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Olfactory Functions in Adults With Autism Spectrum Disorders

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Abstract
Autism spectrum disorders (ASD) are often characterized by atypical sensory behavior (hyper- or hyporeactivity) although evidence is scarce regarding olfactory abilities in ASD; 16 adults with high-functioning ASD (mean age: 38.2, *SD*: 9.7) and 14 healthy control subjects (mean age: 42.0 years, *SD*: 12.5) were assessed in odor threshold, free and cued odor identification, and perceived pleasantness, intensity, and edibility of everyday odors. Although results showed no differences between groups, the Bayes Factors (close to 1) suggested that the evidence for no group differences on the threshold and identification tests was inconclusive. In contrast, there was some evidence for no group differences on perceived edibility ($BF_{01} = 2.69$) and perceived intensity ($BF_{01} = 2.80$). These results do not provide conclusive evidence for or against differences between ASD and healthy controls on olfactory abilities. However, they suggest that there are no apparent group differences in subjective ratings of odors.

Keywords
Autism, olfaction, smell, odor identification, odor threshold, Bayesian

Introduction

Autism spectrum disorders (ASD) are characterized by social and communication difficulties, alongside repetitive behaviors and special interests (American Psychiatric Association, 2013). In addition, ASD is often accompanied by atypical sensory behavior (hyper- or hyporeactivity) for visual, tactile, and auditory information (Jones, Quigney, & Huws, 2003;

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Rogers, Hepburn, & Wehner, 2003). Given its high prevalence among individuals with ASD, unusual sensory processing was recently included in the Diagnostic and Statistical Manual of Mental Disorders (DSM)-5 diagnostic criteria for ASD (American Psychiatric Association, 2016). However, most evidence is based on visual processing while knowledge is yet scarce regarding how olfaction may differ in individuals with ASD relative to controls.

Studies targeting olfaction in ASD present a mixed pattern of findings. Inconsistencies are reported for both sensory-driven olfactory tasks (e.g., odor threshold measurements) and higher order olfactory functions (e.g., odor identification). Some studies report no differences between individuals with ASD and controls in olfactory threshold (Galle, Courchesne, Mottron, & Frasnelli, 2013; Suzuki, Critchley, Rowe, Howlin, & Murphy, 2003; Tavassoli & Baron-Cohen, 2012), whereas other studies report an impaired sensitivity (Dudova et al., 2011), and still others an enhanced olfactory sensitivity (Ashwin et al., 2014). Likewise, available evidence on odor identification is inconsistent with some studies reporting no group differences (Dudova et al., 2011; Luisier et al., 2015) and others reporting identification impairments (Suzuki et al., 2003; Wicker, Monfardini, & Royet, 2016).

Because of these variable findings, there is a need for more empirical data on effects of ASD on olfactory abilities in high-functioning adult individuals. To that end, we examined whether adults with ASD differ from healthy controls in absolute detection threshold (for n-butanol), and in free and cued odor identification for 10 common everyday odors. Also, we investigated whether ASD is associated with a different perceptual experience of pleasantness, intensity, and edibility for these odors. In analyzing similar data, previous studies used null hypothesis significance testing. Although this approach may provide evidence for differences between groups (i.e., individuals with ASD differ from controls), it cannot distinguish between evidence that suggests no group differences and evidence that is inconclusive (i.e., does not provide enough evidence in support of either no group differences or group differences; Dienes, 2016). Therefore, we computed Bayes Factors (BFs) because they can distinguish between these two alternatives (Dienes, 2016; Wagenmakers, Morey, & Lee, 2016; Wiens & Nilsson, 2016).

Materials and Methods

Participants

Sixteen high-functioning individuals with ASD (age range: 25–56 years, mean age: 38.2, *SD*: 9.7; 3 men and 13 women) were recruited from three different neuropsychiatric Internet-forums and from the Autism- and Asperger association in the region of Västmanland, Sweden. All individuals in the ASD group had been diagnosed by a qualified clinician according to DSM-IV criteria. The control group ($n = 14$) was recruited by advertisements at public notice boards (age range: 26–62 years, mean age: 42.0, *SD*: 12.5; 3 men and 11 women). Participant characteristics are presented in Table 1.

Materials and Procedure

The adult autism spectrum quotient. Participants completed the adult autism spectrum quotient, a 50-item self-reported questionnaire with a forced-choice response format about behaviors associated with autistic traits (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The questionnaire comprises five subscales (social skills, attention switching, attention to detail, imagination, and communication). The possible range of scores is from 0 to 50, and higher scores indicate more traits typical of ASD.

