there were qualitative differences in the features of other subtypes reported across the studies.

[Table 1 goes about here]

A considerable proportion of the disparity between subtypes is likely to be associated with the selection of measures and age of the participants (DeBoth and Reynolds 2017). Current standardised measures of sensory differences predominantly rely on parent/caregiver report and vary in composition of total and subscale scores and aspects of the sensory profile assessed. For example, Lane, Molloy and Bishop (2014) report a specific subtype on the Short Sensory Profile (SSP; McIntosh, Miller & Shyu 1999) characterised by taste and smell sensitivity, auditory sensitivity and seeking sensation; a profile that is only possible to describe using the SSP as other measures do not have the same or equivalent subscales. Disparity across studies may also be due to measures being adapted by specific research teams (e.g. Liss, Saulnier, Fein and Kinsbournes [2006] created their own questionnaire using items from the Sensory Profile with additional questions) or entered as part of a range of measures in the analysis (e.g.,Tomchek et al. 2018).

The most frequently used measures have been those within Dunn et al.'s Sensory Profile, which includes the Sensory Profile (SP; Dunn 1999), the Short Sensory Profile (McIntosh et al. 1999), and the Infant Toddler Sensory Profile (ITSP; Dunn 2002). These measures have been recently revised to create the Sensory Profile Second Edition (SP2; Dunn 2014). This version has improved consistency of questions across forms allowing for easier comparison, a change in the order of ratings to reflect a strengths-based approach, a reduction in the number of questions, and an increase in age range and behaviours described based on Dunn's Sensory Processing Framework (Dunn 2014). Furthermore, these changes which classify items under the broader sensory modalities including hypo-responsivity, hyper-responsivity and sensory seeking have been suggested as being more representative of sensory responses (Williams et al. 2018). This measure may prove to be a useful tool for sensory subtyping however only one published study could be found that has used the SP2 as a measure to determine sensory subtypes. Little, Dean, Tomchek and Dunn (2016) used the SP2 to classify subtypes across 1132 children aged 3-14 years recruited through a national study. Based on parent reports, 69.6% of participants were described as typically developing, 17.4% with a diagnosis on the autism spectrum, of ADHD or both, and the remaining 13% with other exceptionalities. Five clusters were identified (see Table 1), with 35.1% of children on the autism spectrum being classified under the balanced subtype, 24.7% vigilant, and 19.5% intense. These results suggest that the SP2 is able to discriminate between different sensory profiles for children on the spectrum. However, given the disparity of results across previous subtyping studies, further subtyping studies using this newly available measures are required.

Developed as part of the SP2, Short Sensory Profile -2 (SSP-2; Dunn 2014)) could provide useful information that may inform intervention efforts. The SSP-2 consists of 34 items from the SP2. The advantage of the SSP-2 is that it can easily be administered within a

clinical practice and the shorter survey length is associated with increased response rates, quality of responses, and survey completeness (Haunberger 2011; Liu and Wronski 2018). The aim of this study was to investigate sensory subtypes with a large population of children on the autism spectrum using the SSP-2.

Method

Data used in this study were drawn from the Longitudinal study of Australian Students with Autism (LASA), a cross-sequential cohort study focusing on child participation and educational outcomes for children on the autism spectrum. The full recruitment procedure for the larger study is described in Roberts et al. (2018). Briefly, primary recruitment for caregivers of children on the autism spectrum aged 4 – 5 and 9 – 10 years living in Australia was through clinics and advertisements on social media. The child's diagnosis of autism was reported by parents. All participants were asked to provide copies of their child's diagnostic reports to confirm diagnosis. The LASA study collects data for the two cohorts at six-time points approximately one year apart, using Qualtrics online survey software. Data for the current analysis were drawn from the first year of data collection. Ethical approval for this study was obtained from participating universities and health authorities.

Participants

There were 272 participants recruited in the first year of the LASA study. Participants were included in this study if they had a community diagnostic report and/or a score of ≥ 15 on the Social Communication Questionnaire (see Measures section). Participants were excluded if their SSP-2 was incomplete and could not be scored (see Measures section). The final sample for this study consisted of data on 248 children on the autism spectrum, with 118 aged between 4 years and 6 years 2 months ($M \, age = 60.3$ months, $SD = 6.7$ months), and 130

aged between 8 years 7 months and 11 years 5 months (*M age* = 118.9 months, *SD* = 7.3

months). The demographic information on the sample is shown in Table 2.

