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Running Head: Sensory Sensitivity and Autistic Traits

The Relationship between Sensory Sensitivity and Autistic Traits in the General Population

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Abstract

Individuals with Autism Spectrum Disorders (ASDs) tend to have sensory processing difficulties (Baranek et al., 2006). These difficulties include over- and under-responsiveness to sensory stimuli, and problems modulating sensory input (Ben-Sasson et al., 2009). As those with ASD exist at the extreme end of a continuum of autistic traits that also evident in the general population, we investigated the link between ASD and sensory sensitivity in the general population by administering two questionnaires online to 212 adult participants. Results showed a highly significant positive correlation ($r=.775$, $p<.001$) between number of autistic traits and the frequency of sensory processing problems. These data suggest a strong link between sensory processing and autistic traits in the general population**,** which in turn potentially implicates sensory processing problems in social interaction difficulties.

Keywords: autism, sensory processing, Autism Spectrum Quotient, autistic traits

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The Relationship between Sensory Sensitivity and Autistic Traits in the General Population

Our senses provide us with key information about ourselves and our environment, such as the identities and locations of objects, the speed of our own movement within the environment and the safety of substances that we ingest (Goldstein, 2009). However, as with all sensory systems, our senses have a finite dynamic range. Considering the auditory system, for example, humans are typically able to hear sounds between 12Hz and 20kHz (Goldstein, 2009), although this frequency range reduces with age (Willott, 1991). Moreover, we cannot hear sounds of very low sound pressure level [0 dB SPL] and sounds above certain amplitudes [120 -140 dB SPL] will cause us pain and also potentially damage the auditory system (Nave, 2006). It is obvious that this "comfort range" for hearing will vary between individuals. Those with sensorineural hearing loss will need higher amplitudes in order to detect a sound and those with other conditions, such as tinnitus (i.e. the perception of sound within the ear in the absence of external sounds), may experience auditory pain at relatively low sound amplitudes (sometimes called "hyperacusis"; Jastreboff, 2000). This type of reduced comfort range is a particular issue for individuals on the autism spectrum (Khalfa et al., 2004).

Although Autism Spectrum Disorders (ASDs) are largely defined in terms of social interaction and communication difficulties (Wing & Gould, 1979), individuals with ASD often appear to have atypical responses to a variety of sensory stimuli (Ben-Sasson, Hen, Fluss, Cermack, Engel-Yeger & Gal, 2009; Bogdashina, 2003). A number of experimental studies have discovered differences between ASD and control groups in a variety of sensory modalities including vision (see Simmons et al., 2009, for a review), hearing (see

Haesen, Boets & Wagemans, 2010, for a review), touch (Cascio et al., 2008), the vestibular system (Kern et al., 2007a), smell (Bennetto, Kuschner & Hyman, 2007) and taste (Tavassoli & Baron-Cohen, 2012), and this consensus will shortly be reflected in revised diagnostic criteria for ASD (APA, 2011). One consistent difference observed in both the visual (Shah & Frith, 1983) and auditory (Mottron, Peretz & Ménard, 2000) domains, is that individuals with ASD tend to exhibit superior local processing. This finding forms an important part of both the Enhanced Perceptual Functioning (EPF; Mottron, Dawson, Soulières, Hubert & Burack, 2006) and Central Coherence (Happé & Frith, 2006) approaches to understanding ASD.

Most commonly, sensory disturbances in ASD are described in terms of hyper- and hypo-sensitivities. Hyper-sensitivity occurs when there is an 'overload' of stimuli – e.g. noises seem exceptionally loud and lights unbearably bright. This phenomenon is sometimes reported to cause individuals with ASD pain (Williams, 1998). The opposite of this experience is hypo-sensitivity, which occurs when the individual under-reacts to the presentation of sensory stimuli (or actively seeks them out --- sometimes called "sensory seeking behaviour") (Bogdashina, 2003). In such instances, people with an ASD may not respond to stimuli which most would find painful, or seem unaware of extreme temperature changes.

There are a number of informative first-hand accounts of the sensory experiences of individuals with ASD. Many "high-functioning" individuals with ASD (i.e. those with a typical-to-high IQ) describe responding to sensory stimulation in unusual ways (Williams, 1998; Jones, Quigney & Huws, 2003). More formal evidence for atypical sensory responses in ASD comes from parent/carer report data (Baranek, David, Poe, Stone & Watson, 2006; Leekam, Nieto, Libby, Wing & Gould, 2007) and self-report data from questionnaires (Crane, Goddard & Pring, 2009). It is thus reasonably well established that a diagnosis of ASD is likely to be associated with atypical sensory functioning, although there is considerable debate about precisely what these atypicalities are, and what causes them.