Table 1. Descriptive Information for Demographics, Olfactory Tests and Ratings, Separately for the Autism Spectrum Disorders Group and the Control Group.

	Group	*N*	Mean	*SD*	*SE*
Age	ASD	16	38.25	9.72	2.43
	CG	14	42.07	12.46	3.33
AQ	ASD	16	32.31	10.55	2.64
	CG	14	10.36	4.29	1.15
Perceived functional impairment	ASD	16	2.44	0.81	0.20
	CG	14	1.36	0.63	0.17
Perceived general olfaction	ASD	16	4.44	0.63	0.16
	CG	14	3.29	0.47	0.13
Perceived olfactory sensitivity	ASD	16	4.50	0.52	0.13
	CG	14	3.64	0.93	0.25
Perceived olfactory identification	ASD	15	3.67	0.90	0.23
	CG	14	3.43	0.76	0.20
Olfactory threshold	ASD	16	8.50	4.07	1.02
	CG	14	6.21	2.91	0.78
Free identification	ASD	16	4.94	2.08	0.52
	CG	14	4.07	1.77	0.47
Cued identification	ASD	16	8.31	1.25	0.31
	CG	14	7.36	1.91	0.51
Odor edibility	ASD	16	8.00	2.00	0.50
	CG	14	7.71	1.44	0.38
Odor pleasantness	ASD	16	3.02	0.55	0.14
	CG	14	2.85	0.32	0.09
Odor intensity	ASD	16	3.58	0.78	0.20
	CG	14	3.66	0.59	0.16

Note. ASD = Autism spectrum disorders; CG = control group; AQ = the adult Autism spectrum quotient.

Olfactory tasks. Participants were assessed in three different olfactory tasks: olfactory threshold, free odor identification, and cued odor identification. Before free odor identification, participants provided subjective ratings of edibility, pleasantness, and intensity.

Olfactory threshold. The odor threshold test consisted of 16 different concentrations of n-butanol presented in pens where 1 represented the *strongest concentration* and 16 the *weakest*. The 16 different pens were in a 1:2 volume per volume (*v*/*v*) dilution series at concentrations ranging from 4% (designated as pen no. 1) to 1.2 ppm_v (parts per million, by volume; pen no. 16; Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997). On each trial, the experimenter presented two pens (one with butanol solution and one with odorless propylene glykol) for approximately 3 s each below both nostrils. The presentation order of the two pens was random. After smelling both pens, participants decided which of the two stimuli "smelled stronger" while keeping their eyes closed. As ASD is associated with attentional deficits, the testing time was reduced by starting the assessment at the intermediate concentration level (pen 8; 0.031% concentration). If for a given trial, participants were able to discriminate between odor pen and propylene glykol, the experimenter presented the same concentration level again until the criterion of three consecutive correct trials was met. Then, the test proceeded with a weaker concentration (e.g., from 8 to 9). However, if participants responded incorrectly, a stronger concentration (e.g., from 8 to 7) was presented

until the criterion of three correct responses was met. Accordingly, a higher number on this test reflects a lower sensory threshold.

Free and cued odor identification. The odor identification test comprised 10 common everyday odors that were selected from the Sniffin Sticks' blue and purple tests sets (Hummel, Kobal, Gudziol, & Mackay-Sim, 2007; Hummel et al., 1997). Only 10 odors rather than the original 16 odors were tested to reduce cognitive and attentional demands (Ashwin et al., 2014). The following common and everyday odors were included: coke, mint, gasoline, chlorine, licorice, banana, fish, soap, orange, and lily of the valley. Identification was assessed by free identification followed by cued identification. In the free identification, participants spontaneously retrieved a name of the presented odor. In the cued identification, participants chose among a set of four words.

Subjective ratings of odor edibility, pleasantness, and intensity. For each odor, participants were asked to respond whether the smell represented an edible object (Yes or No). Ratings of the perceived odor pleasantness and perceived odor intensity were performed on 5-point Likert scales (1 = *very unpleasant* to 5 = *very pleasant* and 1 = *very weak* to 5 = *very strong,* respectively). Edibility was scored as the sum of correct responses (i.e., a yes response for coke, mint, licorice, banana, fish, and orange; and a no response for the other odors). For pleasantness and intensity ratings, means were calculated across all odors.