[Table 2 goes about here]

The child ratio of males to females was 4.6:1, which reflects a higher proportion of

males than that expected given recently published rates of approximately 3.3:1 (Loomes et al.

2017). Over 40% of the children were identified as having co-occurring conditions including

ADHD (14.8%), anxiety (5.1%), and epilepsy (2%). The majority of caregiver informants

were mothers, aged 31 – 50 years, with a tertiary education.

Measures

Autism characteristics. Social Communication Questionnaire Lifetime Version (SCQ;

Rutter et al. 2003) is a parent-completed questionnaire that is used as a screening tool for

autism (Eaves et al. 2006). A cut-off score of ≥ 15 supports characteristics of autism.

Sensory. The Short Sensory Profile 2 (SSP-2; Dunn 2014) is a 34-item parent questionnaire

designed to measure behaviours associated with abnormal responses to sensory stimuli in

children aged 3.0 – 14.11 years. The SSP-2 provides scores in the four quadrants of Dunn's

Sensory Processing Framework based on the child's neurological threshold to sensory input

and their method of self-regulation. The four quadrants are Seeking (e.g., "rocks in chair, on

floor, or while standing"), Avoiding (e.g., "resists eye contact from me or others"),

Sensitivity (e.g., "is distracted when there is a lot of noise around"), and Registration (e.g.,

"bumps into things, failing to notice objects or people in the way"). Cronbach's alphas were

calculated for this sample for each of the four quadrants. Seeking consisted of 7 items (α =

.69), Avoiding consisted of 9 items (α = .83), Sensitivity consisted of 10 items (α = .75), and

Registration consisted of 8 items (α = .75). The frequency the child displays each item

behaviour is scored on a Likert scale ranging from 1 (*almost never* = 10% or less) to 5

(*almost always* = 90% or more). Raw score totals can be calculated for each quadrant. Dunn

(2014) has provided a Normal Curve and Sensory Profile 2 Classification System, based on responses from a normative sample of children without disabilities ($n = 697$). Based on a bell curve normed distribution, the raw score total for each quadrant can be classified as "much less than others" (lower 2%), "less than others" (between 1 SD and 2 SD below the mean, accounting for 14% of the normative sample), "just like the majority of others" (+/- 1 SD from the mean and accounting for 68% of the normative sample), "more than others" (between 1 SD and 2 SD above the mean), and "much more than others (upper 2%).

Analysis

Prior to the cluster analysis, the distribution spread of results for this sample was plotted against the expected distribution of results based upon the normative data in Dunn (2014). A mixture model analysis was chosen for the study as this soft clustering technique allows for the identification of cluster profiles that best explain similarities between the four domains on the SSP-2 (Seeking, Avoiding, Sensitivity, Registration), whilst avoiding hard classifications of individuals who may have features of several subtypes. This analysis was used to determine if different subtype classifications explain the observed results. Initial analysis was conducted on the Sensory Profile 2 Classification System using Normal mixture models to obtain subtypes of responses. Although there was a relatively large number of individuals in the study (N = 248), the discrete nature of the test scores resulted in standardised scores with a limited range of unique values. The number of unique standardised scores ranged from 29 – 34 over the four domains. This coarseness in the data, known commonly as binning, results in a solution where a Multivariate Normal Mixture is likely to have too few components to represent the true underlying density (Alston and Mengersen 2010).

Normed scales of the quadrant scores were calculated based on the Normal Curve and Sensory 2 Profile Classification System. Multivariate clusters of the normed scale scores were detected using Dirichlet process mixture models (DPMM). The DPMM was used in

this analysis because the outcome variables were a mix of continuous (severity) and ordinal categorical data (Molitor et al. 2010). Modelling was performed using the PreMiUM library (Liverani et al. 2015) with R software (R Core Team 2013).

The DPMM incorporates estimating the number of components within the modelling framework, rather than approaching the model selection via fitting a series of models and comparing a measure of fit, such as the Bayesian Information Criteria (BIC). Essentially, the DPMM has an infinite number of components, and the algorithm implemented with Monte Carlo Markov Chain (MCMC) techniques adapts the number of "active" components based on the previous component memberships (Liverani et al. 2015).

