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The Odor Awareness Scale: A New Scale for Measuring Positive and Negative Odor Awareness

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Abstract

The Odor Awareness Scale (OAS) is a questionnaire designed to assess individual differences in awareness of odors in the environment. The theory that odor awareness can be distinguished in awareness of negative (to be avoided) odors and positive (to be approached) odors was tested using confirmatory factor analysis (CFA) on the 34-item questionnaire after completion by 525 respondents. CFA (after deletion of 2 items) showed good fit of the 2-factor theory, resulting in a positive awareness subscale (11 items, Cronbach's α = .77) and a negative awareness subscale (21 items, Cronbach's α = .80). Furthermore, reports of sickness from environmental odors were correlated with the negative odor awareness factor, not the positive odor awareness factor. Respondents scoring high on the overall sum score of the OAS showed significantly better olfactory performance on an odor perception test battery than respondents with a low score. These results suggest a causal relation between awareness of potentially negative odors, olfactory performance and experiencing health effects from environmental odor exposure, that warrants further investigation.

Key words: attention, awareness, factor analysis, health symptoms, metacognition, odor perception

Introduction

There seem to be substantial individual differences in the role that odors play in people's lives. Whereas some individuals are always spontaneously commenting on the aroma of the food they eat, the fragrance of flowers in the yard, or the stench coming from the urinals, others only notice these features after they have been pointed out to them. This characteristic—which we will coin "odor awareness"—is most likely related to individual differences in the ability to pick up a scent out of a barrage of external stimuli attacking our senses or to individual differences in olfactory performance.

One way to conceive of odor awareness would be as a stable trait, rather than a state-like feature, that can predict and explain how humans process olfactory information and react to situations that involve olfactory cues. For example, people who are aware of odors from fresh coffee or their partner may experience deeper or richer emotions than those who are unaware. On the other hand, odor-aware people may be more likely to be negatively affected by, or even experience health symptoms from, strong odors from scented products, spoilt food, or emissions from chemical industry.

Being capable of quickly assessing people's odor awareness may prove useful in predicting their reactions to environmental odors in various in- or outdoor settings where annoyance or adverse health effects may be an issue. Likewise, from a commercial point of view, the widespread and instrumental use of artificial fragrances for commercial applications, such as applied in store environments nowadays, evokes the question whether people notice these fragrances and how they react to them. The present study aimed to develop a questionnaire instrument to assess individual differences in odor awareness, to explore whether this construct can be decomposed into subconstructs or factors with respect to odor character or odor source, and how the main construct relates to odor perception ability.

The terms awareness and consciousness have been used interchangeably in the literature. Following one definition of consciousness as "A person's awareness of his or her own existence, sensations, and cognitions" (Kosslyn and Rosenberg 2001), we are especially interested in "olfactory consciousness" which would be a person's awareness of the olfactory sensations he or she perceives. With reference to (Sommerville and Broom 1998) five degrees of olfactory awareness, the concept of odor awareness used here refers to the 3 levels (cognitive awareness, assessment awareness, and executive awareness). Cognitive awareness refers to awareness of sensory inputs accompanied by both automatic and flexible responses to such inputs, whereas assessment awareness refers to the assessment and deduction of the significance of one situation which may result in a complex reaction. Finally, executive awareness is defined as the ability to plan in relation to long-term intentions.

The Odor Awareness Scale (OAS) was designed to assess self-reported awareness of odors in the environment. There are a number of existing questionnaires in which people give a self-report related to their sense of smell, such as to the extent to which good and bad smells affect liking and memory for places, things, and persons (the Affective Impact of Odor Scale: Wrzesniewski et al. 1999) or their beliefs concerning the sense of smell, its importance and its uses (The Attitudes to the Sense of Smell Questionnaire: Martin et al. 2001). Although there are instruments that cover to some extent awareness of odors in the environment, they do not quite capture the concept of odor awareness as defined here. The Odours in Everyday Life Questionnaire (OELQ), which was developed by Cupchik et al. (2005) to survey the self-perceived role of odors in assessment of the environment, everyday life practices, sexuality, social relations, and memories, seems to be designed with a special interest in body odors either related or unrelated to sexual attraction, as well as in odor masking. In addition, it contains several items that are only very indirectly related to odor awareness (e.g., item 22: do you shave your armpits?).

The Children's Olfactory Behavior in Everyday Life (COBEL) questionnaire that appeared recently (Ferdenzi et al. 2006) and aims to measure responses to situations involving food, social and environmental odors, as well as trace behaviors such as the active seeking of odors, awareness of odors, and affective responses comes closest to our aims but was specifically designed for children, not adults.

