



# The relationship between ADHD traits and sensory sensitivity in the general population

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## Abstract

Preliminary studies in children and adults with Attention Deficit Hyperactivity Disorder (ADHD) report both hypo-responsiveness and hyper-responsiveness to sensory stimuli, as well as problems modulating sensory input. As it has been suggested that those with ADHD exist at the extreme end of a continuum of ADHD traits, which are also evident in the general population, we investigated the link between ADHD and sensory sensitivity in the general population. Two online questionnaires measuring ADHD traits and sensory responsiveness across various sensory domains were administered to 234 participants. Results showed a highly significant positive correlation between the number of ADHD traits and the frequency of reported sensory processing problems. An increased number of sensory difficulties across all modalities were associated with the level of ADHD. Furthermore, ADHD traits predicted sensory difficulties and exploratory factor analysis revealed a factor that combined ADHD trait and sensory processing items. This is the first study to identify a positive relationship between sensory processing and ADHD traits in the general population. Our results suggest that sensory difficulties could be part of the ADHD phenotype. Crown Copyright © 2017 Published by Elsevier Inc. All rights reserved.

## 1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a behavioural disorder defined by either an attentional dysfunction, hyperactive/impulsive behaviour, or both (DSM-V; [1]). ADHD is the most common neurodevelopmental disorder [2,3]. In roughly half of the children diagnosed with ADHD, symptoms persist into adulthood [4]. As a result, ADHD has also been validated as an adulthood disorder, with remaining symptoms in adults including distractibility and difficulties with maintaining goal-directed behaviour rather than hyperactivity [33].

Sensory processing refers to the way that individuals manage incoming sensory information, including the reception, modulation, integration, and organization of sensory stimuli [5]. A related concept, sensory modulation, refers to the capacity to regulate and organise the degree, intensity, and nature of responses to sensory input in a graded and adaptive manner, so that an optimal range of performance and adaptation to challenges can be maintained

[6]. Abnormalities in sensory processing have been found in many developmental disorders such as autism and dyslexia [7–9]. The two most common sensory processing difficulties are hyper- and hypo-responsiveness [10]. Hyper-responsiveness (hypersensitivity) refers to an exaggerated response to a sensory stimulus (e.g., aversion to certain sounds). Hypo-responsiveness (hyposensitivity) can be defined as the lack of response or response of insufficient intensity to sensory stimuli (e.g., diminished response to pain).

Both empirical evidence and anecdotal accounts suggest the presence of sensory processing abnormalities in ADHD [11–13]. A number of studies have discovered differences between ADHD and control groups in a variety of sensory modalities including vision [14–16], hearing [17], touch [18], smell [19], vestibular system [20], and multisensory integration [21]. In addition to this, a number of studies suggest that areas associated with sensory processing are abnormal in ADHD [16,22,23,54]. Previous studies in children have found that ADHD is associated with increased sensitivity to sensory stimuli and environmental changes in infancy [24]. Moreover, children with ADHD show behavioural evidence of difficulty modulating sensory responses and demonstrate over-responsivity significantly more frequently than typically developing children [25].

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A number of previous studies have attempted to empirically investigate sensory processing in ADHD using physiological measures; somatosensory evoked potential (SEP), [13], electrodermal reactivity (EDR), [12]; Hypothalamic Pituitary Adrenal (HPA) activity, [26]; tactile sensitivity, [55]; magnetoencephalography (MEG), [27]. Abnormal responses were found among individuals with ADHD across modalities.

Sensory processing difficulties have been identified in children with ADHD [56] and have been shown to negatively influence their leisure activity preference. A study by Cheung & Siu [28] compared sensory processing profiles in children with ADHD or Autistic Spectrum Disorder (ASD) and typically developing children. Both ADHD and ASD were associated with significantly more sensory processing issues than children without disabilities. However, no major differences in sensory processing issues were found between children with either ASD or ADHD [28]. Other work however has demonstrated hypo- and hypersensitivity symptoms in ADHD that were not related to autistic symptoms or other co-morbid disorders [29].