Results

The distribution spread of participant results for each domain was compared to the Normal Curve and Sensory Profile-2 Classification System, and is displayed in Figure 1. Based on the normative data, 2% of the population were expected to achieve scores in the "much more than others" range. However, on each of the four domains, more than 2% achieved a score within this range; Seeking (37.1%), Avoiding (62.1%), Sensitivity (65.7%), and Registration (56.5%).

[Figure 1 goes about here]

Cluster Profile

Posterior probability of k clusters suggests the two-cluster model is the most probable model (28%), followed by three cluster (26%), four cluster (16%), five cluster (11%), and six cluster (7%). The cluster proportion of score distribution in the two-cluster model is displayed in Figure 2. The profile labels used by Little el al. (2017) were adopted in this study. The first profile, labelled as "Uniformly elevated", includes participants (*n* = 182) who have elevated differences across all domains. It has the highest number of people with scores on scale 5 (definite difference) across all domains, and additionally, with a high level of scale 4

(probable difference) scores in seeking. The second profile, labelled "Raised avoiding and sensitivity", includes participants ($n = 66$) who receive scores within the typical range on seeking and registration domains, as is indicated by the largest component weight (proportion of cluster) being seen with scale 3 (within typical range). This profile has elevated scores on sensitivity and avoiding, as is evidenced by the increased proportion of children allocated to this component who have scores on scale 4 (probable difference).

[Figure 2 goes about here]

As with any latent variable mixture model, there are many possible combinations of the mixture that can result in a satisfactory estimate of the overall density. In this analysis, the number of iterations when the three-cluster model was favoured was almost as high as the two-cluster model (26% vs 28%). However, postprocessing of the MCMC estimates indicate that there were at least two different three-cluster models explored.

Histograms of the number of individuals allocated to each profile during the 12839 iterations which visited the three-cluster model are displayed in Figure 3. It can be noted that the intense cluster has a relatively stable number of individuals assigned to it (mean = 180). For around 10,300 of the iterations, the Extra 1 profile consists of a small number of individuals, 10 or fewer, where one or more of their measures did not necessarily fit the consistent pattern of either the Uniformly elevated or Raised avoiding and sensitivity profile. Because so few individuals belong to this "new" profile, it is inconclusive as to whether this would be applicable to a larger sample. For around 2,500 iterations, there is a third profile which is more substantial, comprising of an average of 28.5 individuals. This Extra 2 profile aligns with individuals who were identified as having slightly different scores on seeking. While this profile contains a much larger number of individuals, overall, it was preferred in very few of the total model iterations and, as such, does not have a large support for this model. The individuals are generally those who would have been allocated to the Raised

avoiding and sensitivity profile under the other models. This phenomenon can be seen in the extended left tail of the histogram for the Raised avoiding and sensitivity profile.

[Figure 3 goes about here]

Frequencies of Item Presentation

Descriptive analysis was conducted at the item level to identify if particular items occurred more or less frequently within this group. Four items were each rated as occurring more than half the time by over 70% of participants. Three items were from the avoiding quadrant: "Needs positive support to return to challenging situations"; "Gets frustrated easily"; "Has strong emotional outbursts when unable to complete a task"; and one item from the sensitivity quadrant, "Is distracted when there is a lot of noise around". Items rated as occurring less than half the time by most participants were "moves stiffly "(70.5%) and "loses balance unexpectedly when walking on uneven surfaces (67%).

Age and Level of Autism Characteristics

Child age and level of autism characteristics based on SCQ scores ($M = 22.33$; $SD = 6.05$) were added as regressors within the model. Based on the posterior distribution of the parameters, no meaningful differences were identified in the cluster models with age or autism characteristics.

Discussion

Using the SSP-2, a two-cluster model provided the best solution to subtype the sensory responses of children on the autism spectrum (4 – 10 years) in this study. The two subtypes within this cohort demonstrated differing responses to sensory input on at least two of the four domains. The subtype profiles Uniformly elevated (high scores across all quadrants) and Raised avoiding and sensitivity (raised scores in the avoiding and sensitivity quadrants), correspond with Little et al.'s (2016) profiles of the Intense and Vigilant subtypes. While

some support for a three-cluster model was indicated, post-modelling analysis identified the clear presence of submodels and their associated covariate patterns reducing the likelihood of a three-cluster model being applicable to these data.