It should be noted that existing standard clinical tests (e.g. visual acuity) will not necessarily detect these sensory processing difficulties (Simmons et al., 2009). Many studies have found that there is little difference in baseline sensory performance (as measured by determining sensory thresholds) between ASD and matched control populations (Bertone, Mottron, Jenenic & Faubert, 2005; Khalfa et al., 2004). This general result indicates that it may not be that those with ASD are more sensitive to sensory stimuli per se, but rather that there may be differences in the way these stimuli are processed by the brain, especially in "real-life", as opposed to laboratory or clinical environments. As a precursor to developing more relevant sensory tests for adults with ASD we constructed a self-report sensory questionnaire[1].

Evidence that relatives of those with ASD exhibit some characteristics of autism, although to a lesser degree (Piven et al., 1994) has recently prompted the development of the concept of the 'broader autism phenotype' (BAP). There is evidence that these characteristics are prevalent in the general population (Constantino & Todd, 2003). A variety of questionnaires have been developed to assess the level of "autistic traits", including the Broader Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick & Piven, 2007), the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) and the Social Responsiveness Scale (SRS; Constantino, 2002). In addition to measuring autistic traits in the general population, these questionnaires have been used to reliably discriminate between individuals with a diagnosis of ASD and typically developing individuals (Baron-Cohen et al., 2001), although it should be noted that they are not designed to be diagnostic tools.

Several studies have related autistic traits to other factors such as personality (Austin, 2005), biological processes (e.g. delayed menarche onset) (Whitehouse, Maybery, Hickey & Sloboda, 2011) and social functioning (Elsabbagh et al., 2011). Furthermore, there is evidence that there are some differences in brain structure and function of those with high and low autistic trait levels. This has been observed in the posterior superior temporal sulcus (pSTS), with high scorers on the AQ demonstrating reduced white matter volume (Von Dem Hagen, Nummenmaa, Yu, Engell, Ewbank & Calder, 2011). The STS is implicated in social cognition, and there is evidence that differences in this brain region could underlie the differences observed in those with ASD and typically developing controls (Redcay, 2008). In terms of sensory processing, it has been recently demonstrated that high- and low-scorers on the AQ perform differently on a variety of visual processing tasks. These have included the Embedded Figures Task (Grinter, Maybery, Van Beek, Pellicano, Badcock & Badcock, 2009a), which involves the detection of a target shape embedded in a more complex pattern, block design tasks (Stewart, Watson, Allcock & Yaquoob, 2009), which measure visuospatial and motor skills and are a subset of many intelligence tests, and tasks involving Navon figures (Sutherland & Crewther, 2010), which are used to investigate local and global processing.

Parent report and autobiographical accounts provide evidence that atypical responses to sensory stimuli can affect the quality of social interaction and the ability to tolerate certain environments amongst individuals with ASD (Williams, 1998; Baranek et al., 2006; Leekam et al., 2007). Decreased social interaction is often observed in individuals with ASD (Sigman & Ruskin, 1999). Systematic avoidance of people and places as a result of sensory intolerances could easily lead to social isolation (Cosbey, Johnston & Dunn, 2010), perhaps resulting in phobias of people, places or certain types of environmental stimuli. Recently it has been suggested that increased levels of neural noise in sensory pathways could be the key neural symptom underlying these sensory performance differences in ASD (Milne, 2011; Simmons et al., 2009).

In order to relate the sensory data to personality and social skills, we presented our sensory questionnaire together with the Autism Spectrum Quotient (AQ: Baron-Cohen et al., 2001). The AQ is a short, self-administered tool which determines the degree to which someone has traits similar to those of individuals on the autism spectrum (Baron-Cohen et al., 2001). It has been shown to be a reliable and valid measurement (Baron-Cohen et al., 2001; Hurley, Losh, Parlier, Reznick & Piven, 2007; Woodbury-Smith, Robinson, Wheelwright & Baron-Cohen, 2005) able to differentiate between those with either autism (Baron-Cohen et al., 2001) or Asperger's Syndrome (Woodbury-Smith et al., 2005) and those without an ASD diagnosis.

Our hypothesis was that individuals with "high" AQ scores who, according to the original study, have an 80% chance of being diagnosed with ASD, would have high scores on our sensory questionnaire, indicating higher frequencies of sensory difficulties, but that those with low and medium AQ scores would show relatively low sensory scores. A higher total sensory score is generally indicative of experiencing both hyper- and hypo-sensitivity to sensory stimuli more frequently, although modality subscales and a breakdown of hyper- or hypo-scores can also be obtained.

