Chem. Senses 34: 111–119, 2009

doi:10.1093/chemse/bjn062
Advance Access publication October 20, 2008

The Implicit Association between Odors and Illness

Patricia J. Bulsing, Monique A.M. Smeets and Marcel A. Van den Hout

Department of Clinical and Health Psychology, Utrecht University, PO Box 80140, 3508 TC, Utrecht, The Netherlands

Correspondence to be sent to: Patricia J. Bulsing, Department of Clinical and Health Psychology, Utrecht University, PO Box 80140, 3508 TC, Utrecht, The Netherlands. e-mail: p.bulsing@uu.nl

Abstract

Some individuals ascribe health symptoms to odor exposures, even when none would be expected based on toxicological dose-effect relationships. In these situations, symptoms are believed to have been mediated by beliefs regarding the potential health effects from odorants, which implies a controlled type of information processing. From an evolutionary perspective, such a form of processing may hardly be the only route. The aim of the present study was to explore the viability of a fast and implicit route, by investigating automatic odor-related associations in the context of health. An Implicit Association Test assessing association strengths between the concept odor and the concepts healthy and sick was conducted. Three experiments ($N = 66$, $N = 64$, and $N = 64$) showed a significantly stronger association between the concepts odor and sick than between odor and healthy. These results did not match explicit associations and provide evidence for a fast and automatic route of processing that may complement consciously controlled processes. A dual-processing theory of olfactory information is proposed leading to new hypotheses regarding the development and maintenance of odor-induced health symptoms.

Key words: health, implicit association test, implicit attitude, implicit measure, indirect measure, odor perception

Introduction

Odors signal the presence of airborne chemicals, some of which, at certain concentrations, cause adverse health effects. Examples of such direct health effects are irritation of the nasal mucosa, increased nasal secretion, respiratory changes, and central nervous system effects (Schiffman et al. 2000). Alternatively, some odorants are the by-products of bacterial activity associated with decomposition or bad hygiene (e.g., sulfides, organic acids, and amines). In such instances, contact with the odor ''source'' should be avoided, but the odorant itself is no direct trigger of health effects and can be considered ''only'' an exposure marker (Schiffman and Williams 2005). However, some people report health symptoms not as a consequence of inhaling highly toxic chemicals or ingesting rotten food but in response to perception of associated, essentially harmless odors. The most extreme variant of odor-related illness is idiopathic environmental intolerance (IEI) or multiple chemical sensitivity (MCS; Ross et al. 1999; Das-Munshi et al. 2007). Individuals suffering from IEI or MCS report symptoms in response to (intense) odors in general. Such odor-induced health symptoms are hard to understand from a toxicological perspective—concentrations do not exceed levels where bodily effects are expected—and in these instances, psychological explanations can be helpful (e.g., Dalton et al. 1997; Devriese et al. 2000; Shusterman 2001).

Dalton and Hummel (2000) proposed an information-processing model of chemosensory perception to explain individual differences in interpretations of and reactions to odors in the context of health (see also Smeets and Dalton 2005). Besides ''bottom-up'' processing of olfactory information (initiated by the stimulus itself; e.g., concentration, quality), effects of ''top-down'' processing play a central role in this model, referring to influences of beliefs and expectations on the perception and interpretation of the olfactory stimulus. Knowledge and beliefs and sometimes clear misconceptions regarding potential health effects from exposure to odorous chemicals can be considered ''mental models'' that facilitate the access to relevant information and application of that information to further processing (Reiser et al. 1985). It has been repeatedly demonstrated that such top-down processes, indeed, influence individual perception and reactions to odors (e.g., the influence of various coping styles, Cavalini et al. [1991]; personality, Smeets and Dalton [2005]; being environmentally worried, Shusterman [2001]; and psychological stress, Dayal et al. 1994).