A two-cluster solution differs from the findings of a previous study that used the SP-2 and that proposed a five-cluster model (Little et al. 2016). An explanation of these different findings may lie in details related to the study populations and type of analyses conducted. While the Little et al. study sample consisted of a large sample of children ($N = 1132$), by far the largest group were typically developing ($n = 788$) compared to a much smaller number of children on the autism spectrum ($n = 77$). The current study sample consisted only of children on the autism spectrum ($n = 248$) who may show an autism-specific profile that could have been overshadowed by the large number of typically developing children in the Little et al. study. In addition, the age ranges in the two studies differed, with the Little et al. study including a wider age range than the current study. Children in this study were clustered around two mean age points (5 years 3 months and 9 years 9 months) and this age range appears to coincide with highest rates of reported sensory differences in children on the autism spectrum compared with the typical population (6-9 years; meta-analysis Ben-Sasson et al. 2009). While further research is needed to confirm the two-cluster model, this study makes an important contribution in highlighting how sensory profiles of children on the autism spectrum may differ from those in the non-autistic population.

In relation to data analyses, the (BIC) used by Little et al. (2016) looks at the overall fit of the mixture model to the density of the whole data set, and when the addition of clusters' improved fit is outweighed by model complexity, no further clusters are added. Using a BIC strategy may miss small but important clusters, as the underlying strategy for the BIC is to represent the density of the whole data set with minimal complexity (minimising the number of parameters via component numbers). Therefore, when modelling a large data

set, as was the case in the Little et al. study, and a few individuals do not fit well into the current mixture density, adding a cluster for them will not really enhance the overall model fit, and as such, this cluster addition will be rejected, and the individuals will be assigned to a current cluster. As a result, the children allocated to the largest cluster may or may not be appropriately allocated in the latent variable update, and a closer examination of the data would be required. In Little et al., the largest cluster was the Balanced profile and 35.1% of the children on the autism spectrum were allocated to this subtype. However, children on the autism spectrum, or those on the spectrum with a co-morbid diagnosis of ADHD, predominantly made up the Intense (37.9%) and Vigilant (45.1%) subtypes, suggesting this may be more representative of these children as reported in the current study.

The findings from this study differ also from those that have used the SSP (Lane et al. 2014; Lane et al. 2011; Lane et al. 2010). The use of different measures has been one of the explanations given for sensory subtypes differing across studies (DeBoth and Reynolds 2017), and this outcome appears to be supported in this study. That is, it is likely that differences between the SSP-2 and SSP have resulted in different sensory subtypes. A key difference between the two assessment tools is that the SSP consists of seven domains (tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive/seeks sensation auditory filtering, low energy/weak, visual/auditory sensitivity) while the SSP-2 consists of only four domains (seeking, avoiding, sensitivity and registration). This change occurred through a reclassification of items and development of new items that formed the new domains. Using the SSP, Lane and colleagues (2010; 2014; 2011) identified a subtype characterised by extreme taste/smell sensitivity; however, these items are no longer included in the SSP-2 and therefore would not be replicated in the current study. A comparison of items between the two measures reveals that less than 30% of items are matched on item description, and the avoiding domain on the SSP-2 has no comparable match on the SSP. In

order for sensory subtyping to be diagnostically and clinically useful, it will be important to have some consensus among researchers about subtyping methodology and selection of measures. As mentioned in theIintroduction, the SSP-2 has advantages over earlier versions, with improved consistency of questions across forms allowing for easier comparison, a change in the order of ratings to reflect a strengths-based approach, fewer questions, and an increase in the age range and behaviours covered. Further work is needed, but based on an adequate sample size (larger than 62% of the previous sensory subtyping studies detailed in Table 1) and use of the SSP-2 in this study, there is preliminary support for a two-cluster model of sensory subtypes in children on the autism spectrum.

In this study, autism characteristics, as measured by the SCQ, were not identified as a contributing factor to the sensory subtypes, a finding consistent with some earlier studies (Lane et al. 2014; Jasmin et al. 2009). However, previous findings in this regard have been mixed, with Ben-Sasson et al., (2009) reporting some association between autism characteristics and sensory subtypes. Once again, comparison across studies is difficult with samples differing in age and with different measures of sensory responsiveness and autism characteristics. Therefore, the current findings need to be interpreted with caution.