In the development of the OAS, we tried to avoid some common problems. Firstly, we framed most of our items not as general statements but in terms of concrete situations, items, or activities, to which most people can relate. To this end, we made use of the 4 categories of odor experiences distinguished by Schleidt et al. (1988) (civilization, food and drink, nature, and man), so as to be representative of the odors people encounter on a day-to-day basis. Furthermore, in order to assess awareness, questions were phrased using verbs such as *noticing*, *paying attention to*, or *importance attached to* as much as possible.

The main purposes of this study were (i) to develop a questionnaire (OAS) that is capable of assessing individual differences in odor awareness and (ii) to investigate whether the concept of odor awareness can be divided in meaningful dimensions. One such conceivable subdivision could be along the dimension of hedonic value. In a series of elegant experiments, involving the "attentional blink" paradigm, Ogawa and Suzuki (2004) demonstrated that affectively negative stimuli were more likely to reach the research subject's awareness under conditions in which recognition of other, affectively positive or neutral, stimuli were suppressed. This led them to conclude that a predisposition toward negative information allows organisms to better adapt to the natural environment (Ogawa and Suzuki 2004). Likewise, the organism would be better served by picking up negative odors than positive odors, as negative odors may signal potentially poisonous food sources that should be avoided in the interest of survival. We conducted a confirmatory factor analysis (CFA) to test the hypothesis of 2 factors: a negative factor, endorsed by items that signal unpleasant odors or odors coming from potentially dangerous sources which are best avoided, and a positive factor, endorsed by items involving pleasant odors or odors coming from attractive sources, which can be safely approached.

To this end, 34 items were constructed and administered to 525 respondents. The results were subjected to a CFA ($n = 263$), in order to determine the number of factors that best summarize the various forms of odor awareness. The results of the analysis were cross-validated on a different subset of the sample using a CFA ($n = 262$).

In addition to the main purposes, we wished to address a few other, more exploratory, issues. Several questions related to health effects attributed to environmental odors were administered along with the OAS. Dalton and Hummel (2000) proposed a cognitive–perceptual model of chemosensory processing in order to explain how health symptoms associated with exposure to generally low-level environmental chemicals may arise in individuals with idiopathic environmental intolerance. In this model, an important role is assigned to "top–down" effects, that is, from information stored in memory on chemosensory processing. Individuals who have previously experienced adverse health effects from odor exposure may be more inclined to monitor their environment for odors and thus be more aware of odors when they are in fact present. We will investigate whether increased symptom reporting in the presence of odors is associated with higher odor awareness.

The OAS can be considered as a metacognitive measure, with metacognition referring to the knowledge of one's knowledge, processes, and cognitive and affective states and the ability to consciously and deliberately monitor and regulate them (Hacker et al. 1998, in Gurung and Bord 2008). In order to determine how the person's knowledge

about their own awareness of odors is related to other metacognitive abilities, correlations between the OAS and 2 other metacognitive questions (estimation of own olfactory ability as compared with other people's, ranking of the importance of the sense of smell related to 2 other bodily functions) was determined.

Finally, we had high versus low scorers on the OAS come to the laboratory to test their olfactory performance using the Sniffin' Sticks test (Hummel et al. 1997) in order to explore whether increased odor awareness is related to enhanced odor perceptive ability. This was done in order to obtain a first impression of the relation between the OAS, which is based on (subjective) self-report, and a relevant (objective) behavioral measure. Olfactory performance was chosen as behavioral measure because increased awareness or attention has previously been shown to be associated with enhanced perception, for example, by Marks and Wheeler (1998), who were able to demonstrate that a tastant's threshold was lower when selectively attended to, than when unattended to (Marks and Wheeler 1998).

Materials and methods

Respondents

Questionnaire study

Questionnaires were completed mostly by students from the social sciences, journalism, and technical sciences in Utrecht, Groningen, and Delft. Respondents were approached in the building or on the street to fill out the questionnaire. A total of 525 respondents completed the questionnaire in 2005 and 2006. Mean age of the subjects was 23.1 years (standard deviation [SD] = 5.8), with the minimum being 17 and the maximum 61 years. Of the subjects, 368 (70.1%) were female, 155 (29.5%) were male (missing $n = 2$). There were 377 (70.8%) nonsmokers, 90 (17.1%) current smokers, and 57 (10.9%) past smokers (missing $n = 1$). Thirty-three respondents (6.3%) reported having asthma (missing $n = 5$) and 122 (22.9%) respondents reported allergies (missing $n = 3$).