Method

Materials

The study made use of two questionnaires: the Glasgow Sensory Questionnaire (GSQ; which we developed as part of the study) and the AQ (Baron-Cohen et al., 2001). The sensory questionnaire was initially constructed based on a) reports in the literature of sensory signs and symptoms commonly associated with ASD (Baranek et al., 2006; Bogdashina, 2003) and b) signs and symptoms reported by parents of children with autism (Robertson & Simmons, 2008). Two ASD researchers and a consultant psychiatrist who specialises in ASD revised the original questionnaire. Changes to the phrasing were made and the response scale was altered before piloting with a small group (n=5) of people with varying AQ scores. One of the participants in the pilot group had a confirmed diagnosis of high-functioning autism, and we worked with him on an individual basis to ensure that the questions were clear and understandable. After further revisions, the questionnaire (consisting of 70 quantitative and 4 qualitative items) was administered, online, to our participants. Only the results from the quantitative items are reported here – the qualitative results are reported elsewhere (Robertson & Simmons, 2010). The qualitative questions were open, rather than forced-choice, and asked participants to detail sensory events that were most problematic and soothing for them.

The Kaiser-Meyer-Olkin measure of sampling adequacy and the Bartlett test for sphericity indicated that the data were suitable for factor analysis. Principal Components Analysis (PCA) was performed in order to reduce the number of items in the sensory questionnaire, as well as to determine whether the questions grouped into underlying factors. The majority of items had their highest loading on a single factor. The output from the PCA was used to reduce the number of questionnaire items from 70 to 42 for the purposes of analysis (but note that all data were collected with the original 70-item questionnaire). The reduction affected all modalities equally (the number of items for each modality was reduced from 10 to 6, with an even split between questions targeting hyper-sensitivity and hypo-sensitivity). Further PCA analysis confirmed that the single-factor model was appropriate, as did a Scree Plot.

Reliability analysis for the 42 key items of the questionnaire utilized Cronbach's Alpha ($r=.935$) and Guttman's Split-Half technique ($r=.929$). These scores indicate acceptable levels of reliability. The questionnaire appears to have reasonable face validity, as all items ask questions about sensory experiences. In addition, there is reasonable content validity, as 1) all items were checked by five independent observers and deemed appropriate for inclusion within the questionnaire and 2) the number of sensory experiences discussed in the qualitative questions, reported elsewhere (Robertson & Simmons, 2010), increase alongside total sensory score.

All results from the original data were re-analysed using the shortened version of the sensory questionnaire. The final version (on which the results reported in this paper are based) has 42 items and investigates both hyper- and hypo-sensitivities in seven modalities: visual; auditory; gustatory; olfactory; tactile; vestibular and proprioceptive. Items were equally distributed among sensory modalities, with three questions assessing reported hyper-sensitivity and three determining hypo-sensitivity. Sample questions include: "*Do you find yourself fascinated by small particles?"*, "*Do you notice that you have hurt yourself but did not feel any pain?"* and *"Do you react very strongly when you hear an unexpected noise?".* All questions asked how frequently certain sensory events were experienced, with participants responding using the scale: "Never – Rarely – Sometimes – Often – Always". Responses were coded on a scale from 0 to 4, with possible scores ranging from 0 to 168.

There is a great deal of evidence that subclinical autistic traits are common in the general population (Austin, 2005) and, indeed, that they are continuously distributed (Constantino & Todd, 2003). The AQ is one questionnaire that assesses the degree to which a person possesses autistic traits. It consists of 50 statements, to which the respondent shows how much they agree or disagree by answering with one of the following: "Definitely Agree – Slightly Agree – Slightly Disagree – Definitely Disagree". Items are grouped into five subscales ('Social', 'Attention to Detail', 'Attention Switching', 'Communication' and 'Imagination'), with ten items contributing to each. As in the original paper (Baron-Cohen et al., 2001), responses were coded as either 0 or 1, with all scores ranging from 0 to 50.

Participants and Recruitment

English-speaking individuals (n = 212 (n=270, before exclusion criteria were applied); 142 females, 70 males; mean age = 26.75 years, S.D. = 9.84 years, range = 16 - 66 years) were recruited from the general population. Ethical permission from the Faculty sub-committee of the University Ethics Committee was granted prior to recruitment commencing. Students and colleagues from the University of Glasgow were invited to participate by email, and encouraged to forward the email on to others who might be interested. In order to recruit those with high AQ scores, an advert was also placed on an online forum for those with a diagnosis of Asperger Syndrome. The majority of participants were based in the UK (n=180). Potential participants were provided with a paragraph explaining the study and a hyperlink taking them a survey website (Survey Monkey: www.surveymonkey.com). Note that the experiment was carried out entirely online with no face-to-face contact between participants and experimenter. Although the AQ was developed as a 'pen-and-paper' questionnaire, it has been administered online previously to a large sample, with no differences reported (Wheelwright et al., 2006). Furthermore, there is evidence that there is little variation in responses when 'pen-and-paper' questionnaires are presented online (van de Looij-Jansen & Jan de Wilde, 2008; Wu et al., 2009). Individuals were advised that completion of the study would take approximately 25 minutes in total. Participants from the UK were offered the chance to enter into a prize draw for one of three £15 vouchers.