Implications

The results from this study identified that children on the autism spectrum demonstrate differences in responses to sensory input, with overall differences in the Avoiding and Sensitivity quadrants. Understanding these profiles has important implications for both clinicians and researchers working with or supporting children on the spectrum. Once valid and reliable sensory subtypes are established, they can be explored in terms of their presentation (e.g., behavioural presentation), relationship with frequently reported co-morbid diagnoses (e.g., anxiety) and impact (e.g., academic outcomes, caregiver experiences). Exploring the profile of subtypes over time can also aid with prognosis and identification of

children who may benefit the most from tailored and subtype-specific interventions. Valid and reliable subtypes also have clear implications for neurobiological studies that aim to link sensory profiles with the underlying mechanisms (Ausderau, Sideris et al. 2014).

Through gathering data on sensory measures to explore sensory subtypes, it is also possible to explore item-level profiles which may provide further insight into sensory experiences for individuals on the spectrum. For example, within this sample, over 80% of the group scored *frequent/almost always* on the item "is distracted when there is a lot of noise around". This level of information could inform the creation of "autism-considerate" environments that control some of the factors in the environment that may be challenging for children on the autism spectrum.

Limitations and Future Research

Sensory responses are interpreted based on the individual's behavioural response to the sensory input. Current sensory measures used in clinical practice require an interpretation of the behaviour, by the parent or therapist, and may not reflect individual experiences. The relationship or extent to which behaviour aligns with sensory or other autism-related behavioural difficulties requires further investigation.

Children in this study were drawn from a larger study with two age cohorts and when combined, ages ranged from 4 – 11 years. This can be viewed as an advantage, as results may be less confounded by age-related variability in sensory profiles. However, caution must also be taken in relation to generalizing these results to younger or older children not represented in the sample. Because parents were enrolled in to a larger, longitudinal study focusing upon educational outcomes, the risk of recruitment bias is limited for parents who are particularly interested in, or having difficulties with, their child's sensory profile. However, a different recruitment bias may be introduced with only parents who were interested in educational outcomes and willing and/or able to commit to a 6-year study enrolling into the study.

Finally, the survey is cross-sectional. There has been little research investigating the stability of the sensory profile over time. One large study (Ausderau, Furlong et al. 2014) suggests that 91% of children remained stable in their subgroup over 1 year. However, this was based on a different measure and a larger number of subtypes. It may be that with a smaller number of subtypes, profiles remain more stable, although this is as yet unknown and needs to be explored longitudinally.

Conclusion

This is the first study to identify sensory subtypes in children on the autism spectrum using the SSP-2. The results suggest that the children (4 – 11 years) on the autism spectrum experience differences in responses to sensory input, in particular in the area of sensitivity and avoiding, with overall differences in the avoiding and sensitivity sensory behaviours ranging from elevated differences on items classified in the sensitivity and avoiding quadrants through to marked differences across all sensory quadrants.

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Table 1

Sensory Subtype Classifications of Children on the Autism Spectrum

Author/year	Population	Measure	Subtypes
Ausderau et al. (2014)	N = 1294 Time 1 N = 884 Time 2 2 – 12 years	Sensory Experiences Questionnaire	1. Mild (n = 308; 29%)*: lower than average on hypo-responsiveness (HYPO), hyper-responsiveness (HYPER), sensory interests and seeking behaviours (SIRS), enhanced perception (EP) 2. Extreme mixed (n = 291; 28%): Elevated scores on HYPO, HYPER, SIRS, EP 3. Sensitive-Distressed (n = 179; 17%): Elevated scores on HYPER and EP 4. Attenuated-Preoccupied (n = 182; 17%): Elevated scores on HYPO and SIRS
Ben-Sasson et al. (2008)	N = 170 18 – 33 months	Infant Toddler Sensory Profile	1. Low frequency (n = 44; 25.9%): on under- and over-responsivity and seeking scales 2. High frequency (n = 49; 28.8%): on under- and over-responsivity and seeking scales 3. Mixed (n = 77; 45.3%) high frequency of under- and over-responsivity, low frequency of seeking
Lane et al. (2010)	N = 54 33 – 115 months	Short Sensory Profile	1. Sensory-based inattentive seeking (n = 24; 44.4%): typical with mild elevation in auditory filtering and under-responsive/seeks sensation 2. Sensory modulation with movement sensitivity (n = 17; 31.5%): severe differences on all domains 3. Sensory modulation with taste/smell sensitivity (n = 13; 24.1%): differences across domains with extreme differences in taste/smell but typical on movement sensitivity and low energy/weak

