J Autism Dev Disord (2012) 42:1419–1424
DOI 10.1007/s10803-011-1377-8

ORIGINAL PAPER

Taste Identification in Adults with Autism Spectrum Conditions

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Published online: 18 October 2011

Abstract Sensory issues are widely reported in Autism Spectrum Conditions (ASC). Since taste perception is one of the least studied senses in ASC we explored taste identification in adults with ASC (12 males, 11 females) compared to control participants (14 males, 12 females). 'Taste strips' were used to measure taste identification overall, as well as bitter, sour, sweet and salty tastes. Results revealed lower taste scores overall in the ASC group, as well as for bitter, sour and sweet tastes. Salty taste scores did not differ between the groups. Examining error types showed that adults with ASC more often misidentified a taste as salty or as no taste. Future studies should investigate underlying mechanisms of taste identification difficulties in ASC.

Keywords Autism spectrum conditions · Taste processing · Taste identification · Taste strips

Introduction

Many children with autism are finicky and will eat only certain foods. Their eating problems usually have a sensory basis (Grandin, p. 71, 1996). Autism spectrum conditions (ASC) are characterized by difficulties in social interaction and communication, alongside unusually narrow interests and strongly repetitive behaviour (A.P.A. 1994). Additionally anecdotal reports indicate sensory issues in ASC (Chamak et al. 2008; Grandin 1996). Beyond anecdotes, sensory questionnaires such as the widely used Sensory Profile show differences in sensory processing in over 90% of children and adults with ASC (Crane et al. 2009; Dunn et al. 2002; Kientz and Dunn 1997; Watling et al. 2001; Wiggins et al. 2009). Differences on the Sensory Profile are confirmed across the lifespan in individuals with ASC (Crane et al. 2009; Kern and Carmody 2007) and cross culturally (Cheung and Siu 2009).

Moreover, sensory subtypes in ASC can be differentiated on the basis of taste and smell sensitivities and vestibular and proprioceptive processing (Lane et al. 2011). Taste buds are responsible for identifying chemicals in food: if the food is rich in calories (sweet receptors), high in salt (salty receptors) or acid (sour receptors) and/or potentially poisoned (bitter receptors) (Bradbury 2004; Carpenter 2003). In ASC questionnaire-based studies show atypical eating and food preferences (Schreck and Williams 2006; Schreck et al. 2004). Temple Grandin suggests that 'eating problems usually have a sensory basis'. Children with ASC for example eat a smaller variety of foods such as fruits and vegetables compared to typical developing children regardless of texture (Bandini et al. 2010; Schreck et al. 2004). Thus, it is important to investigate taste processing in ASC. However, experimental investigations of taste perception in ASC so far are rare.

Taste processing in ASC has been investigated far less than other senses such as vision or hearing (Bonnel et al. 2003; Simmons et al. 2009). To the best of our knowledge only one study has looked at taste processing in adolescents (10–18 years) with ASC (Bennetto et al. 2007), finding that they were *less* accurate in identifying sour and bitter tastes but showed similar identification for sweet and salty tastes. In addition, electrogustometry (in which electrical signals

This work was conducted in association with the NIHR CLAHRC for Cambridgeshire and Peterborough NHS Foundation Trust.

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produce a sour and metallic taste) show intact taste thresholds in adolescents with ASC (Bennetto et al. 2007). The aim of the current study was to further investigate taste identification accuracy and error types in adults with ASC (above the age of 18 years) using 'Taste Strips'. This chemical taste test has been used in other clinical conditions such as diabetes, attention-deficit/hyperactivity disorder (ADHD) and Alzheimer's disease (Naka et al. 2010; Schumm et al. 2009; Welge-Lussen et al. 2011). Women with ADHD and Bulimia Nervosa for example show average taste identification (Weiland et al. 2011). Alzheimer patients on the other hand show taste identification deficits (Steinbach et al. 2010). To the best of our knowledge 'Taste Strips' have never been used to investigate taste identification in adults with ASC.

Methods

Participants

In total 23 adults with ASC (21 with Asperger Syndrome, 2 with High-Functioning Autism) were compared to 29 control participants with no previous or current psychiatric condition. Participants provided background information including, age, current medication, history of psychiatric conditions and when, where and by whom they were diagnosed. All ASC participants were previously diagnosed by a qualified clinician according to DSM-IV criteria (APA 1994). To screen control participants for autistic traits the Autism Spectrum Quotient (AQ) was used, excluding anyone with a score of 26 or above (Baron-Cohen et al. 2001). Three participants in the control group were excluded from further analysis on the basis of this cut-off criterion. All participants were recruited from our volunteer database (www.autismresearchcentre.com) and completed a measure of intelligence, the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler 1939). There was no significant group difference between IQ scores ($p > 0.05$). The ASC group had higher AQ scores ($t\,(47) = 17.44, p < 0.01$) and were also significantly older than control participants ($t\,(48) = 2.72, p < 0.01$) (see Table 1). Age was included as a covariate for further analysis. The current experiment was part of a larger study investigating perception in ASC (results reported elsewhere).