It has been argued that ADHD psychopathology can be viewed dimensionally, with inattentive and hyperactive-impulsive symptoms distributed continuously in the general population [30]. Evidence at the level of molecular genetics also provides support for the hypothesis that ADHD represents the extreme end of traits present in the general population [31]. A number of recent studies have exploited the dimensional property of ADHD and revealed significant differences between healthy individuals with high and low levels of ADHD traits [16,23,32].

Studying the relationship between sensory processing difficulties and ADHD traits is important as higher levels of sensory sensitivity symptoms have been linked to greater levels of aggressive or delinquent behaviour [12]. Despite the existing reports of sensory abnormalities in children, sensory processing functions are typically not studied in research describing the ADHD phenotype. That is even more clearly the case with adult ADHD, where to our knowledge, only one study has examined sensory processing difficulties in adults, in a clinical ADHD population [29]. So far, no study has examined sensory processing difficulties in adults in the general population with ADHD traits. The discovery of such difficulties related to ADHD traits would provide further crucial evidence in support of the dimensional view of ADHD. The purpose of this study was therefore to examine links between symptoms of ADHD and sensitivity to sensory stimuli in healthy adults. More specifically, to examine the relationship between level of ADHD traits and self-reported sensitivity to sensory stimuli across modalities.

## 2. Methods

### 2.1. Participants

234 participants (173 female) were recruited from the volunteers' list of the University of Sheffield. The ages of the

participants varied from 18 to 69 ( $M = 33.59$ ,  $SD = 13.26$ ). All the participants were either native (80%) or excellent English speakers. Only participants with normal or corrected-to-normal vision and hearing were recruited and were naive as to the purpose of the experiment.

### 2.2. Materials

The Adult ADHD Self-Report Scale (ASRS; [33]) was administered to determine ADHD-like traits in participants. The ASRS is an instrument consisting of the 18 DSM-IV-TR [57] criteria for ADHD and was developed in conjunction with the World Health Organization (WHO), and the Workgroup on Adult ADHD. The scores obtained through the ASRS have been found to be predictive of symptoms consistent with ADHD [58]. The ASRS contains eighteen items from DSM-IV-TR but measures the frequencies of the symptoms. The subjects are asked to report how often they experience each symptom in a period of six months on a five point Likert scale which ranges from 0 for never, 1 for rarely, 2 for sometimes, 3 for often, and 4 for very often [33]. Higher scores on the ASRS indicate higher level of ADHD traits. The ASRS examines only current adult symptoms of ADHD. The internal consistency (Cronbach's alpha) for the two subscales of inattention (0.77) and impulsivity (0.76) as well as for the total ASRS (0.93) in our sample were satisfactory and similar to values reported by earlier studies [23,59].

The Glasgow Sensory Questionnaire (GSQ; [8]) was used to assess sensory sensitivity. The GSQ consists of 42 items and investigates both hyper- and hypo- sensitivities in seven modalities: visual; auditory; gustatory; olfactory; tactile; vestibular, and proprioceptive. Items are equally distributed among sensory modalities, with three questions assessing reported hyper-sensitivity and three determining hypo-sensitivity. Higher scores in the GSQ indicate experiencing both hyper- and hypo-sensitivity to sensory stimuli more frequently. GSQ scores highly correlate with scores in widely used sensory questionnaires; for example the Cardiff Anomalous Perceptions Scale ( $r = 0.55$ ; [34]). The internal consistency of the scale in our sample was excellent ( $\alpha = 0.93$ ). The GSQ has been previously used to assess sensory sensitivity in healthy and clinical populations [8,35,36].

### 2.3. Procedure

All participants were tested online and remotely. Participants were given a link to a Qualtrics survey, an online data collection platform. The survey included the ASRS and the GSQ followed by a set of questions (demographics, mental health issues, information about hearing or eye-sight problems). Participants were recruited via email from the University of Sheffield volunteer list and announcement to the student list at Staffordshire University. Neither IQ nor comprehension skills were formally assessed.

