J Autism Dev Disord (2012) 42:905–909
DOI 10.1007/s10803-011-1321-y

ORIGINAL PAPER

Olfactory Detection Thresholds and Adaptation in Adults with Autism Spectrum Condition

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Published online: 6 July 2011

Abstract Sensory issues have been widely reported in Autism Spectrum Conditions (ASC). Since olfaction is one of the least investigated senses in ASC, the current studies explore olfactory detection thresholds and adaptation to olfactory stimuli in adults with ASC. 80 participants took part, 38 (18 females, 20 males) with ASC and 42 control participants (20 males, 22 females). A subgroup of participants (N = 19 in each group) also conducted an adaptation task. Standardized "Sniffin' Sticks" were used to measure olfactory detection levels and adaptation. Adults with and without ASC showed similar olfactory detection thresholds, and similar adaptation to an olfactory stimulus. Since diminished adaptation in ASC has been previously suggested, future research needs to examine adaptation in other modalities as well.

Keywords Autism Spectrum Condition · Olfaction · Olfactory detection and adaptation

> *One person with ASC refused to walk on the lawn because he could not bear the smell of grass* (Grandin, 1996; p. 71).

Introduction

Autism Spectrum Conditions (ASC) are characterized by social and communication difficulties, alongside repetitive behaviours and special interests (APA 1994). In addition, anecdotal reports (Chamak et al. 2008; Grandin 1996) and studies using sensory questionnaires (Brown et al. 2001; Kientz and Dunn 1997) suggest perceptual differences (particularly sensory hyper-sensitivity) in ASC. Regarding olfactory issues in ASC specifically, sensory questionnaires report differences between individuals with and without ASC (Brown et al. 2001; Crane et al. 2009; Kientz and Dunn 1997; Leekam et al. 2007; Tomchek and Dunn 2007). The widely used Sensory Profile, a sensory questionnaire, shows differences in over 90% of children (Kientz and Dunn 1997; Tomchek and Dunn 2007) and adults (Crane et al. 2009) with ASC. Children with ASC (55%) show more clinical symptoms in smell/taste sensitivity on the Short Sensory Profile compared to children with Sensory Modulation Disorder (SMD; 32%; Schoen et al. 2009). The Short Sensory Profile also identifies subgroups of children with ASC according to smell and taste sensitivity (Lane et al. 2010). Using the Diagnostic Interview for Social and Communication Disorders (DISCO) Leekam et al. (2007) show sensory symptoms in 94% of the children with autism compared to 5% in typical developing children. Significantly more children with autism showed olfactory symptoms compared with children in comparison groups (e.g., with developmentaldisability, language impairment and typical development).

In addition to questionnaire-based studies, olfaction in ASC has been investigated in laboratory settings. Suzuki et al. (2003) reported impaired odour identification using the University of Pennsylvania Smell Identification Test in adults with ASC, particularly Asperger syndrome, but intact odour detection (Suzuki et al. 2003). A second study by Bennetto et al. (2007) reported that adolescents (10–18 years) with ASC were less accurate in olfactory identification (Bennetto et al. 2007). Olfactory identification was measured using the "Sniffin Sticks", which

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consist of 12 common odours. Recently a study also showed that children with ASC rate some odours (pineapple and cinnamon) as less pleasant than children without ASC (Hrdlicka et al. 2011). However identification differences could reflect linguistic/labelling issues, rather than sensory issues per se.

The aims of the current investigation were first, to investigate olfactory detection thresholds and second, to measure adaptation in adults with ASC. There have been no studies looking at olfactory adaptation in ASC at any age. This is surprising given that studies in the visual and tactile domain suggest that adaptation is diminished in ASC (Pellicano et al. 2007; Tommerdahl et al. 2007). Olfactory adaptation can be described as a "repeated or prolonged exposure to an odorant which typically leads to a stimulus specific decrease in olfactory sensitivity" (Dalton 2000). Adaptation is an important process, allowing the individual to adjust to changes in the environment, and olfactory neurons show reduced responses to an odour even within seconds (Stortkuhl et al., 1999). The degree of olfactory adaptation depends on the amount and time of exposure of the odour (Dalton 2000; Stortkuhl et al., 1999; Colbert and Bargmann 1995; Wuttke and Tompkins 2000).