Each participant completed the AQ and the Sensory Questionnaire and was assigned to a group based on their AQ score. Although some participants disclosed that they had a diagnosis of ASD (n=2), we collected data based purely on AQ score, as recent evidence suggests that autistic traits lie on a continuum in the general population (Constantino & Todd, 2003). Neither IQ nor comprehension skills were formally assessed, but participants were encouraged to provide feedback on how they found the questionnaires and were excluded from analysis if they indicated comprehension problems on multiple items (n=1). Group 1 (n=79) consisted of those who scored less than 19 on the AQ, Group 2 was composed of those who scored between 19 and 31 (n=94) and Group 3 (n=39) contained 'high-scorers' (i.e. had a score of 32 or more). The value of 32 was chosen for the 'High' scoring group because this was the reported score in Baron-Cohen et al (2001)'s original paper at which 80% of those with autism score. In addition, we decided to set the lowest value for the 'Medium' group at 19. This was chosen in order to ensure that we were targeting those with a 'higher-than-average' AQ score in the 'Medium' group (the mean AQ score for controls in the original AQ study was 16.4).

Missing data and comprehension difficulties

If more than 10% of the responses were left blank for the AQ (5 items) or the Glasgow Sensory Questionnaire (4 items), the data were excluded from analysis (n=57). In order to compensate for missing data, total scores were corrected by using the following calculation: total score + (mean item score x number of missing items) (Hoekstra, Bartels, Verweij & Boomsma, 2007;Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008). Furthermore, those who indicated they did not understand multiple questions (n=1) were excluded from analysis. When participants indicated they had comprehension difficulties with a single question (n=1), their response for that particular question was dealt with in the same way as the missing response data.

Data Analysis

Statistical analysis was performed using IBM Statistical Package for Social Sciences (IBM SPSS, version 19.0). Group differences in age were analysed using a one-way ANOVA, with gender differences assessed using Independent Samples t-tests. The relationship between total sensory score and AQ score was analysed using Pearson Correlation analysis, as were the relationships between the AQ subgroups and sensory score. Differences in the sensory scores of the AQ subgroups (Low = 0-18; Medium = 19-31; High = 32-50) were analysed using Independent Samples t-tests, compensating for multiple comparisons using Bonferroni Corrections. Effect sizes (which measure the strength of a relationship between variables) were also included for all inferential statistics.

Results

Descriptive Statistics

Although the distributions of the AQ score and total sensory score appeared to be slightly positively skewed, they were both found to be normally distributed using the

Kolmogorov-Smirnov test statistic (p>.05). There were almost twice as many female participants as males (33% males) in the whole dataset, although these ratios differed throughout the subgroups. Males were more likely to have high or medium AQ's, with the women more spread out across the continuum (Low = 19.0% males; Medium = 43.6% males; High = 36.0% males). There was no significant difference in the mean sensory scores [t(210) = 1.578, p<.116] of males and females. However, there was a significant difference in the AQ scores of males and females, as would be expected [t(210) = 2.92, p<.01] (Baron-Cohen et al., 2001). Furthermore, there was no effect of age on either sensory scores [F(3, 209) = .857, p=.465] or AQ scores [F(3, 209) = 1.41, p=.241]. Descriptive statistics for both AQ and the GSQ are provided in Table 1.

(TABLE 1)

Relationship between sensory score and AQ score

Pearson correlation analysis indicated that AQ score had a positive, linear relationship with total sensory score [r = .775, $p < .0001$, R^2=.600]. This indicates that individuals with high AQ scores report having more frequent and extreme reactions (both hyper- and hypo-) to sensory stimuli than individuals with lower AQ scores (see Figure 1).

(FIGURE 1)

In order to determine whether any AQ sub-scales were driving the correlation observed in Figure 1, separate Pearson correlations were calculated for each sub-scale of the AQ. All of the sub-scales indicated a significant, positive correlation with total sensory score and are displayed in Table 2.

(TABLE 2)

Group Differences

As previously mentioned, participants were split into three distinct groups based on AQ score, in order to ascertain which range(s) of AQ scorers were driving the correlation (Low = 0-18; Medium = 19-31; High = 32-50). There were significant differences between the sensory scores of all three groups (see Figure 2). Medium scorers on the AQ had a significantly higher sensory score than Low [$t(171) = 20.4$, $p < .0001$, $r = .839$], while also being significantly lower than High [$t(131) = 22.0$, $p < .0001$, $r = .888$]. Furthermore, the mean sensory scores of the Low and High AQ groups were also found to be different [$t(116) = 32.05$, $p < .0001$, $r = .950$].

(FIGURE 2)

In order to determine whether the group trend was driven by particular modalities, we calculated the mean sensory scores within each modality for the three groups (Figure 3).

(FIGURE 3)

Figure 3 shows a trend pervasive throughout all seven modalities tested. The mean sensory score increases with AQ level for each sensory modality, with the mean scores being similar across all modalities except auditory.