Procedure

Participants were tested individually. After being orally informed about the general aim and the procedure of the study, participants provided written informed consent. Participants were then asked to fill in a questionnaire concerning perceived general odor function and more specific olfactory aptitude (i.e., sensitivity to odors and ability to identify odors), and ability to function in everyday life. The olfactory ratings were done on a 5-point scale (1 = *much worse than others at my age* and 5 = *much better than others at my age*) and perceived functional status on a scale with 1 = *no functional impairment* and 5 = *Large functional impairment*. After completion of the ratings, the threshold test was administered. Then, each of the 10 odors in the identification task was presented individually, and participants rated the odor in terms of edibility, pleasantness, and intensity. They also identified each odor by means of free and cued identification. First, participants were instructed to freely identify the presented odor by providing a verbal descriptor. If they failed to retrieve the correct label, they were provided with four written response alternatives—one target and three foils—and were instructed to choose the label that best matched the specific odor (i.e., cued identification). Each odor was presented approximately 2 cm under the participant's nose for about 3 s. The interval between odors was 30 s to minimize effects of adaptation. The presentation order of odors was randomized. Total testing time was about 45 min. Subjects were rewarded a movie voucher as compensation for their participation.

Results

The raw data and the analyses can be accessed here (https://osf.io/bwp6q) and as online supplements. Table 1 shows the descriptive information for the various olfactory tests and ratings, separately for the ASD group and the control group. Table 2 shows results of independent-samples *t* tests of these variables between the groups. (The supplement also shows results of Mann–Whitney tests.) Table 2 further includes results for the *probability of superiority*, a nonparametric, intuitive measure of effect size (Ruscio & Mullen, 2012). Here, it denotes the probability that if one individual is taken randomly from each group,

Table 2. Results of Independent-Samples *t* Tests Between the ASD Group Minus the Control Group.

							Mean difference 95% CI				PS 95% CI	
	t	*df*	*p*	Mean difference	*SE* difference	Cohen's *d*	Lower	Upper	BF_{01}	PS	Lower	Upper
Age	−0.94	28.00	.354	−3.82	4.12	−0.35	−12.12	4.48	2.07	.43	0.21	0.64
AQ	7.27	28.00	<.001	21.96	2.88	2.66	15.77	28.15	<0.001	.96	0.83	1.00
Perceived functional impairment	4.01	28.00	<.001	1.08	0.27	1.47	0.53	1.63	0.02	.85	0.67	0.95
Perceived general olfaction	5.62	28.00	<.001	1.15	0.20	2.06	0.73	1.57	<0.001	.90	0.75	0.96
Perceived olfactory sensitivity	3.18	28.00	.004	0.86	0.28	1.16	0.31	1.41	0.09	.77	0.58	0.90
Perceived olfactory identification	0.77	27.00	.449	0.24	0.31	0.29	−0.40	0.87	2.29	.59	0.40	0.78
Olfactory threshold	1.75	28.00	.092	2.29	1.28	0.64	−0.40	4.97	0.94	.65	0.43	0.83
Free identification	1.22	28.00	.234	0.87	0.70	0.45	−0.59	2.32	1.66	.63	0.41	0.79
Cued identification	1.64	28.00	.111	0.96	0.60	0.60	−0.24	2.15	1.07	.68	0.46	0.85
Odor edibility	0.44	28.00	.661	0.29	0.63	0.16	−1.04	1.61	2.69	.56	0.34	0.77
Odor pleasantness	1.01	28.00	.324	0.17	0.16	0.37	−0.18	0.51	1.98	.52	0.31	0.72
Odor intensity	−0.30	28.00	.769	−0.08	0.25	−0.11	−0.60	0.45	2.80	.50	0.27	0.71

Note. ASD = Autism spectrum disorders; CG = control group; AQ = the adult Autism spectrum quotient.
The BF_{01} denotes the Bayes Factor for the null hypothesis relative to the alternative hypothesis (i.e., the ASD group differs from the control group). The PS is the probability of superiority (ASD greater than CG).