Although top-down influences of mental models on odor perception and the production of health effects are no doubt important, some caution as to their precise role is warranted. First of all, the use of the term mental models suggests a rich network of connected propositions (Reiser et al. 1985) that is both comprehensive and consistent. However, preliminary data from our laboratory on the content of such mental representations through focus groups and interviews (unpublished data) have revealed that there are substantial individual differences in degree of sophistication of these knowledge structures. In most people, the mental model is not exhaustive—that is to say, it may hold beliefs regarding what symptoms may follow from exposure to odorants but shows gaps concerning the mechanism by which odorants would provoke these symptoms or concerning the general workings of the sense of smell. Thus, the notion that smelling an odor activates an advanced mental network of interrelated cognitions concerning olfaction and health is probably an overstatement of the mental process that takes place in most people. Second, the mental model may hold incompatible beliefs, or misconceptions, and is often difficult to access via introspection. As noted earlier by Leventhal et al. (1980), the cognitive structure comprising illness representations may be nonverbal (but rather perceptual) and, thus, difficult to represent verbally. And finally, the mental model approach suggests extensive information processing of olfactory input. However, this idea does not correspond with our general conception of the sense of smell as the gatekeeper of the senses, whose function is to quickly decide whether to approach or avoid. The function of olfaction would actually be better served by a capacity-free, unconscious and automatic form of information processing than by a capacity-dependent, conscious, and controlled manner of processing (Bargh 1989).

Although we do not question the influence of mental models, it is unlikely that they guide quick, initial approach or avoidance evaluation by extensive and controlled cognitive processes. This reasoning suggests the presence of another pathway that assists people's perceptions of and reactions to environmental odors. Such a pathway would predominantly rely on quick associations between odors and health effects, as opposed to rich networks of knowledge structures, and on preattentive, perceptual associations. The notion of olfactory cognitive processing as a dual-route system, with one automatic, involuntary route enabling rapid approach or avoidant responses, as well as a higher level, conscious, and deliberate route to making consciously and deliberate evaluations, is in line with recent models of information processing (e.g., the model of medically unexplained symptoms, Brown [2004]; the model of cognitive mechanisms underlying threat processing, Bar-Heim et al. [2007]; the model of selective processing in anxiety, Mathews and Mackintosh [1998]).

The aim of the present study was to explore the viability of this first route, by investigating automatic odor-related associations in the context of health. To this end, the Implicit Association Test (IAT) was conducted (Greenwald et al. 1998), whereby association strengths between the concept odor and the concepts healthy and sick were assessed. The term "implicit test" (or "indirect measure") in the context of the IAT refers to the fact that subjects 1) are not necessarily aware of the fact that the association is being measured, 2) do not need conscious access to the association, and 3) have less control over the measurement outcome compared with questionnaires (De Houwer 2006). Others take a slightly different viewpoint and prefer to classify the IAT as a measurement tool that measures activated associations which have not been subject to validation processes, whereby "validation" refers to deliberate consideration about the truthfulness of one's automatic associations (Gawronski et al. 2007). In other words, the IAT is considered to capture ideas that have not been consciously "checked." During the IAT, items belonging to 1 of 4 concepts (in the present case: odor, house, healthy, sick) are categorized as quickly as possible in 2 categories by pressing 1 of 2 response keys. In a first part of the test, items representing the concepts odor and healthy are categorized by pressing one and the same key, whereas items representing the neutral house category and the concept sick are categorized by an alternative key. In the second part of the IAT, now items representing the concepts odor and sick share the first one key, whereas items belonging to the concepts neutral and healthy share the other key. The comparison between response times of the 2 conditions is an indication of association strengths between the concepts. For instance, subjects who categorize items more quickly when odor is paired with healthy, compared with the condition when odor is paired with sick, are presumed to have an implicit dominant association between the concepts odor and healthy.

The present paper describes the results of 3 IAT experiments. From an adaptive tendency, we expected that the concept of odor would be more closely associated with the concept of illness than with the concept of health because the role of odors to signal the presence of chemicals or foods of which the inhalation or ingestion may promote illness is probably more important than the role of odors to signal chemicals or foods that promote health. The results of Experiment 1, indeed, provided support for the prediction of an implicit odor–illness association.