Lane et al. (2014)	$N = 228$ 2 – 10 years	Short Sensory Profile	1. Sensory adaptive (n = 84; 36.8%): typical with mild elevation in auditory filtering and under-responsive/seeks sensation 2. Taste/Smell sensitive (n = 92; 40.4%): extreme taste/smell sensitivity and elevated auditory filtering, under-responsive/seeks sensation 3. Postural inattentive (n = 23; 10.1%): extreme low energy weak, and elevated auditory filtering, under-responsive/seeks sensation 4. Generalised sensory difference (n = 29; 12.7%): differences on all sensory domains
Lane et al. (2011)	$N = 30$ 41 – 113 months	Short Sensory Profile	1. Cluster 1 (n = 4; 13.3%): severe difference in taste/smell and low energy/weak, moderate differences in under-responsive/seeks 2. Cluster 2 (n = 6; 20.0%): low differences 3. Cluster 3 (n = 6; 20.0%): high under-responsivity and sensory seeking 4. Cluster 4 (n = 9; 30.0%): severe difference in taste/smell 5. Cluster 5 (n = 4; 13.3%): moderate to severe differences in all domains
Liss et al. (2006)	$N = 144$ Mage(SD) = 102.4 (50.1) months	Sensory Profile (52 of the 125 items selected) plus 43 additional questions specific to sensory behaviours in autism	1. Cluster 1 (n = 17; 11.8%): sensory over responsivity 2. Cluster 2 (n = 36; 25.0%): low differences 3. Cluster 3 (n = 44; 30.6%): high under-responsivity and sensory seeking 4. Cluster 4 (n = 47; 32.6%): sensory over responsivity (not as high as Cluster 1)
Little et al. (2017)	$n = 101$ (ASD, ASD+ADHD) 3 – 14 years	Sensory Profile 2	1. Balanced (n = 36; 35.6%): within typical range 2. Interested (n = 9; 8.9%): elevated sensory seeking 3. Intense (n = 22; 21.8%): elevated across all domains

			4. Mellow until… (n = 11; 10.9%): elevated on registration and avoidance
			5. Vigilant (n = 23; 22.8%): elevated on avoiding and sensitivity
Tomchek et al. (2018)	*N* = 400 3 – 6 years	Short Sensory Profile	1. Sensorimotor (n = 204; 51.0%): increased taste/smell sensitivity, seeking, hypo-responsiveness 2. Selective-Complex (n = 59; 14.8%): increased taste/smell and auditory/visual sensitivity, seeking, hypo-responsiveness 3. Perceptive-Adaptive (n = 98; 24.5%): slightly increased response in seeking 4. Vigilant-Engaged (n = 39; 9.7%): increased taste/smell and auditory/visual sensitivity, and seeking
Uljarevic´ et al. (2016)	*N* = 57 11 – 17 years	Short Sensory Profile	1. Sensory adaptive (N = 19; 33.3%): responses within normative range 2. Sensory moderate (N = 29; 50.9%): responses 1 – 3 *SDs* below the mean 3. Sensory severe (N = 9; 15.8%): responses 6= – 3 *SDs* below the mean (Note: lower scores indicate more severity)

Table 2

Child and Caregiver Characteristics (Total sample = 248)