More narrowly, we aimed to measure basic adaptation using only a brief pre-exposure to an odour. The olfactory detection and adaptation tasks used in the current study were kept as simple as possible to avoid cognitive processes otherwise influencing olfactory adaptation. For example, when participants have a negative association with the odour, there is less adaptation than when it is described as being positively valenced (Dalton 2000). Participants beliefs about the odour also modulate the degree of adaptation (Dalton 1996). We therefore aimed to measure low-level sensory detection levels and adaptation and aimed to reduce interfering cognitive factors (such as pleasantness ratings). In summary the questions we aimed to answer through the current studies were:

1. Do adults with and without ASC have different olfactory detection thresholds?
2. Do adults with ASC adapt to an olfactory stimulus as much as control participants?

Methods

Participants

In total 80 adults took part: 38 adults with ASC were compared to 42 control participants. All participants with ASC had previously been diagnosed by a qualified clinician according to DSM-IV criteria (APA 1994).

Table 1 Descriptive characteristics of the ASC and control participants in the olfactory detection task

Characteristics	ASC group (N = 38)	Control group (N = 42)
Sex ratio (f:m)	18:20	20:22
Mean age in years (SD)	35.9 (10.9)	28.8 (6.5)
Full scale IQ (SD)	112.6 (15.3)	115.7 (10.8)
AQ (SD)	35.4 (9.5)	16.4 (4.1)

ASC autism spectrum conditions, *FSIQ* full scale IQ, *AQ* autism spectrum quotient, *SD* standard deviation

Table 2 Descriptive characteristics of the ASC and control participants in the olfactory adaptation task

Characteristics	ASC Group (n = 19)	Control group (n = 19)
Sex ratio (f:m)	8:11	8:11
Mean age in years (SD)	28 (8)	30 (6)
Full scale IQ (SD)	113 (14.5)	118 (8.9)
AQ (SD)	36.7 (5.0)	14.3 (3.9)

ASC autism spectrum condition, *FSIQ* full-scale IQ, *AQ* autism spectrum quotient, *SD* standard deviation

Participants were recruited from a volunteer database (www.autismresearchcentre.com). To screen control participants for autistic traits, the Autism Spectrum Quotient (AQ) using a standard exclusionary criteria of a score of above 26 was used (Baron-Cohen et al. 2001; Woodbury-Smith et al. 2005). Three participants in the control group were excluded from further analysis on the basis of this cut-off criterion, leaving 42 control participants (out of originally 45) in the analysis. All participants completed a measure of intelligence, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1939; see Table 1). This was not completed for 2 participants in the ASC group, and one participant in the control group.

All 80 participants took part in the olfactory detection task. Only a subgroup of participants additionally participated in an olfactory adaptation task (see Table 2). For the adaptation task 19 adults with ASC (17 participants with Asperger Syndrome and 2 with high functioning autism) were compared to 19 adults with no history of psychiatric disorders.

Questionnaires

All participants completed the Autism Spectrum Quotient (AQ), which was used to screen control participants for autistic traits. The AQ is a short questionnaire measuring autistic traits, with 5 subscales (social skills, attention switching, attention to detail, imagination and communication; Baron-Cohen et al. 2001). Results from the AQ have been replicated cross culturally (Wakabayashi et al. 2007) and across different ages (Auyeung et al. 2008; Baron-Cohen et al. 2006). The AQ is also sensitive to the broader autism phenotype (Wheelwright et al. 2010).

Olfactory Detection Threshold Task

The 'Sniffin' Sticks Olfaction Test' (Burghart, Messtechnik, Germany) was used to measure olfactory detection thresholds. The Sniffin' Sticks Test is a standardised test to investigate olfactory functioning (Hummel et al. 2007). Odour thresholds for n-butanol were measured using a single staircase, triple-forced choice procedure according to the Sniffin' Sticks instructions. The experimenter wore odourless gloves during testing. Participants neither ate nor drank anything else but water for 30 minutes prior to testing. Participants were acquainted with the odour of n-butanol using the pen with the highest concentration (Sniffin Stick number 1). During testing participants were blindfolded. On each trial three sticks were presented in a randomized order for 5 s each. The participant had to indicate the butanol containing stick. There were 16 different concentrations of butanol. The test starts with the lowest butanol concentration (Sniffin Stick number 16), followed by 1-dilution step higher (dilution ratio 1:2). In between each trial there was a 10 s break. The participant has to identify the butanol-containing pen in two successive trials. Then the descending staircase starts until the participant misidentified the pen once. There were 4 descending and 3 ascending trials. The olfactory threshold is the mean of the last four trials. Scores can range from 16 (able to detect the lowest concentration) to 0 (unable to detect even the highest concentration).