Table 1 Descriptive characteristics of the ASC and control group

Characteristics	ASC group (n = 23)	Control group (n = 26)
Sex ratio (f:m)	11:12	12:14
Mean age in years (SD)	35.8 (12.5)	28.1 (6.4)
Full scale IQ (SD)	114.6 (16.7)	114.7 (10.2)
Performance IQ (SD)	113.1 (19.1)	115.6 (9.7)
Verbal IQ (SD)	108.1 (16.1)	110.1 (9.1)
AQ (SD)	39.8 (5.5)	16.4 (3.9)

ASC autism spectrum conditions, *AQ* autism spectrum quotient, *SD* standard deviation

Materials

Questionnaires

The Autism Spectrum Quotient (AQ) is a short questionnaire measuring autistic traits, with five 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. 2004) and across different ages (Auyeung et al. 2008; Baron-Cohen et al. 2006).

Taste Identification Test

A psychophysical chemical taste test called 'Taste strips' (Burghart, Messtechnik, Germany) was used to measure taste identification overall, as well as for sour, bitter, sweet and salty tastes (Landis et al. 2009). Normative data on these strips are based on a sample over 500 participants (Landis et al. 2009). Taste Strips are strips of paper impregnated with four taste qualities: sweet, sour, salty, and bitter, each of these containing four different concentrations resulting in 16 strips in total. Specifically, these were: sweet: 0.4, 0.2, 0.1, 0.05 g/ml sucrose; sour: 0.3, 0.165, 0.09, 0.05 g/ml citric acid; salty: 0.25, 0.1, 0.04, 0.016 g/ml sodium chloride; and bitter: 0.006, 0.0024, 0.0009, 0.0004 g/ml quinine hydrochloride.

Procedure

Before the taste test began participants were instructed not to eat or drink anything other than water for an hour. One taste strip a time was placed on the middle of the tongue and participants were allowed to close their mouth. The participant's task was to identify the taste from a list of four descriptors; sweet, sour, salty, and bitter (multiple forced-choices). Descriptors were presented visually as printed words. Participants independently used "no taste" to describe taste strips as well even though "no taste" was not a descriptor given. After each trial participants were asked to rinse their mouth with water. Taste strips were presented in an increasing manner according to instructions. Taste scores were calculated by adding up the number of correctly identified tastes. Taste overall scores could therefore range from 0 (lowest) to 16 (highest). Higher taste scores indicate better taste identification. Specific scores for

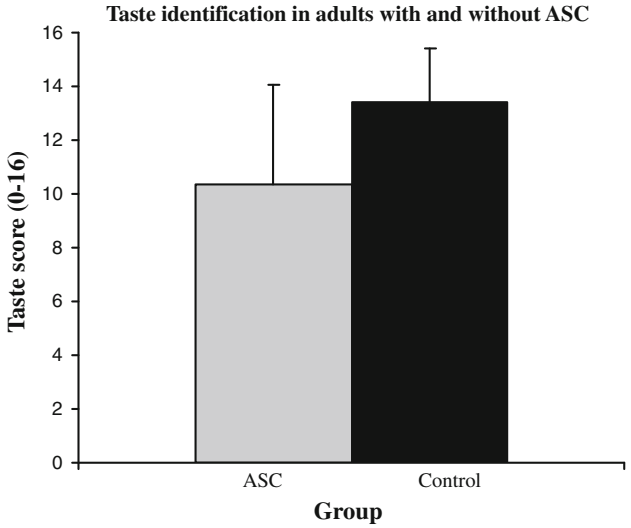

Fig. 1 The *bars* represent taste identification accuracy scores overall for adults with and without ASC. The antennas indicate standard error of mean. The overall score can range from 0 to 16 (the higher the better) and is based on identifying sweet, sour, salty and bitter taste strips. Adults with ASC had significant lower taste identification scores than control participants ($p < 0.05$)

sweet, sour, bitter and salty could range from 0 to 4. Additionally, we calculated accuracy scores, e.g. percentage of correct labelling (see Wang et al. 2009) and error scores (e.g. how often was salty, sweet, sour, bitter and no taste chosen wrongly to identify a taste).

Results

The data were analysed using PASW Statistics 18. Descriptive statistics were computed and tests of normality (Kolmogorov–Smirnov test statistic) were conducted showing that taste accuracy scores were normally distributed in both groups ($p > 0.05$).