Olfactory testing

Respondents whose sum score based on the original 34 items was relatively low versus high and who had indicated on the OAS to be interested in participating in future studies for financial remuneration were invited to visit the laboratory for a test on olfactory performance. Based on the sum score of the final 32-item version (after CFA, see below), subjects were assigned to the low versus high group by median split, with the median being 114. A total of 24 subjects, with a mean sum score of 124.42 (SD = 6.46) were tested in the higher group, and 21, with a mean sum score of 102.43 (SD = 6.51) in the lower group. There were 12 males and 32 females (sex of one subject was missing). Mean age of the sample was 22.8 years (SD = 3.7). There was no significant difference in age across the groups.

Methods

Questionnaire construction

Thirty-four items were formulated for the first draft of the OAS (see Table 1). Because of the central focus on awareness, most questions were phrased in terms of a person's tendency to notice, pay attention or attach importance to odors in certain everyday situations that were representative of the odor categories described by Schleidt et al.(1988), as stated earlier.

The selection of these situations was partly based on insights obtained from running a series of focus groups on the topic of odors for a different project, which had yielded over 100 items, and partly on the investigators' own professional knowledge and personal experiences. Care was taken that the odors and situations described could be potentially pleasant as well as unpleasant. In addition, 2 extra questions were added; one asking about the importance attached to odors in life generally (item 29) and general sensitivity to odors as compared with others (item 24).

Odors can affect our moods (Ehrlichman and Halpern 1988: items 14, 15, 16, 21), evoke vivid memories (Engen 1991: item 17), and act as distractors (Danuser et al. 2003: item 4) or affect product purchase (Bone and Jantrania 1992; Spangenberg et al. 1996; items 32, 33, 34). Finally, items 13, 18, 25, 29 of the OAS were based on comparable items from the OELQ (Cupchik et al. 2005). Other items were included as exemplars of "approach" or "avoidance". Examples of approach items are item 1, dealing with nature; 2, concerning the appealing aromas from food; and item 23, related to sexual attraction. Examples of avoidance items are 5, dealing with other people's territory; 8 and 31, concerning unappealing body odors; and 11, related to spoilt food and impending danger. For a complete overview of which items were assigned to either scale, please see Table 2. Five-point scales were used as response categories in most cases (Table 1). Response categories were not always the same but varied. This was done partly to keep the respondent alert. Questions were grouped according to response category, so as to avoid confusion that would add to the error variance.

Several additional questions that are not considered part of the OAS were filled out after completion of the OAS for exploratory purposes outlined in the "Introduction." To explore relations between self-reported odor awareness and perceived effects of odors on health, 3 questions were included indicating the frequency with which respondents became nauseous from food odors, experienced respiratory effects from artificial scents such as air fresheners, or experienced sensory irritation (burning or stinging) when slicing onions. Responses were given on a 5-point scale "always,"

Table 1 Odor Awareness Scale

This questionnaire asks about odors and smelling in different situations. Please mark the box that best expresses your opinion or feeling in the given situation

1. When you walk through the woods, do you pay attention to the odors surrounding you?
2. When someone is busy in the kitchen, do you notice the odor of the food being prepared?
3. Do you notice food odors emanating from houses when you are outdoors?
4. When you are studying, or concentrated in general, do you get distracted by odors in the environment?
5. When you visit someone else's house, do you notice how it smells?
6. Do you sniff at a new book?
7. When an acquaintance smells differently from normal, for example, because of a new perfume, do you immediately notice?
8. Do you notice the smell of people's breath or sweat?
9. Do you pay attention to the perfume, the aftershave or deodorant other people use?
10. Are you the first one to smell gas?
11. Are you the first one to smell when the milk is sour?
12. Are you the first one to smell a fire, even when the smell only comes from a barbecue or fireplace?
13. Are you the first one to smell spoilt food in the fridge?
14. Do you feel cheerful or happy when you pick up a pleasant odor in the air?
15. Do you get angry or annoyed by an indistinct or unfamiliar smell in the environment?
16. Does an unpleasant smell in the environment that won't go away make you anxious?
17. Do odors revive strong or vivid memories in you?
18. Do you sniff at clothes before you put them on?
19. The smell of smoke or food is still lingering in your clothes from the night before. Do you put on new clothes because of the smell?
20. Does the smell of food sometimes put you off it?