### 3. Results

#### 3.1. Demographics

The mean age of the participants was 33.6 ( $SD = 13.3$ ,  $Min = 18$ ,  $Max = 69$ ). The majority of the respondents were female (73.8%) and 1.3% non-binary/other. The majority of the participants were British (74.3%). Level of education was also reported: 29.6% had a Bachelor's Degree; 23.9% a Master's Degree; 10% a Doctorate Degree; 29.8% did not have a degree; the rest did not disclose this information. Four (1.7%) participants self-reported a clinical diagnosis of ADHD, and 4 (1.7%) reported a diagnosis of ASD. Overall, 18.7% (43 participants) reported having been diagnosed with at least one psychiatric disorder (this included any disorder apart from ADHD and ASD) in their lives.

#### 3.2. Primary results

Scores on the ASRS varied from 4 to 55 and the mean was 30.52 ( $SD = 9.2$ ). The mean score on the inattention subscale was 17 ( $SD = 5.2$ ) and the hyperactivity subscale 13.52 ( $SD = 5.5$ ). The two subscales were correlated,  $r(234) = 0.47$  ( $p < 0.01$ ). The mean score on the GSQ was 90.68 ( $SD = 22$ ,  $Min = 42$ ,  $Max = 164$ ). Mean scores for the GSQ subscales are presented on Table 1. Scores on both questionnaires were normally distributed as revealed by the Kolmogorov-Smirnov test statistic ( $p > 0.05$ ).  $t$ -Tests showed no significant gender differences were found in ASRS and GSQ scores ( $p > 0.05$ ).

Self-reported abnormal sensory experiences were positively correlated with ADHD traits. More specifically, a correlation was found between overall ASRS scores and GSQ scores ( $r(234) = 0.57$ ,  $p < 0.001$ , Fig. 1). Correlations were found between GSQ and both subscales of the ASRS; Inattention ( $r(234) = 0.45$ ,  $p < 0.001$ ), Hyperactivity ( $r(234) = 0.51$ ,  $p < 0.001$ ). This suggests that individuals with higher ASRS scores report having more frequent and extreme reactions (both hyper- and hypo-) to sensory stimuli than individuals with lower ASRS scores.

Total Adult ADHD Self-Report Scale (ASRS) scores were positively correlated with all subscales of Glasgow Sensory Questionnaire GSQ (Table 1) suggesting increased

sensory processing difficulties across modalities in individuals with higher level of ADHD traits. Moderate positive correlations were also reported between all the GSQ subscales (Table 1).

#### 3.3. Controlling for potential confounds

All correlations between the questionnaires were recalculated excluding participants reporting previous history of mental illness, ADHD diagnosis, and ASD diagnosis. No significant change was observed in the correlations between ASRS scores and the GSQ ( $r = 0.56$ ,  $p < 0.001$ ) suggesting that these potential confounds were not responsible for the results. Age was negatively correlated with GSQ scores ( $r = -0.28$ ,  $p < 0.001$ ). The moderate relationship between ASRS scores and GSQ remained significant after controlling for age ( $r = 0.55$ ,  $p < 0.001$ ).

#### 3.4. Predicting sensory sensitivity

A multiple regression was performed utilizing GSQ scores as the criterion and ASRS scores and age as predictors to determine if sensory sensitivity scores could be predicted as a function of ADHD traits and age. The analysis was found to be statistically significant  $F(181) = 50.5$ ,  $p < 0.001$ , indicating that ASRS scores and age are good predictors of GSQ scores. This multiple regression accounted for 36% of the variability, as indexed by the  $R^2$  statistic. Participant's ASRS scores, as indexed by a  $\beta$  value of 0.53, had the strongest relationship to GSQ. The  $\beta$  value for age was  $-0.22$ .