Taste Identification Accuracy

Multivariate tests revealed a significant effect of group on taste scores (F (5,46) = 2.78, $p = 0.05$) (see Fig. 1). Tests of between-subject effects showed that age had no effect on taste scores ($p = 0.95$). Separate univariate ANOVAs showed lower taste scores overall in the ASC group (F (1) = 10.20, $p = 0.003$), as well as for bitter taste F (1) = 9.27, $p = 0.004$), sour tastes (F (1) = 5.71, $p = 0.02$) and sweet tastes (F (1) = 4.03, $p = 0.05$). However, salty taste identification accuracy did not differ between the groups (F (1) = 2.98, $p = 0.09$) (see Table 2).[1]

[1] The MANCOVA was repeated excluding participants who were on medication. Adults with ASC showed lower taste scores (Pillai's trace F (5,32) = 0.24, $p = 0.05$). Separate univariate ANOVAs showed lower taste scores overall in the ASC group (F (1) = 11.54, $p < 0.002$), as well as for bitter taste (F (1) = 4.62, $p = 0.007$), sour tastes (F (1) = 3.41, $p = 0.02$) and sweet tastes (F (1) = 3.51, $p = 0.05$). However, salty taste accuracy did not differ between the groups (F (1) = 1.85, $p = 0.08$).

Table 2 Descriptive characteristics of taste identification scores for adults with and without ASC

Mean score	ASC group (n = 23)	Control group (n = 26)	Difference?
Taste overall (SD)	10.4 (3.7)	13.0 (2.0)	Yes ($p = 0.003$)
Bitter score (SD)	2.3 (1.3)	3.2 (0.7)	Yes ($p = 0.004$)
Sour score (SD)	1.9 (1.3)	2.8 (0.8)	Yes ($p = 0.02$)
Sweet score (SD)	3.3 (1.0)	3.7 (0.4)	Yes ($p = 0.05$)
Salty score (SD)	2.9 (1.1)	3.3 (0.7)	No ($p = 0.09$)

Taste identification scores overall can range from 0 to 16. Bitter, sour, sweet and salty scores can range from 0 to 4. Taste scores are given as group means. Adults with ASC were less accurate in identifying tastes overall, as well as for bitter, sours and sweet tastes ($p < 0.05$)

ASC autism spectrum conditions, *SD* standard deviation

Error Analysis

An analysis of error type revealed that the ASC group misidentified tastes more overall (F (5,43) = 2.48, $p = 0.04$). Between-subject tests showed that adults with ASC misidentified tastes significantly more as salty ($F(1) = 5.07$, $p = 0.02$), and as no taste compared to the control group ($F(1) = 5.55$, $p = 0.02$). Groups had similar error rates for mislabelling sweet ($p = 0.14$), sour ($p = 0.35$) or bitter ($p = 0.29$) tastes.

Descriptive Error Analysis

Taste confusion matrices were used to visualize error patterns within the ASC and control group (Table 3a, b). Percentage rates were calculated (score divided by total score times 100). Confusion matrices illustrated that both the ASC and control group found it easiest to label sweet tastes. Both groups showed high error rates for misidentifying sour taste strips as salty.

Discussion

To the best of our knowledge this is the first study to investigate taste identification in adults with ASC (above the age of 18 years). Adults with ASC were *less* accurate in identifying tastes overall (irrespective of medication or age). Specifically, adults with ASC had lower scores for identifying bitter, sweet and sour tastes. In contrast, adults

Table 3 Taste confusion matrices

	Correct taste strip			
	Sour	Sweet	Bitter	Salty
(a) Control group response				
Sour	2.77	0.08	0.50	0.38
	(69.25%)	(2.00%)	(12.50%)	(9.50%)
Sweet	0.11	3.73	0.04	0.04
	(2.75%)	(93.25%)	(1.00%)	(1.00%)
Bitter	0.50	0.04	3.19	0.23
	(12.50%)	(1.00%)	(79.75)	(5.75%)
Salty	0.50	0.11	0.04	3.30
	(12.50%)	(2.75%)	(1.00%)	(82.50%)
No taste	0.11	0.04	0.51	0.04
	(2.75%)	(1.00%)	(12.75%)	(1.00%)
(b) ASC group response				
Sour	1.91 ↓	0.31 ↑	0.50	0.35↓
	(47.75%)	(7.75%)	(12.50%)	(8.75%)
Sweet	0.26 ↑	3.35 ↓	0.09 ↑	0.17 ↑
	(6.50%)	(83.75%)	(2.25%)	(4.25%)
Bitter	0.56 ↑	0.09 ↑	2.32 ↓	0.39 ↑
	(14.00%)	(2.25%)	(58.00%)	(9.75%)
Salty	1.04 ↑	0.09 ↓	0.64 ↑	2.91 ↓
	(26.00%)	(2.25%)	(16.00%)	(72.75%)
No taste	0.22 ↑	0.17 ↑	0.45 ↓	0.16 ↑
	(5.50%)	(4.25%)	(11.25%)	(4.25%)