Response category used for items 1-20: Always (5), often (4), sometimes (3), seldom (2), never (1)

21. When a room has an unpleasant smell, does it influence your mood?
22. When someone has an unpleasant body odor, does that make you find him or her unattractive? The body odor . . .
23. When someone has a pleasant body odor, do you find him or her attractive? The body odor. . .

Response category used for items 21-23: Has very much influence (5), much influence (4), some influence (3), a little influence (2), (almost) no influence (1)

24. People differ in their sensitivity for odors. An unpleasant smell can leave one person unaffected yet be unbearable to another. How sensitive to odors do you think you are?

Response category for 24: Much more sensitive than others (5), more sensitive than others (4), equally sensitive as others (3), less sensitive than others (2), much less sensitive than others (1)

25. How annoyed are you when you cannot smell because of a cold or the flu?

Response category for 25: Not annoyed at all (1) to very annoyed (5), 5-point scale

26. How important is it to you that your sheets smell fresh?
27. How important is it to you that your (future/potential) partner has a pleasant smell?
28. Nowadays many cultivated flowers no longer have a fragrance. Do you find it important that flowers are fragrant?
29. How important are odors to you in your everyday life?

Response category for 26–29: Very important to not important at all, on a 5-point scale

30*. What would you miss most?

0 loss of hearing in one ear

0 loss of smell

0 loss of your little toe

Table 1 Continued

31. You are in a public space sitting close to someone who has an unpleasant smell. Do you look for another seat if possible?
Response category to be used: Yes (5), probably (4), perhaps (3), probably not (2), no (1)
32. Suppose you are at a supermarket where it smells bad. Is this a reason for you not to return there?
0 I will never return there (4)
0 I will only return if there is no other possibility (3)
0 I will go there less often than I would go to a better smelling supermarket (2)
0 I will not let my shopping be influenced by the way a supermarket smells (1)
33a** When buying products various properties are important. Fragrance is one of them. Below you will find a number of products and properties that may play a role during product purchase. Please indicate how important each of the properties is to you. Give 1 to the most important, 2 to the next most important, etc.
Shower gel:
—*package*
—*price*
—*smell*
—*performance*
Same question for All purpose cleaner (33b)
Same question for Deodorant (33c)

To save space, response categories are listed below all questions to which they apply. Please mark the box that best expresses your opinion or feeling in the given situation.
*This item was originally included in the OAS, but not included in the model for CFA testing. In future administrations it could be left out.
**These items have been recoded in SPSS, such that a higher score indicates greater importance. Thus, 1 becomes 4, 2 becomes 3, 3 becomes 2, 1 becomes 4 etc. After CFA the items 33a and c were deleted from the questionnaire to improve model fit.

"often," "sometimes," "seldom", and "never". In addition, respondents completed the modified Chemical Odor Intolerance Index (CII) (Bell et al. 1993, for the modified version see Dalton 1999) asking about how often respondents felt sick after smelling pesticides, cut flowers, new carpeting, human body odors, household cleaning products, perfume, animal excrement, paint, air fresheners, and traffic exhaust. The same response scale (from "always" to "never") was used.

There were several questions related to metacognition. One additional question asked people to rate how their sense of smell compared with others, varying from "much better than that of others" to "much worse than that of others" on a 5-point scale. Several questions that were considered part of the OAS can also be considered as metacognitive, for example, item 24 about estimated sensitivity to odors, and item 29, about estimated importance attached to odors. Finally, an item (item 30) was included that was based on Wrzesniewski et al. (1999), which involved a choice which subjects would least like to lose: their hearing in one ear, permanent loss of their sense of smell, and their left small toe. This item was not included in the factor analyses, as it is not a direct measure of odor awareness.

The questionnaire ended with demographical questions. Respondents who were interested in participating in a follow-up experiment, could indicate such interest and include name, email address and telephone number. The questionnaire was introduced as one of odors and odor perception, whose purpose it was to learn about how people perceive their environment and the role of smell.

Sniffin' Sticks test

The Sniffin' Sticks test (Hummel et al. 1997) was used to determine olfactory functioning. Odors diluted in propylene glycol, presented in pen-like devices, were used as stimuli. The task consisted of 3 tests of olfactory function: threshold detection, discrimination, and Identification. On each subtest, scores can vary between 0 and 16. The scores for each of the 3 subtests were summed to yield a total threshold detection identification (TDI) score. For further details on the procedure, the reader is referred to Hummel et al. (1997) and Kobal et al. (2000).