Analysis of AQ scores <28

In order to analyse a full range of AQ scores, we advertised for participants with a diagnosis of AS as well as recruiting participants in the general population. As a result, we had a number of participants with scores of 28 (n=54) and 32 (n=39) or higher, which may be indicative of AS (Woodbury-Smith et al., 2005) or autism (Baron-Cohen et al., 2001) respectively. In order to ensure that the results observed are applicable to the general population, and are not solely driven by the inclusion of participants who may have a diagnosis of ASD, we performed additional statistical analysis on all participants with AQ scores less than 28 (n=158). Although the high-scorers group consists of those with an AQ score greater than 32, we felt that it was prudent to exclude those who scored between 28 and 31 from the medium scoring group too, in order to exclude as many with a potential diagnosis of ASD as possible. This resulted in two new subgroups being formed (Low-2, n=79; Medium-2, n=79).

A Pearson's correlational analysis showed that a significant positive relationship was still found between AQ score and total sensory score [$r=.602$, $p < .001$, $R^2=.362$]. Although the observed correlations between the AQ subscales were smaller than with the complete sample, they were significant in all cases: Social [$r=.273$, $p < .001$, $R^2=.075$], Attention Switching [$r=.375$, $p < .001$, $R^2=.141$], Attention to Detail [$r=\cdot494$, $p < .001$, $R^2=.244$], Communication [$r=.404$, $p < .001$, $R^2=.163$] and Imagination [$r=.342$, $p < .001$, $R^2=.117$]. Furthermore, even with the removal of all scores above 28, an Independent Samples t-test showed that the mean sensory score for low (0-18) and medium (19-27) scorers was still significantly different [$t(156) = 8.39$, $p < .0001$, $r = .555$].

Discussion

This study investigated whether the sensory difficulties experienced by those with ASD (Grandin, 1996; Williams, 1998; Baranek et al., 2006; Leekam et al., 2007) might extend to those with high levels of autistic traits in the general population. Results showed that atypical sensory responsiveness (including both hyper- and hypo-sensitivity), as measured by our sensory questionnaire, was much more common in individuals with higher levels of autistic traits, as measured by the AQ (Baron-Cohen et al., 2001). In particular, individuals with medium AQ scores (19-31) reported moderate levels of sensory difficulties, significantly different from those with either low (0-18) or high (32-50) scores on the AQ. This result is not confined to a specific sensory modality and does not seem to favour a particular sub-scale of the AQ.

The finding that those with high levels of autistic traits also experience sensory disturbances is consistent with a growing number of studies, which have found differences in visual processing (Grinter et al., 2009a; Grinter, Van Beek, Maybery & Badcock, 2009b; Stewart et al., 2009; Bayliss & Kritikos, 2010; Sutherland & Crewther, 2010) and speech perception (Stewart & Ota, 2008; Yu, 2010) between those with high and low levels of autistic traits. Our results indicate that these differences may be present in multiple sensory domains, and it would be interesting to see whether the differences observed in touch (Cascio et al., 2008) and taste (Tavassoli & Baron-Cohen, 2011) for those with ASD are replicated in low/high AQ scorers within the general population.

In this study, we found a positive correlational relationship between number of autistic traits and the frequency of atypical responses to sensory stimuli. This is in line with the results of Yu (2010), who found a significant correlation between normalization for phonetic context and AQ scores. However, our results somewhat contrast with Kern et al. (2007b), who found that severity of autism was related to scores on the Sensory Profile (Dunn, 1999) in children, but not in adolescents or adults. Furthermore, they found that sensory sensitivities reduced with age (which was also observed in certain sensory domains for Leekam et al., 2007). However, like Crane et al. (2009), we found no age effect in our sample. This contrast could be a result of methodological differences, as both this study and Crane et al (2009) used a self-report questionnaire, whereas Kern et al. (2007b) utilised a parent report design. Alternatively, it may be that sensory issues are more severe in children and stablilize once reaching adulthood. A final possibility, linked with the methodological differences, is that sensory processing difficulties are apparent to individual adults on the autism spectrum, or with high autistic trait levels, but have less obvious effects than in childhood: in other words these adults are able to cope but they are still bothered by sensory stressors more than those with low autistic trait levels.

This result has important implications for society. First, and least controversially, our data support findings that autistic traits are continuously distributed in the general population (Constantino & Todd, 2003). The key novel finding is the high correlation between AQ score and the frequency of experiencing problematic sensory responses. To our knowledge, this is the first report of a significant correlation between sensory ability and autistic traits in a broad population. Our results suggest that the sensory differences experienced by those with a diagnosis of ASD can also be extended into the general population and could be indicative of a sensory phenotype.

The current data link sensory performance differences to social behaviour differences, a connection which has recently been made elsewhere (Cosbey et al., 2010; Hilton et al., 2010). Whilst there is much work to do to definitively demonstrate causality between these outwardly disparate areas, it is evidently worthy of further investigation.