Olfactory Adaptation Task

After measuring olfactory detection thresholds, an olfactory adaptation task followed. Olfactory adaptation was measured using a repeated and prolonged exposure to the highest concentration of butanol (Sniffin Stick number 1). The stick was presented for 30 s before measuring the olfactory detection threshold and for 10 s in-between trials. The olfactory detection threshold was otherwise measured identically as described above using a forced-choice paradigm.

Results

Descriptive Statistics

The data was analysed using SPSS 16. Normality tests were conducted using the Kolmogorov–Smirnov (KS) test statistic. Olfactory detection thresholds before and after adaptation were log normal distributed in both groups ($p > .05$) and no outliers were present. In addition Levene's test was not significant ($F = 2.74$, $p = .10$). There were no significant group differences between intelligence quotient (IQ) scores or age ($p > .05$). As expected the ASC group had higher AQ scores ($t = 13.99$, $p < .0001$).

Olfactory Detection Thresholds

An independent t-test showed no significant difference between the mean olfactory threshold of the ASC group (9.97 ± 2.67, 95% Confidence Interval (CI); 8.43–11.40) and control group (9.38 ± 3.26, 95% CI; 8.14–10.78; $t = -.89$, $p = .39$; see Fig. 1).

Olfactory Adaptation

Multivariate tests showed that there were no significant differences in olfaction detection thresholds between the groups before adaptation (ASC group: 9.92 ± 3.08, Control group: 9.46 ± 2.74), nor after adaptation (ASC: 6.47 ± 3.36, Control group: 6.13 ± 2.60; Pillai's Trace = $F(2,35) = .14$, $p = .86$; see Fig. 2). In addition a repeated measure ANOVA with adaptation level (score before and after adaptation) as a within-subject factor and group as the between-subject factor was conducted. Tests of within-subject contrasts showed a significant main effect of adaptation level ($F(1,36) = 56.42$, $p < .0001$), but no interaction between adaptation level and group ($F(1,36) = .001$, $p \leq .99$; see Fig. 2).

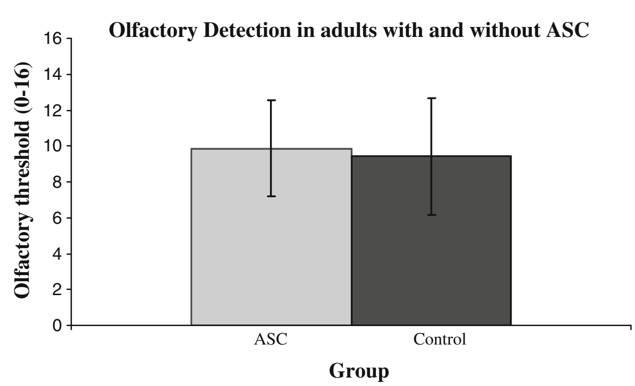

Fig. 1 Olfactory detection thresholds in adults with and without autism spectrum conditions (*ASC*). *Bars* represent olfactory detection threshold (including error bars). Both groups showed similar olfactory detection