(a), (b) Represent confusion matrices for correct taste strips and response given within the control group (a) and the ASC group (b). The ASC group scored lower (indicated by ↓) on all correct responses (e.g. sour–sour) and higher (indicated by ↑) on most error answers (e.g. sour–sweet). Percentages are given as well in brackets

with ASC did not significantly differ in regards to detecting salty tastes. Examining error types showed that adults with ASC more often misidentified a taste as salty or as no taste. Taste confusion matrices visualized differences in error patterns between groups. Besides these differences, taste confusion matrices also showed that both, the ASC (83% correct) and control (93% correct) group, found it easiest to label sweet tastes.

Our finding of impaired and intact taste identification is in line with Bennetto et al. (2007) who report that adolescents with ASC show no differences for salty tastes, but only for sour and bitter. On the other hand Bennetto et al. (2007) report no differences for sweet tastes, unlike the current study. Both groups in the current study were extremely good in identifying sweet tastes (see confusion matrices). The question however, arises why two studies so far found that salty tastes remain unaffected in ASC (current study and Bennetto et al. 2007).

Each taste is associated with a different physiological significance: sweet for metabolic energy, sour for acidity, bitterness for poison and salty for sodium chloride concentration (Carpenter 2003). Looking at the peripheral difference between the various tastes and respective receptors shows that these create action potentials in different ways: salty taste is generated by direct depolarization, sweet and bitter bind to receptors (both G-Protein dependent), and sour likely blocks voltage-depending channels (Barker et al. 2003). In addition, different structures (papillae) are responsible for responding to different tastes: bitter and sour receptors are linked to circumvallate papillae, and sweet and salty to fungiform papillae (Carpenter 2003). If ASC are associated with atypicalties on this sensory level would however need to be investigated in more detail.

A more speculative explanation for similar salty taste identification in adults with and without ASC could be the strategy used by adults with ASC. Error type analysis in the current study showed that adults with ASC mislabelled tastes more often as salty compared to the control group. So rather than being better in identifying salty tastes per se, adults with ASC might use salty to describe tastes more often which could lead to a better salty accuracy score in the ASC group compared to sour, sweet and bitter scores. Furthermore the statistical power could be insufficient to detect differences between individuals with and without ASC in identifying salty tastes ($p = 0.09$ in the current study, and $p = 0.24$ in Bennetto et al. 2007).

One limitations of the current study is the unequal age across groups especially since taste perception decreases with age (Landis et al. 2009). However, age had no main effect in the current study. Above and beyond the limitations we believe that our findings are worthy of systematic exploration in future studies. An interesting future direction would be to investigate taste perception in children. So far taste identification has only been tested in adolescent participants with ASC (Bennetto et al. 2007) and adults (current study). It would be interesting to explore if taste identification is problematic from young age, or if problems develop during the lifetime (e.g. due to specific food intake). Difficulties in taste identification could on one hand help to explain the extreme fussiness in eating habits that are reported clinically and anecdotally in ASC (Grandin 1996). On the other hand children with ASC eat a smaller variety of food (e.g. less vegetables, fruits, dairy) regardless of texture and refuse more food than typical developing children (Bandini et al. 2010; Schreck et al. 2004). Thus restricted diets might alternatively explain why adolescents and adults are less accurate in identifying tastes. Besides taste identification other factors such as texture of the food, presentation and the interaction with olfactory system to create flavour play a role and should be taken into account in future studies.

Another avenue would be to investigate underlying mechanisms of taste perception in ASC. As previous

research suggested, taste identification differences in ASC might stem from a central rather than a peripheral level (Bennetto et al. 2007). Central areas such as the thalamus, insula and cingulate cortex are involved in taste discrimination (Kinomura et al. 1994). Areas including the thalamus have been shown to be reduced in size in individuals with ASC (Tsatsanis et al. 2003), thus the difference in taste processing might be the result of atypical activity in these areas.

Last, future studies could investigate if taste identification issues are specific to ASC. A recent study reported that female adults with ADHD and Bulimia Nervosa have no taste identification issues (Weiland et al. 2011). A taste identification test might even become useful for differentiating between ADHD and ASC. Taste perception is important in everyday life and further scientific explorations in conditions such as ASC are needed.

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

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

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