Limitations

It could be argued that recruiting individuals from an online forum for those with AS could be a limitation of the study, as they would be likely to be aware of the relationship between ASD and sensory issues. However, the number recruited from that particular source was small (n=31) and it is arguably a strength of our study that we have investigated all aspects of the 'Autistic Spectrum', recently highlighted as a direction for future research (Von dem Hagen et al., 2011). Furthermore, by reanalyzing the data of all participants who scored less than 28 on the AQ, we found that the pattern observed in the whole sample can also be seen in this subsample (therefore the high scorers in the 'medium' group and those in the 'high' group are not overly-influencing the data).

A further limitation of the study is that the validity of the questionnaire has not been rigorously assessed, nor has test-retest reliability been determined. We do have plans to administer the Glasgow Sensory Questionnaire alongside established measures of sensory responsiveness, in order to better determine content validity. Moreover, it should be noted that the frequency of sensory experiences detailed by our participants in the qualitative questions (which were administered alongside the questionnaires, but will be reported elsewhere) correlated with both sensory scores and AQ scores (Robertson & Simmons, 2010), indicating reasonable validity.

Another limitation with our study is that, due to time constraints, we were unable to assess IQ. A previous study has found a modest negative correlation between autistic traits and IQ ($r = -.27$), which was mainly explained by communication problems (Hoekstra, Happé, Baron-Cohen & Ronald, 2010). However, the authors stress that autistic traits and IQ are mostly independent. It should be noted that we asked participants to disclose any difficulties they had with understanding the questionnaire, with very few indicating comprehension difficulties with any of the questions (n=2). Finally, whilst the unequal age distribution is another limitation of the study, statistical analysis showed that age effects for both the sensory questionnaire and the AQ was non-significant.

Implications for further research

This study investigated the relationship between sensory processing and autistic traits in adults. One interesting direction for future research would be an investigation into the sensory processing of children with varying levels of autistic traits. Furthermore, it would be interesting to investigate whether the differences observed in those with high and low levels of autistic traits in behavioural studies (Grinter et al., 2009a; Grinter, 2009b; Stewart & Ota, 2008) and fMRI (Von dem Hagen, 2011) would also be found in children. In addition, it would be an important next step to determine whether self-reported sensory sensitivity actually corresponds to differences in threshold. According to our results, it would appear that a significant proportion of the population is affected by either hyper- or hypo-sensory sensitivity in some way and that consideration should be given to modifying the environment to counter at least the most severe sensory stressors. It would also be interesting to replicate the study with a larger group, including those with explicit diagnoses of ASD, in order to further validate the sensory questionnaire.

There are many potential practical applications of this research. First, the sensory questionnaire we have developed adds to the battery of tests that can be used to establish the precise sensory processing difficulties of individuals on the autism spectrum. In addition, we recently found that sensory sensitivities can affect productivity and concentration of those with ASD, and that low-impact sensory environments are essential for these individuals (Simmons & Robertson, 2012). It is anticipated that, in the future, environments could be systematically screened for potential sensory stressors and steps taken to ameliorate any problems identified, as they already are in some ASD-specific schools and intervention programmes. By also using the sensory questionnaire, those responsible for providing a comfortable working environment would be able to pinpoint the most common issues for a certain individual, and work with them to reduce any problems.

A final issue for further research is the extent to which sensory stress is a problem for a large number of people without explicit diagnoses of ASD, but with higher levels of autistic traits, possibly linked with social interaction problems, or at least a tendency to avoid social situations. Whilst it is tempting to argue that these individuals will have other conditions such as tinnitus or migraine, or simply be succumbing to the effects of normal ageing, it may be that many of us are tolerating high levels of anxiety or discomfort brought on by sensory stress and that there is a need to recognize this in building design, town planning and environmental health contexts. A tentative explanation for these individual differences at the neural level is in terms of higher levels of internal neural noise in those with higher levels of sensory sensitivity (Milne, 2011; Simmons et al, 2009).

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Footnotes

1. Note that a self-report sensory questionnaire (The Adult/Adolescent Sensory Profile: AASP) has previously been published by Brown & Dunn (2002). However, this instrument was not specifically designed to target the sensory issues associated with ASD populations, and contains some questions which overlap with those on autism diagnostic instruments, which made it unsuitable for our purposes. In addition, our questionnaire assessed reported sensitivity separately in the proprioceptive, vestibular, taste and smell modalities (these modalities are combined into 'taste/smell' and 'movement' in the AASP), as well as including items for visual, auditory and touch sensitivity. Furthermore, we did not include items on 'activity level', which is assessed in the AASP.

Figure Captions

Figure 1. Correlation between total sensory score (measured by the Sensory Questionnaire) and AQ score (measured by the Autism Spectrum Quotient; Baron-Cohen et al., 2001). Pearson correlation was positive ($r = .775$).