Statistical analyses

CFA was used to test the fit of the proposed 2-factor model consisting of a hedonically positive and a hedonically negative factor. Table 2 provides an overview of item allocation to the positive and negative factor. Of the 34 items, 12 were allocated to the positive factor and 22 to the negative factor. Some allocations were straightforward (e.g., in the case of

Table 2 Allocation of items to positive factor (p) or negative factor (n)

Item No.	Item	Factor allocation
1	Woods	p
2	Kitchen	p
3	Food odor street	n
4	Concentration	n
5	Other house	n
6	Book	p
7	Acquaintance	p
8	Mouth/sweat	n
9	Perfume	p
10	Gas	n
11	Milk sour	n
12	Fire	n
13	Spoilt food	n
14	Cheerful	p
15	Angry	n
16	Anxious	n
17	Memories	p
18	Clothes	n
19	Smoke in clothes	n
20	Aroma food	n
21	Unpleasant space	n
22	Unpleasant body	n
23	Pleasant body	p
24	Sensitivity	n
25	Cold	n
26	Sheets	n
27	Partner	p
28	Flowers	p
29	Odors general	p
30	Miss most	Not included
31	Public place	n
32	Supermarket	n
33a	Shower gel	p
33b	All-purpose cleaner	n
33c	Deodorant	n

Item 30 was not included in the CFA, as it is not a direct measure of odor awareness.

item 6 ''Do you sniff at a new book''—positive factor—and item 20 ''Does the smell of food sometimes put you off it?''—negative factor). Other allocations may be subject to debate, such as in case of item 3 (''notice food odors emanating from houses when outdoors''), which could be interpreted both positively as well as negatively. In such cases, we chose the interpretation that seemed most likely, keeping in mind that reallocation may be necessary based on suboptimal fit of the model after statistical testing. However, as we will see later, the results prompted only very few adjustments with regard to the original model. Item 30, which was adopted from Wrzesniewski et al. (1999) and included in the original version of the OAS as the 35th item, was not included in the model, as we felt in retrospect it did not directly assess odor awareness.

The CFA is the theory-driven twin of the exploratory factor analysis, which is a purely data-driven technique. In a CFA model, each indicator (item) is defined as a continuous variable represented as having 2 sources: the factor that the item is supposed to measure and an error term representing all unique sources of causation. The measurement errors can be assumed to be independent of each other, and the factors and all associations between factors (correlates and covariation) do not need to be analyzed. In order to be able to conduct and cross-validate the CFA, the original data file, holding the data of 525 respondents, was split in half according to respondent ID. The first CFA was run on 263 odd-numbered respondent IDs on a fully imputed file (the validation sample). Missing data were imputed in SPSS using the Expectation–Maximalization (EM) algorithm. The validation sample was used to build a fitting final model. The results of this CFA were cross-validated by running the final factor model on the remaining 262 even-numbered IDs (the calibration sample) (Kaplan 2000). Both models fitted equally well, so the model can be considered robust. The data files were thereupon merged, and the CFA was conducted on the complete file; now missing data were imputed in AMOS 7 (Arbuckle 2003) using full information maximum likelihood (FIML) imputation to obtain an optimal data set as FIML imputation is statistically superior to EM (Enders and Bandalos 2001). Furthermore, a 2-group CFA on sex was conducted to show robustness of the factors across sex. This is important because for the construct of odor awareness to be considered robust factor loadings indicating the relation between items and the construct should be equal across subgroups. For this particular sample, males and females are meaningful subgroups across which the construct of odor awareness should not differ.

Results

OAS: descriptive results

After CFA and subsequent deletion of 2 items (see below), 32 items remained. The distribution of sum scores looked

normal with a mean of 113.65 (SD = 12.14), median of 114, and minimum and maximum scores of 72 and 151, respectively. Skewness was –0.07, kurtosis 0.04.

Confirmatory factor analysis

Following Anderson and Gerbing (1998), we report the separate results from the 2 CFA's that were run on the positive items and negative items, respectively.

CFA on positive items

The CFA on the positive items of the OAS showed good fit ($\chi 2 = 90.6$, degrees of freedom [df] = 41, CFI = 0.95, root mean square error of approximation (RMSEA) = 0.048). All indicators loaded significantly on the factor except item 33a (shower gel); this item was therefore omitted. For reasons indicated earlier, a 2-group CFA on sex was conducted to show robustness of the factors across the sex groups. After constraining the factor loadings to be equal across groups, the model held equally well for males and females (CFI = 0.93, RMSEA = 0.033). All items show medium to large loadings between 0.343 and 0.701 (see Table 3), which is very acceptable. Reliability analysis showed a Cronbach's alpha of 0.77 for 11 items, with no more items needing to be deleted. These results support the theoretical notion of positive odor awareness. Results for the 11-item positive factor ($N = 525$) were as follows: the distribution looked normal, with $M = 41.54$, SD = 5.19, a median of 42, minimum of 23, and maximum of 54. Skewness was 0.19, kurtosis –0.07.