| Demographic variables	*N* (%)
Child gender	
Male	204 (82.3)
English language spoken at home	248 (100)
Co-occurring conditions	119 (40.1)
Caregiver's relationship to the child	
Mother	217 (87.5)
Father	25 (10.1)
Other	6 (2.4)
Caregiver's age (or mean)	
< 30 years	14 (5.6)
31 – 40 years	127 (51.2)
> 41 years	107 (43.2)
Caregiver's highest level of education	
No formal/Primary school	2 (0.8)
Secondary school	54 (21.8)
Tertiary education	191 (77.0)
Missing	1 (0.4)
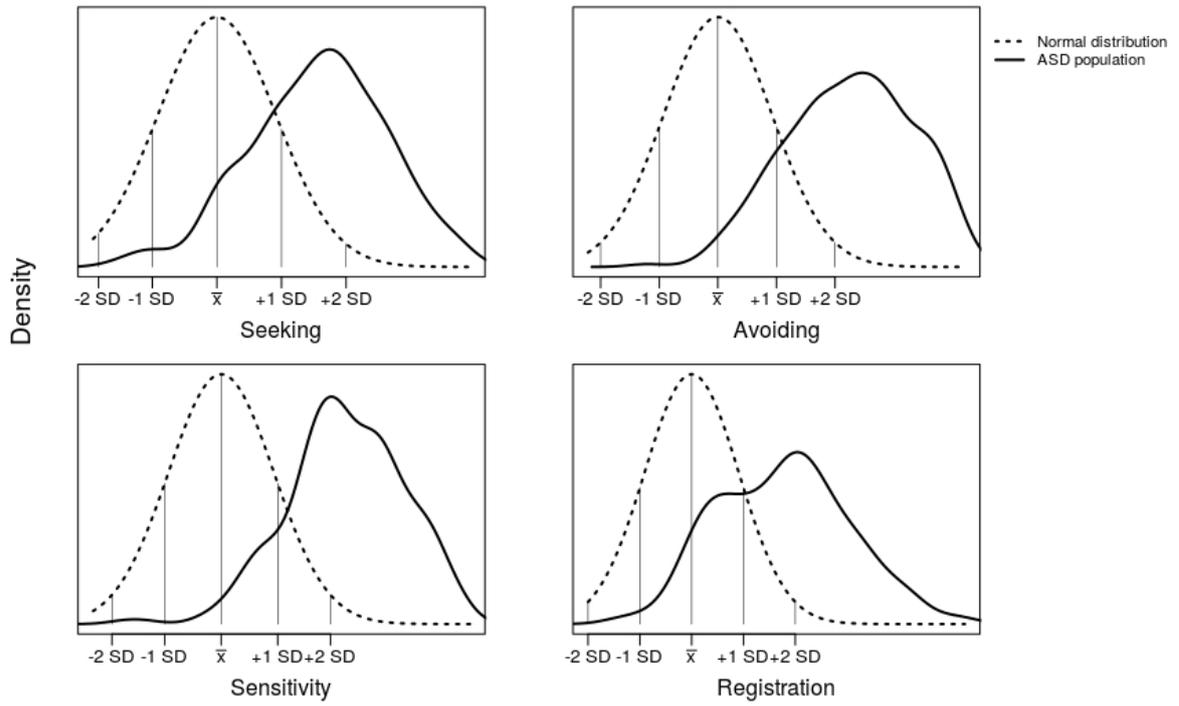