#### 3.5. Factor analysis

An exploratory analysis was conducted to identify the factors underlying the participants' responses in the ASRS and GSQ. First the factorability of the data was examined. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.88, above the recommended value of 0.6, and Bartlett's test of sphericity was significant ( $\chi^2(300) = 2369.6$ ,  $p < 0.01$ ) suggesting that factor analysis could be conducted. Oblique rotation (oblimin) was utilised as non-independence of the underlying factors was hypothesised [37]. The analysis yielded two factors explaining a total of 35.69% of the

Table 1  
Correlations among and descriptive statistics for ASRS and GSQ subscales.

	<i>M</i> ( <i>SD</i> )	1	2	3	4	5	6	7	8
1. ASRS	30.52 (9.2)	–	0.39**	0.45**	0.5**	0.42**	0.48**	0.47**	0.56**
2. Tactile	12.6 (4)		–	0.66**	0.63**	0.65**	0.61**	0.56**	0.62**
3. Gustatory	12.77 (3.7)			–	0.69**	0.68**	0.62**	0.65**	0.7**
4. Proprioceptive	10.68 (3.8)				–	0.61**	0.58**	0.63**	0.7**
5. Visual	12.85 (4.1)					–	0.62**	0.68**	0.67**
6. Auditory	17.7 (4.4)						–	0.56**	0.63**
7. Olfactory	12.16 (3.5)							–	0.66**
8. Vestibular	12 (4.14)								–

$N = 234$  for all reported data.

\*\*  $p < 0.001$ .

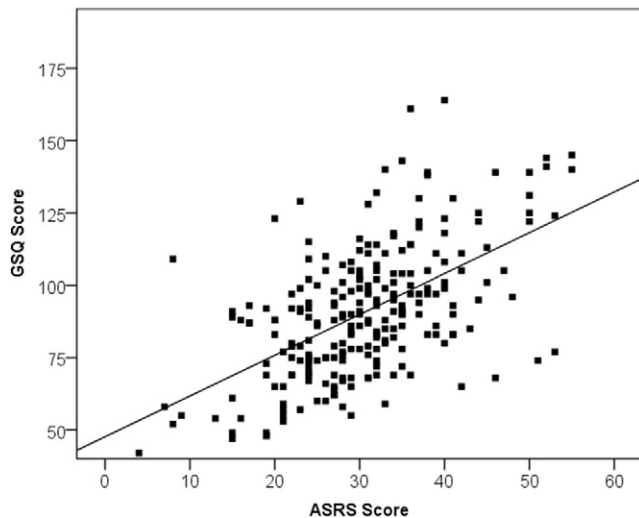


Fig. 1. Scatterplot showing the relationship between ASRS and GSQ score.

variance for the entire set of variables. Factor 1 was labeled ADHD + Sensory Sensitivity as it included items from both scales and Factor 2 was labeled ADHD as it included only items from the ASRS. The two factors were correlated ( $r = 0.48, p < 0.01$ ). A summary of the results is presented on [Table 2](#).

#### 4. Discussion

To our knowledge, this is the first study to investigate the relationship between sensory difficulties and ADHD traits in the general population. Results showed that individuals with high levels of ADHD traits report more symptoms of atypical sensory responsiveness (including both hyper- and hypo-sensitivity). This relationship was not limited to a specific sensory modality; ADHD traits were associated with a higher frequency of sensory difficulties in all modalities measured by the GSQ. Furthermore, both subscales of the ASRS were associated with increased levels of abnormal sensory experiences. Overall ASRS scores were the best predictor of the sensory sensitivity symptoms.

Our finding is consistent with a number of studies on sensory processing in individuals with ADHD ([28]; Engel-Yeger & Ziv-On, 2011). In particular, differences between ADHD patients and controls have been reported in sensory processing and modulation across all senses [38]. Deficits in sensory modulation have been linked clinically with impaired attention, arousal, and impulsivity since the early 1970s [39]. Sensory hyper- and hypo- sensitivity could potentially account for some of the symptoms observed in individuals with ADHD or high levels of ADHD traits (e.g. distractibility).