CFA on negative items

The model for the negative items related to odor awareness fit the data ($\chi 2 = 309$, df = 173, $\chi 2/df < 2$, normed fit index (NFI) = 0.93, RMSEA = 0.039). One item (33c: deodorant) was deleted from the file. The multigroup CFA again showed robustness of the factor across sex (NFI = 0.90, RMSEA = 0.029). All items demonstrated medium to large loadings between 0.230 and 0.637 (see Table 4). Cronbach's alpha was 0.80 for 21 items. These results support the theoretical notion of negative odor awareness. Results for the 21-item negative factor ($N = 525$) were as follows: the distribution looked normal, with $M = 72.5$, SD = 8.03. The median was 72, minimum 49, and maximum 97. Skewness was –0.02, kurtosis 0.05.

The positive and negative factors were highly correlated ($r = 0.67$). This demonstrates that the factors are not orthogonal but related. Individuals who are aware of one type of odor are usually also aware of the other type, although not always to the same extent.

Sniffin' Sticks

The high groups average TDI sum score on the Sniffin' Sticks task was significantly higher than the low group ($t_{43} = 1.99$,

Table 3 Factor loadings for the items on the factor "positive odor awareness" by item for total sample, females, and males

Item	Estimate	SE	β ($N = 523$)	β females ($n = 368$)	β males ($n = 155$)
1	1.000		0.371*	0.379	0.373
2	0.648	0.115	0.372*	0.384	0.366
5	1.658	0.246	0.413*	0.428	0.400
7	1.504	0.227	0.529*	0.544	0.516
9	1.592	0.237	0.545*	0.546	0.539
14	1.308	0.194	0.552*	0.536	0.545
17	1.624	0.239	0.564*	0.565	0.558
23	1.060	0.178	0.409*	0.397	0.420
27	1.181	0.183	0.490*	0.466	0.498
28	0.942	0.185	0.343*	0.288	0.327
29	1.649	0.227	0.701*	0.678	0.711

SE, standard error; *$P < .01$.

Table 4 Factor loadings for the items on the factor "negative odor awareness" by item for total sample, females, and males

Item	Estimate	SE	β ($N = 523$)	β females ($n = 368$)	β males ($n = 155$)
3	1.000		0.420*	0.435	0.362
4	1.016	0.148	0.397*	0.423	0.349
5	1.467	0.182	0.567*	0.591	0.537
8	1.121	0.160	0.501*	0.506	0.465
10	1.301	0.181	0.506*	0.543	0.442
11	1.025	0.187	0.327*	0.333	0.306
12	1.347	0.184	0.513*	0.555	0.459
13	1.373	0.192	0.523*	0.519	0.450
15	0.744	0.152	0.286*	0.282	0.259
16	0.940	0.176	0.317*	0.312	0.304
18	1.209	0.188	0.426*	0.425	0.383
19	0.496	0.123	0.230*	0.231	0.179
20	0.724	0.154	0.289*	0.281	0.231
21	0.903	0.145	0.385*	0.407	0.357
22	0.766	0.132	0.357*	0.359	0.332
24	1.376	0.176	0.637*	0.647	0.584
25	1.045	0.177	0.380*	0.370	0.333
26	0.834	0.152	0.397*	0.333	0.298
32	0.484	0.116	0.230*	0.234	0.200
31	0.869	0.157	0.331*	0.339	0.290
33b	0.852	0.0155	0.352*	0.323	0.337

SE, standard error. *$P < .01$.

$P = .026$, 1 tailed) indicating better olfactory performance. On each of the 3 subtasks threshold detection, discrimination, and identification, the difference between the high and low group in mean score was in the expected direction (see Figure 1). However, a multivariate analysis of variance carried out on these 3 subscores with group as between-subjects factor did not show statistical significance on the combined dependent variables (multivariate: $F_{3,41} = 1.29$, $P = .29$, 2 tailed). Therefore, we did not proceed to report the results for each of the dependent variables separately. The results for total TDI score are in line with those from a comparable healthy control sample reported in Kobal et al. (2000).