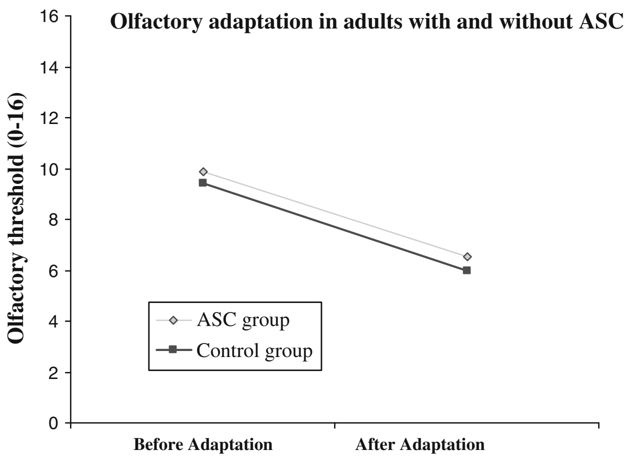

Fig. 2 Olfactory Detection Thresholds before and after adaptation. *Lines* represent olfactory detection thresholds before and after adaptation, for the ASC and the control group respectively. Both groups showed similar adaptation to an olfactory stimulus

Discussion

The current study investigated olfactory detection thresholds before and after adaptation in adults with ASC (above 18 years of age). Adults with and without ASC did not differ overall in olfactory detection thresholds. In addition adults with ASC showed normal adaptation to an olfactory stimulus, being less sensitive to an olfactory stimulus after prolonged exposure. Adults with ASC however did not differ in the amount of adaptation compared to adults without ASC. This is the first study to show normal olfactory adaptation in ASC.

The finding of similar olfactory detection thresholds in adults with and without ASC is in line with Suzuki et al. (2003) who found no difference in olfactory detection, alongside impaired identification (Suzuki et al. 2003). Previous questionnaire based studies suggest that children with ASC show greater sensory differences than adults with ASC when compared to age-matched controls (Kern et al. 2006). Since the current study involved adults, the results may not hold true for children. Future studies could examine olfactory detection and adaptation issue in children with ASC.

However the question arises as to why sensory questionnaire studies of ASC should find clear, consistent group differences whereas in laboratory-based sensory psychophysical studies, in all modalities, sensory detection differences between individuals with ASC and without are often inconsistent (Heaton et al. 2008; Simmons et al. 2009). The complexity of the detection tasks used could be a potential confounding factor. For example, the forced-choice paradigm used in this study involves remembering and comparing different Sniffin' Sticks and a simpler version where individuals with ASC only need to state if they smell something or not might be useful for future studies. An alternative explanation might be that self-report measures reflect attentional differences rather than basic sensory differences in ASC.

In addition, adults with ASC showed normal adaptation to an olfactory stimulus. This finding is important given that diminished adaptation to touch and vision has previously been reported (Pellicano et al. 2007; Tommerdahl et al. 2007). Tommerdahl et al. (2007) found that increasing the duration of the adapting stimulus had no effect on tactile spatial discrimination in participants with ASC, whereas increasing duration of the adapting stimulus led to better spatial discrimination in control participants. In regards to the visual domain, Pellicano et al. (2007) reported diminished adaptive face-coding mechanisms in children with ASC. The level of adaptation in previous studies differed from the current study however: the visual task was more complex, using faces as stimuli. In addition, mechanisms underlying tactile adaptation and spatial inhibition involve complex interactions. The current study on the other hand used a basic olfactory adaptation task. Future studies could investigate adaptation in olfaction using a variety of odours and levels of complexity. In addition it would be interesting to investigate basic adaptation in other modalities such as vision, hearing and touch.

In conclusion, whilst individuals with ASC show more olfactory 'symptoms' on questionnaires such as the Short Sensory Profile or the DISCO (Leekam et al. 2007), they do not show differences in either olfactory detection or adaptation. Inspection of items on sensory questionnaires highlights the role of a range factors, such as attention, distractibility and affective reactions. In everyday life factors such as mood, stress and anxiety levels could also influence the subjective experience of sensory stimulation, though these are more difficult to measure in research settings. Future studies should investigate at what level of sensory processing differences in ASC originate.

Acknowledgments T.T. was supported by the Pinsent Darwin Trust and Autistica during the period of this work. S.B.C. was supported by the MRC UK. This work was conducted in association with the NIHR CLAHRC for Cambridgeshire and Peterborough NHS Foundation Trust. We are grateful to the participants for their generous cooperation, and to Bonnie Auyeung, Jillian Sullivan, Emma and Chris Ashwin, and Bhismadev Chakrabarti for valuable discussions.

Conflict of interest The authors of this paper report no biomedical financial interests or potential conflicts of interest.

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