After Experiment 1, we decided to conduct 2 additional experiments for 2 reasons: 1) to test whether the odor–illness association was a general and a stable one and 2) to test whether the use of neutral target category house influenced the results. The latter refers to the fact that the IAT always measures associations with a certain concept of interest (in this case odor) relative to the associations with the other concept (in this case house). For example, most IATs use opposite concepts (De Houwer 2002), like male versus female, or black versus white, whereby a strong positive association with the concept male automatically implies a more negative association with the concept female (which is more negative in this example). Because the concept odor does not have its own contrary counterpart, we used a matching or reference category on the assumption that neither the concept nor the exemplars of the concept were intrinsically associated with healthy or sick and, thus, that an odor–sick association or an odor–health association did not necessarily imply an house–healthy association or a house–sick association, respectively (see also De Jong et al. 2001). However, to be certain that the results of Experiment 1 were really based on an intrinsic association between odors and illness, the neutral reference category was replaced by 2 different ones in 2 additional experiments. If the dominant association between odor and illness found in Experiment 1 was caused by the choice of a relatively positive reference category, it would disappear after substitution with a truly neutral category.

Experiment 2A describes an IAT with an odor versus clothes target dimension. Experiment 2B describes an IAT with an odor versus sound target dimension. The concept clothes again represents objects, like house, that we presume to be of neutral value. On the other hand, subjects might coincidentally have implicit positive associations with all kinds of objects, and thus, the concept sound was chosen in Experiment 2B. Because sound refers to the sense of audition and odor to the sense of olfaction, sound as reference category may be a better match than any object category.

Materials and methods

Subjects

In Experiment 1, 67 students from Utrecht University (57 females, 10 males) were tested. Mean age was 20.77 (standard deviation [SD] = 2.25). In Experiment 2A, 65 students were tested (46 females and 19 males). Mean age was 21.45 years (SD = 3.41). In Experiment 2B, 64 students were tested (46 females and 18 males). Mean age of this group was 22 years (SD = 2.34). Subjects received either course credits or financial remuneration for their contribution. They were not informed about the test purpose prior to their participation.

Stimulus words

One of the dimensions of the IAT used in Experiment 1 consisted of the 2 word categories: house (porch, basement, room, hallway, attic) and odor (whiff, aroma, smell, nose, scent). The other dimension also consisted of 2 word categories: the healthy category, containing words related to positive health (vital, fit, strong, well, and happy), and the sick category, containing words related to negative health (weak, fever, flu, headache, and virus). All words were checked for their frequency and length (in Dutch) in order to have 2 comparable word categories on both dimensions. The concept house had been chosen as a neutral category previously because it was assumed that neither this concept nor the exemplars of the concept were intrinsically associated with the concepts good or bad (Bulsing et al. 2007; see also De Jong et al. 2001). Likewise, we assumed that the concept house would be neutral in terms of "healthiness" and, thus, that neither the concept itself nor the exemplar words would be intrinsically associated with the concepts healthy or sick. To explore whether this was the case, we had an independent student sample ($N = 47$) to rate the healthiness of the concept words house and odor and the associated 5 exemplar words for all 4 concepts on a 5-point scale (ranging from 1 to 5) with unhealthy (low scores) versus healthy (high scores) as extreme categories. Mean ratings of the concept words house and odor were 3.21 (SD = 0.66) and 3.49 (SD = 0.78), respectively. Mean ratings of the 5 exemplar words were 3.01 (SD = 0.28) for the house words, 3.27 (SD = 0.43) for the odor words, 1.52 (SD = 0.41) for the sick words, and 4.61 (SD = 0.40) for the healthy words. In conclusion, the odor and house concept words and exemplar words were rated as neutral and the healthy and sick exemplar words were rated as healthy and unhealthy, respectively.