Metacognitive questions and correlations with self-reported health effects

Approximately 60% of respondents believed their sense of smell to be as good as or worse than other people's; 40% believed it to be better or much better than that of others, which reflected that respondents in general did not overestimate their olfactory ability. Most respondents (59.4%) rated loss of smell as worse than the loss of hearing in one ear (which 33.8% rated as worst) or the loss of the left small toe (which 6.7% rated as the worst loss).

The better the respondents believed their sense of smell to be, the higher the sum score on the OAS, and thus the more aware respondents were about odors in the environment ($r = 0.55$, $P < .001$). Likewise, the higher participants ranked their sense of smell, the higher their OAS score (Spearman's $\rho = 0.12$, $P < .01$), although, clearly, the association is much smaller for the latter combination of variables than the former.

Correlations were also established between the overall sum score and positive and negative factor sum scores of the OAS on the one hand, and health items as measured by the sum score of the 10-item–modified CII (based on good reliability as indicated by Cronbach's $\alpha = 0.89$ of 10-item scale), as well as items related to nausea from food odors (nausea), respiratory problems or coughing from artificial scents (respiratory), and irritancy of eyes or nose from onions (irritancy) on the other hand (The last 3 health-related items were not combined into a scale due to low reliability as indicated by Cronbach's $\alpha = 0.34$. This is not problematic, as these items were formulated precisely to tap diverse aspects of odor-related health experiences.). The first column of Table 5 shows a modest positive correlation between the overall OAS sum score and health symptom reports. The second and third columns of Table 5 show partial correlations between the negative factor after controlling for the effects of the positive factor, and vice versa, to obtain an impression of the unique influence of one form of odor awareness on health symptoms after controlling for the other. All correlations, except for the correlation between the negative factor and Nausea, which was 0.249, were somewhat lower after controlling for the other factor. As can be seen in the table, most correlations between the negative factor of the OAS and health symptoms were (still) significant, although not very high, after controlling for the influence of the positive factor. In contrast, most correlations between the positive factor of the OAS were low and nonsignificant after controlling for the negative factor. Reporting adverse health symptoms is more closely related to awareness of odors in negative situations or of unpleasant odors than to awareness of odors in positive situations or of pleasant odors.

Finally, the fact that scores from the olfactory performance task were related to the OAS sum score will be evident, as it was discussed earlier that subjects scoring high on the OAS had significantly higher TDI sum scores than subjects scoring low on the OAS. This relation was stronger for the positive factor of the OAS, although not significantly

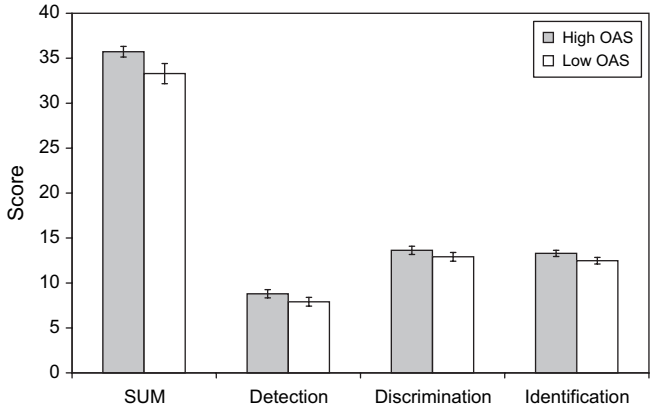

Figure 1. Results from Sniffin' Sticks test on olfactory performance (TDI sum score and scores on the 3 subtasks. Bars indicate standard errors of the mean).

Table 5 Correlations and partial correlations between OAS sum score and negative and positive factors of the OAS on the one hand and health symptoms on the other hand

	Correlation (df ≥ 501)	Partial correlation (df = 498)	
	OAS sum score	Negative factor, controlling for positive factor	Positive factor, controlling for negative factor
CII (modified)	0.268**	0.207**	0.007
Nausea	0.203**	0.267**	−0.118*
Respiratory	0.182**	0.136*	0.015
Irritancy	0.091*	0.055	0.02

Nausea indicates tendency to become nauseous from food odors, respiratory indicates tendency to experience respiratory effects from artificial scents, irritancy indicates tendency to experience irritancy in nose or eyes when chopping onions.
$P < .01$, $^{**}P < .001$.

($r = 0.26$, $.05 < P < .1$, 2 tailed, $n = 45$), than for the negative factor ($r = 0.14$, not significant).