Figure 2. Comparison of total sensory score for low, medium and high scorers on the AQ. Error bars represent the standard error of the mean.

Figure 3. Comparison of sensory scores in each modality for low, medium and high scorers on the AQ. Error bars represent the standard error of the mean.

1 Top

Figure 1

Correlation between total sensory score and AQ score

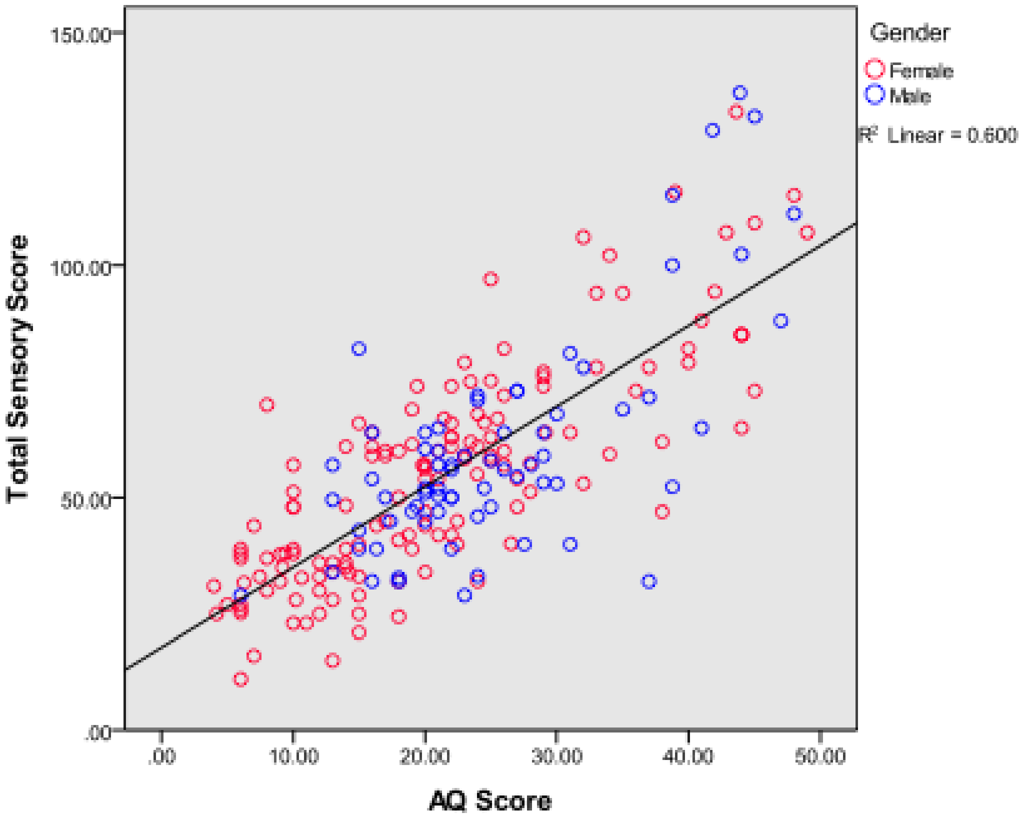

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Figure 2

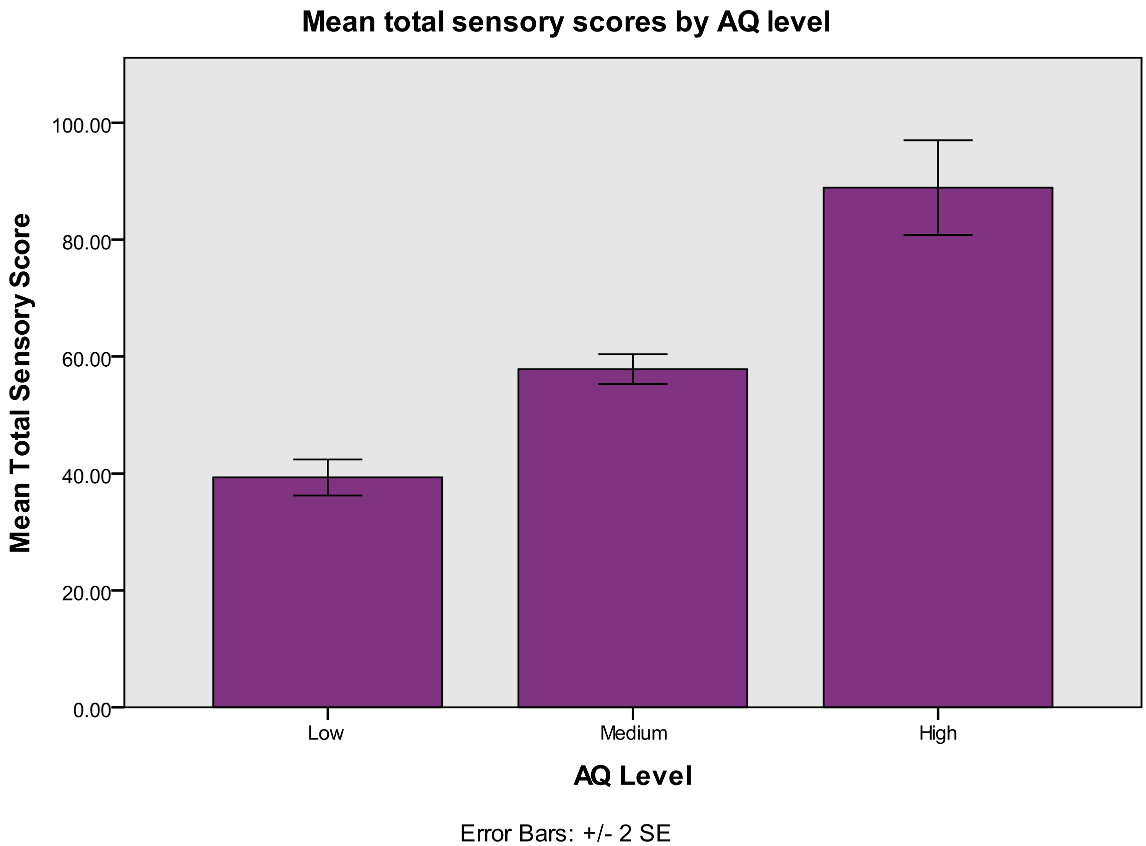