Our results offer further support for the contention that ADHD traits are continuously distributed in the general population. The key novel finding is the high correlation between ADHD traits and the frequency of experiencing

problematic sensory responses across modalities. To our knowledge, this is the first study to report such a relationship between sensory sensitivity and ADHD traits in a non-clinical population. This result suggests that sensory sensitivity could part of the ADHD phenotype.

Furthermore, the relationship between abnormal sensory processing and ADHD traits suggest a potential role of sensory processing in ADHD symptomatology. Recent theories propose that individuals with ADHD have abnormalities in brain regions involved in sensory processing such as the superior colliculus (Overton, 2008) [16,21,23,40]. Higher resting-state activity in lower – level sensory areas has been reported in ADHD patients [41]. These findings suggest that sensory processing difficulties are part of the ADHD phenotype and could be a potential area of future research. Beyond diagnosis and assessment, these findings could also have implications for treatment interventions. It is conceivable that if sensory symptoms could be treated successfully, some symptoms of ADHD could be reduced. Future studies should examine whether a sensory based intervention can alleviate ADHD symptoms.

Exploratory factor analysis was used to examine whether ADHD traits and sensory sensitivity symptoms group together or form separate factors. Items from the GSQ subscales were combined with ADHD items into a single ADHD + Sensory Sensitivity factor, while other ASRS items were grouped into a separate ADHD factor. Both factors were correlated, further suggesting a positive relationship between ADHD traits and sensory sensitivity. Items from the ASRS that loaded on the ADHD + Sensory Sensitivity factor covered both hyperactivity and attentional aspects of ADHD, corroborating correlations elsewhere which showed that sensory processing difficulties were not selectively associated with particular ADHD traits.

Previous studies which found sensory processing difficulties in ADHD were conducted almost exclusively in children [42]. Our study was the first to examine sensory sensitivities in an adult population with varying levels of ADHD traits. Age is a significant covariate in evaluating sensory processing [28,43]. In particular, sensory sensitivities have been shown to reduce with age [7]. Adults with high levels of ADHD traits had significantly more sensory sensitivities even when controlling for age effects, suggesting that the relationship we observed was not driven by age differences.

Atypical sensory responses have also been identified in individuals with autism spectrum conditions (ASC) [34,44]. In particular, a positive relationship has been shown between autistic symptoms and prevalence of abnormal sensory experiences [44] and sensory hyper- and hypo- sensitivity [8]. Studies using the GSQ have shown that individuals with high autistic traits score significantly higher than controls in all subscales of the questionnaire across modalities reporting both hypo- and hyper- symptoms [8,34]. This is consistent with our findings; ADHD traits were associated with higher GSQ scores across modalities with individuals with higher

Table 2

Summary of exploratory factor analysis results for the ADHD and GSQ using maximum likelihood estimation ( $N = 234$ ).

Item	Factor loadings	
	ADHD + sensory sensitivity	ADHD
ADHD 1: wrapping up the final details of a project		0.33
ADHD 2: difficulty getting things in order		0.3
ADHD 3: problems remembering appointments or obligations	0.37	
ADHD 4: avoid or delay starting difficult task		<b>0.4</b>
ADHD 5: fidgeting or squirming	<b>0.58</b>	
ADHD 6: feeling overly active and compelled to do things	<b>0.49</b>	
ADHD 7: making careless mistakes	<b>0.48</b>	0.35
ADHD 8: difficulty keeping attention	<b>0.44</b>	<b>0.51</b>
ADHD 9: difficulty concentrating on what people say	<b>0.45</b>	
ADHD 10: misplacing or having difficulty finding things	0.33	
ADHD 11: distracted by activity or noise	0.35	
ADHD 12: leaving seat in meetings		
ADHD 13: feeling restless or fidgety	<b>0.59</b>	0.33
ADHD 14: difficulty unwinding and relaxing	<b>0.4</b>	
ADHD 15: talking too much		0.33
ADHD 16: finishing other people's sentences		0.3
ADHD 17: difficulty waiting turn		<b>0.4</b>
ADHD 18: interrupting others when busy	0.3	<b>0.43</b>
GSQ: tactile	<b>0.73</b>	
GSQ: gustatory	<b>0.8</b>	
GSQ: proprioceptive	<b>0.78</b>	
GSQ visual	<b>0.77</b>	
GSQ auditory	<b>0.74</b>	
GSQ olfactory	<b>0.76</b>	
GSQ vestibular	<b>0.82</b>	
Eigenvalues	7.6	2.46
% Of variance	27.6	8.14
Total variance (%)		35.69