the score will be higher for the individual from the ASD group than the control group. Table 2 suggests that individuals with ASD perceived themselves as having a better general olfactory function and a higher odor sensitivity than the healthy controls. In contrast, for the olfactory tasks there were no apparent differences between groups ($ps > .05$); however, the nonsignificant p value does not allow one to distinguish between two alternatives: the groups do not differ or the data are inconclusive (i.e., the data are equally consistent with the presence of no group differences and the presence of group differences; Dienes, 2016). To separate these two alternatives, we computed BFs as implemented in the freeware *JASP* (Love et al., 2015; for an instructional example, see Wetzels et al., 2011). These are also shown in Table 2. Whereas the p value captures only the probability of the data (or more extreme results) given the null hypothesis, the BF_{01} compares how well data are predicted by the null hypothesis compared with the alternative hypothesis (for a basic introduction, see Wiens & Nilsson, 2016). If the BF_{01} is close to 1, both null hypothesis (of no group differences) and alternative hypothesis (of group differences) predict the data equally well; thus, the evidence is inconclusive. Here, the alternative hypothesis was defined by a Cauchy distribution (width = 0.707) that captured the idea of group differences in either direction with a small rather than large effect size. As shown in Table 2, the BF_{01} was close to 1 for olfactory threshold, free identification, and cued identification; thus, the data were inconclusive. Similarly, the BF_{01} for pleasantness (1.98) may be considered inconclusive.

In contrast, the BF_{01} for perceived edibility (2.69) and perceived intensity (2.80) provided some support for the null hypothesis (of no group differences), as $BF > 3$ is commonly considered moderate evidence (Dienes, 2016). For convenience, annotated results can be downloaded here (https://osf.io/bwp6q).

Discussion

We found that ASD and healthy controls had a similar sensitivity for olfactory information and performed equally well in free and cued odor identification. Also, ASD and controls did not differ in the overall perception of the qualities of common everyday olfactory information. However, the BFs (close to 1) suggested that the evidence for no group differences on olfactory tests was inconclusive. In contrast, there was some evidence for the absence of group differences on perceived edibility and perceived intensity.

The results from this study provide only inconclusive evidence for the notion that ASD is associated with an altered olfactory function. Specifically, the BFs were close to 1 for olfactory threshold, free identification, and cued identification. This means that the present data are equally well predicted by assuming that there are no group differences and by assuming that there are group differences.

In accordance with previous findings, identification of odors was higher in both groups when retrieval cues were available (Arshamian, Willander, & Larsson, 2011; Larsson et al., 2016). It is well established that identification of familiar odors is a highly effortful task that poses demands on lexical access and verbalization (Olofsson & Gottfried, 2015). Notably, when retrieval demands are lessened, both groups benefited positively and to a similar extent from provision of retrieval cues. This outcome suggests that individuals with ASD have comparable access to olfactory knowledge and may use contextual information as efficiently as healthy age-matched adults.

Although anecdotal reports and evidence from questionnaires in general describe a sensory hypersensitivity and olfactory symptoms in ASD (Cesaroni & Garber, 1991; Kientz & Dunn, 1997), we did not find any evidence of that ASD perceived the olfactory qualities different from controls. Here, autistic participants rated the odors as equally pleasant, intense, and edible as the controls. Importantly, the BF (BF_{01}) was about 2.69 for perceived edibility and 2.80 for perceived intensity. These findings mean that the null hypothesis (of no group differences) predicts the present data about three times better than the alternative hypothesis (of group differences). Because BFs are a continuous measure of evidence and because $BFs > 3$ are commonly considered as moderate support (Dienes, 2016), these findings provide tentative support for the absence of group differences for edibility and intensity. As such, these findings match those reported recently by Galle et al. (2013), who did not observe any differences between ASD and controls in the average ratings of odor intensity, pleasantness, or perceived familiarity.

Some limitations of the present study should be noted. First, as is true for most previous work on autism and olfaction, only few participants with ASD ($n = 16$) participated. So, larger samples are needed to provide sufficient evidence for or against the null hypothesis. Also, although participants in the ASD group were high-functioning individuals, we did not assess intelligence. Hence, it is unknown to what extent variation in intelligence might have contributed to the observed results. Further, because the olfactory threshold was determined for only one odor (n-butanol), any generalizations for other odors should be made with caution.

In sum, the present findings do not provide conclusive evidence for or against the notion that ASD is associated with atypical olfactory functions. However, the present findings

provide tentative support that ASD does not affect subjective ratings of odors. Given the mixed pattern of findings documented across studies, an important goal for future research is to conduct a systematic review of olfactory functions in ASD. This systematic review may be conducted as a meta regression to study the potentially moderating role of variables such as age, type of task, and IQ. Such a meta-analysis can provide valuable information about current knowledge gaps.

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Supplementary Materials

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