Figure 1. Distribution of participant quadrant scores compared with the Normal Curve and Sensory Profile 2 Classification System.
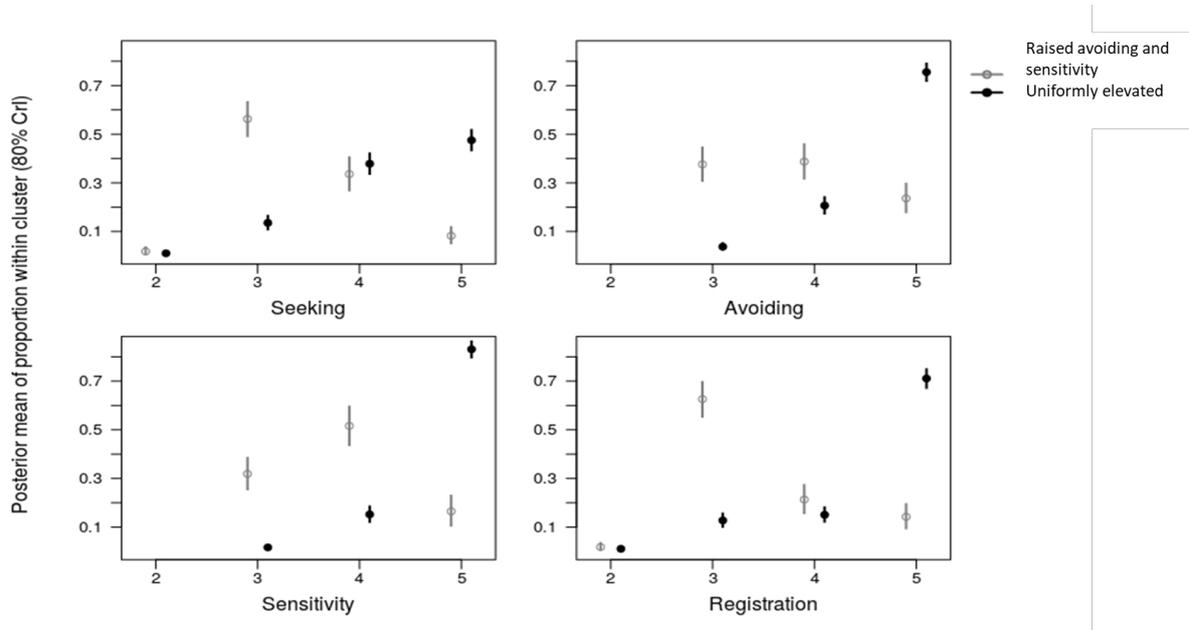
Figure 2. Posterior summary of proportion of sample contained in each cluster. Posterior mean identified by open/closed circles and indicated spread denotes 80% credible interval.
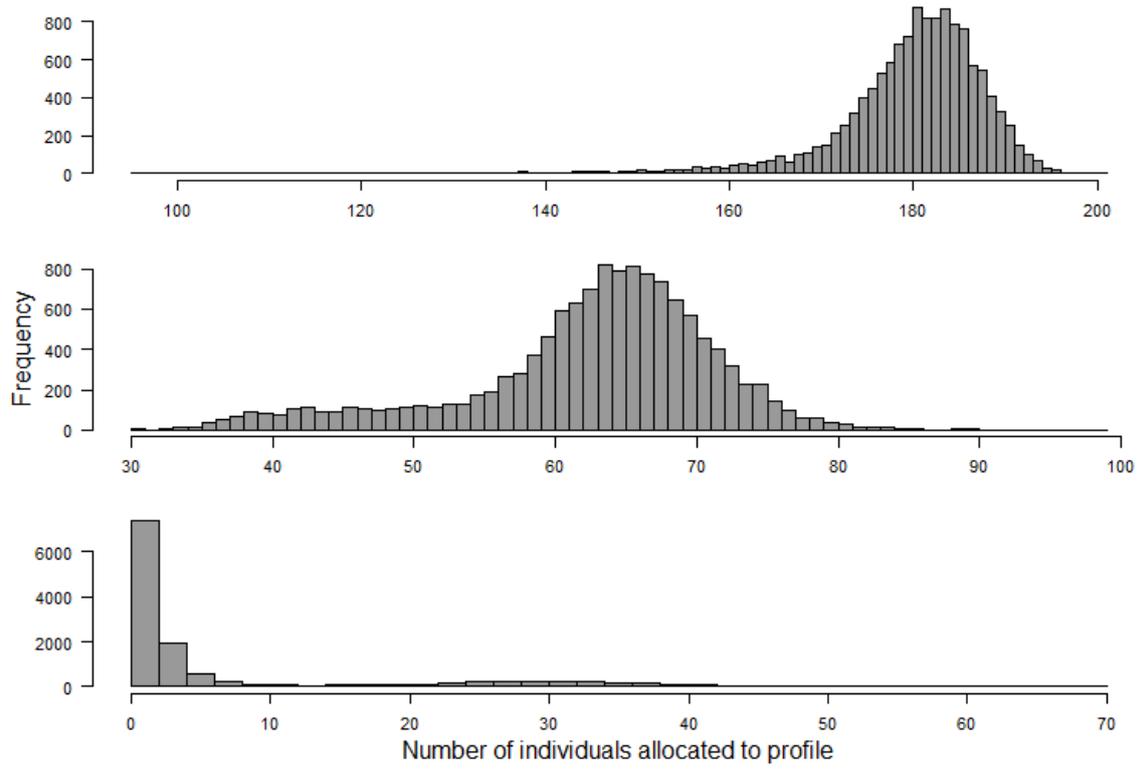
Figure 3. Histograms of number of individuals assigned to each profile over 12,839 iterations of the sampler containing three components. Top Panel: Uniformly elevated, Middle Panel: Raised avoiding and sensitivity, Bottom Panel: Extra 1 and 2.