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Figure 3

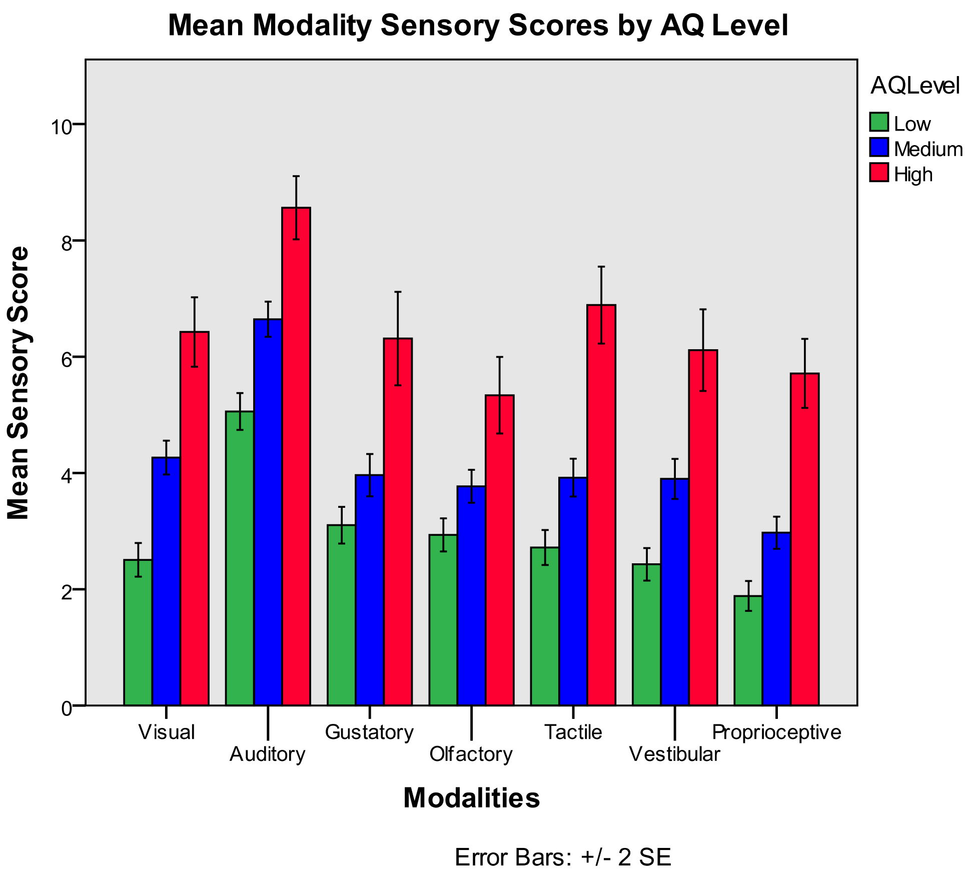

Table 1 – Descriptive statistics for AQ and GSQ scores

	Min	Max	Mean	Standard Deviation
AQ *(0-50)*	4	49	22.48	10.57
GSQ *(0-168)*	11	137	56.65	23.60

Table 2 – Correlations of AQ subscales with total sensory score

AQ sub-scale	Correlation with total sensory score
Social	.631**
Attention Switching	.612**
Attention to detail	.532**
Communication	.687**
Imagination	.631**

*Significance levels: * p<.05; **p<.01*