Discussion

The fact that individual differences in perception of and reactions to odors in the environment may be predicted by initial differences in awareness of such odors prompted the creation of an instrument to assess such differences. This instrument, which we called the OAS, originally consisted of 34 items that captured a person's tendency to notice, pay attention to, or attach importance to odors in the environment across situations spanning food and drink, civilization, nature, and man. Based on the presumed function of the sense of smell to allow for a quick discrimination between approach and avoidance of food sources, predators, mates and such, a theoretical distinction was proposed between odor sources and situations that are predominantly negative versus positive. As stated by Engen (1991): "Odor perception serves both as a prototypical sensor for self-preservation against potentially harmful substances in the atmosphere and as a hedonic agent for the enjoyment of fragrances." (Engen 1991, p. 2). A test of a model consisting of 2 such factors using CFA on results from a sample of 525 respondents demonstrated good fit, which, after elimination of 2 items, resulted in an 11-item positive odor awareness factor and a 21-item negative odor awareness factor, both with good reliability. This finding supports the notion that awareness of odors in the environment is not always equally distributed over "good" and "bad" odors. Some people are more aware of odors signaling potentially dangerous or unpleasant sources or situations, whereas others are more aware of odors signaling healthful or pleasant situations and sources. However, the correlation of 0.67 between the factors at the same time shows that tendencies to pay attention to negative and positive odors are not completely divergent: people may be more aware of odors in general with some individuals leaning more toward negative than positive odors and vice versa.

The OAS sum score was significantly related to another metacognitive question that involved self-rated sense of smell: the better own sense of smell was perceived to be, the more people claimed to be aware about odors in the air. These results may demonstrate a true relation between 2 cognitive functions yet also a tendency to overestimate one's own abilities. The finding of a significantly better olfactory performance using an olfactory test battery in a subgroup of subjects with high odor awareness compared with a subgroup of subjects with low odor awareness would support the former association. Apparently, people who are very aware of odors in their environment are also better at perceiving odors. The causal direction of this relation is, of course, not clear and remains to be established.

The finding of a relation between a self-report measure (odor awareness) and a behavioral measure (odor performance) is surprising—because self-report measures about behavior are not often related to that behavior—yet not unique, as Johansson et al. (2006) also reported a significant relation between self-reported odor intolerance and the objective test of capsaicin cough sensitivity. White and Kurz (2003), on the other hand, showed considerable impairment in patients with chemosensory disturbances in rating their own olfactory ability. In 42% of the cases ($N = 203$), patients' self-reports did not match the objective measure of olfactory ability (see also Nordin et al. 1995). Interestingly, younger patients were more likely to underestimate their olfactory ability, whereas older patients were inclined to the opposite.

One of the goals of the study was to investigate whether odor awareness is in some way related to health symptom reports from odor exposure. We found significant—althoug modest—correlations between negative odor awareness, but not positive odor awareness, and feelings of sickness from a variety of odors or nausea from food odors. In other words, the tendency to notice potentially dangerous or unpleasant odors is related to a tendency to feel sick from odors in general. The causal direction of this relation is at present unclear, as increased attention to odors can lead to increased reactivity (sickness) from odors as much as the opposite.

The finding of a relation between negative odor awareness and experiencing health effects from odors, in combination with the finding that people who are more aware of odors are also better at processing olfactory information, triggers 2 questions. The first is that of a causal path relating all 3 variables. One of several potential hypotheses could be that increased odor awareness may lead to enhanced olfactory performance as well as to increased physiological reactivity to environmental odors. The second hypothesis is that of personality as a potential underlying variable responsible for the orientation toward negative olfactory stimuli in the environment. The most likely candidate personality feature is negative affectivity, a general dimension of subjective distress, also known as neuroticism or trait anxiety (Watson and Clark 1984). Individuals with high levels of negative affectivity are more likely to experience distress in the absence of overt stressors, to interpret ambiguous stimuli in a negative manner, and to report more subjective health complaints (Watson and Pennebaker 1989). A number of previous studies have investigated relations between negative affectivity, odors, and health (Smeets and Dalton 2005; Ihrig et al. 2006), as well as between neuroticism and olfactory sensitivity (Pause et al. 1998; Koelega 1970). A better understanding of the causal path between odor awareness, odor perception, and health effects from odors, and especially the role of personality, would benefit industry, government, and residents exposed to outdoor environmental emissions or workers exposed to indoor chemical agents and are thus worthy of further investigation. Interventions aimed at reducing health effects from odorous emissions might be served by steering attention away from odors in those

who are especially aware, by manipulating cues related to the other modalities in the environment.

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