Factor loadings over 0.40 appear in bold.

levels of ADHD traits scoring high on both hypo- and hyper-sensitivity items. There is a significant overlap between ADHD and ASD in clinical [45] and subclinical populations [46]. Future studies should examine whether sensory sensitivity could potentially partly account for this relationship.

While we do not suggest that the presence of sensory processing deficits is central to the diagnosis of ADHD, the presence of such symptoms could have potential implications for our understanding of the disorder and its treatment. The link between sensory processing and ADHD traits suggests that sensory traits could potentially serve as a dimensional measure of the severity of ADHD. Even though sensory issues are often reported in patients with ADHD, this area of research has been neglected. Future studies should attempt to empirically test sensory processing in individuals with high levels of ADHD traits across modalities to examine the extent of the self-reported difficulties.

Executive function deficits are often reported individuals with ADHD or high ADHD traits [2,47]. Previous research has shown that certain sensory deficits could be associated with executive dysfunction (e.g. repetitive behaviours, [48]), hence the positive relationship between ADHD traits and sensory sensitivity symptoms as measured by the GSQ could be partly explained by changes in frontal function affecting

responses to the less purely sensory items of the GSQ. Nonetheless, the very high Cronbach (0.93) for the GSQ suggests the result we report probably holds for both sensory processing and sensory experience.

There are several limitations in our study. We did not measure anxiety, which can affect the relationship between ADHD and sensory processing [49]. Previous research has shown that abnormal sensory processing in healthy adults is associated with trait and state anxiety [50]. This could indicate that individuals with high levels of ADHD traits might benefit from interventions, such as occupational therapy, that target their sensory hypo/hypersensitivity symptoms.

The majority of the participants in our study did not report having a clinical diagnosis of ADHD. Even though previous research has shown that individuals with high ADHD traits tend to have deficits similar to those with a clinical diagnosis [16,23,32], it is possible that these differences are driven by distinct underlying mechanisms (e.g. differences in brain function). In order to establish a clear relationship between sensory processing deficits and ADHD, future studies should examine the neurological basis of these differences in individuals with ADHD and various levels of ADHD traits.

Sensory sensitivity appears to be a feature of many disorders such as schizophrenia, depression, and anxiety

[51,52]. Only ADHD traits were examined in our study. Potential differences in sensory sensitivity profiles in ADHD and other disorders should be investigated.

Another limitation with our study is that we were unable to assess IQ. Previous research suggests that IQ can interact with sensory processing [53]. We did, however, ask participants at the end of the study whether they had any difficulties understanding the questionnaire and answering any questions. No participants reported any issues.

## 5. Conclusion

The current study investigated the relationship between sensory difficulties and ADHD traits in the general population and showed a significant positive correlation between ADHD symptomatology and self-reported level of atypical sensory responsiveness. Our findings suggest a new area of study for ADHD research and shed light to the possible mechanisms involved in the disorder. To our knowledge, this is the first report of a significant correlation between sensory ability and ADHD traits in a general population. Our results suggest that the sensory difficulties reported by those diagnosed with ADHD could also be extended into the general population, adding further weight to the proposal that ADHD can be viewed dimensionally as a “continuum disorder”. Furthermore, our results suggest that sensory difficulties could be part of the ADHD phenotype.

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