For Experiment 2A, the house category of Experiment 1 was replaced with the clothes category (coat, pants, socks, shoes, shirt), and for Experiment 2B, the house category was replaced with the category sound (listen, tones, vibration, ear, hearing). The odor category was identical to that in Experiment 1. The other dimension again consisted of the 2 word categories healthy and sick. An independent student sample ($N = 37$) rated the healthiness of the concept words clothes, sound, and odor and the 5 exemplar words of all 5 categories (clothes, sound, odor, healthy, sick) on a 5-point scale (ranging from 1 to 5) with unhealthy (low scores) versus healthy (high scores) as extreme categories. Mean ratings of the concept words clothes, sound, and odor were 3.27 (SD = 0.45), 3.22 (SD = 0.48), and 3.46 (SD = 0.73), respectively. Mean ratings of the 5 exemplar words were 3.07 (SD = 0.32) for the clothes words, 3.18 (SD = 0.40) for the sound words, 3.17 (SD = 0.39) for the odor words, 1.45 (SD = 0.34) for the sick words, and 4.36 (SD = 0.36) for the healthy words. In conclusion, the odor, clothes, and sound concept words and exemplar words were rated as neutral in terms of healthiness, the healthy and sick exemplar words were rated as healthy and unhealthy, respectively.

Procedure

The IAT was programmed in E-prime, version 1.2. Following Greenwald et al. (1998), the test consisted of 5 blocks and 2 practice blocks. During Block 1, subjects were trained on how to differentiate between the odor words and the house words. The 5 house words and 5 odor words were presented twice (Block 1: 20 trials). Subsequently, subjects had to use the same response keys for classification of the 5 healthy words and the 5 sick words, which were also presented twice (Block 2: 20 trials). During practice Block 3a, the 2 former tasks were combined. Half of the subjects started the combined task with pressing the same key for odor words and healthy words (Order 1). The other half started this block with pressing the same key for odor words and sick words (Order 2). Because Block 3a was a practice block, words from all concepts were presented once (Block 3a: 20 trials), and reaction times were not registered. Block 3b was the same as Block 3a, except that now registration took place and words from all concepts were presented twice (Block 3b:

40 trials). During Block 4, the categories house and odor changed positions on the computer screen, resulting in a required switched response for the associated words. Again the 5 odor words and the 5 house words were presented twice (Block 4: 20 trials). No exemplar words from the healthy and sick categories were presented during this block. Practice Block 5a was again a block where the 2 tasks were combined but now with the switched odor/house dimension. Words from all concepts were presented once (Block 5a: 20 trials). Block 5b was the same as Block 5a, except that registration took place and all words were presented twice (Block 5b: 40 trials).

Subjects were instructed to categorize as quickly and accurately as possible the words into the 4 categories by pressing the corresponding response keys on a computer keyboard. The words that had to be classified appeared one by one in the center of the screen. During each IAT block, the category concepts remained visible in the left and right upper corners of the screen. Orders 1 and 2 both had 2 versions where the target–attribute pairs were allocated to different sides of the screen. Subjects had to respond by pressing the "q" (index finger left hand) for words that belonged to a category in the left corner and the "p" (index finger right hand) for words that belonged to a category in the right corner. In case of a wrong answer, a red cross appeared. Subjects had to correct the mistake by quickly pressing the alternate (correct) key. As soon as the correct key was pressed, the next word appeared.

After completion of the test, subjects were asked to rate the explicit "healthiness valence" of the concept and exemplar words on a 5-point scale with unhealthy (low scores) versus healthy (high scores) as extreme categories. In this manner, differences between subjects' implicit and explicit associations were assessed. They were debriefed about the study aim before leaving.

Procedures of Experiment 2A and 2B were the same as in Experiment 1.

Analyses

A repeated-measures analysis of variance with within-subject factor Association (odor and healthy vs. odor and sick) and between-subjects factor Order (Order 1 vs. 2) was conducted on the dependent variable reaction times of the 2 critical blocks (3b and 5b). A significant main effect of Association would indicate that either the odor and healthy block or the odor and sick block was completed faster. It was expected that this would be the case for the odor and sick blocks. IAT effects were reported along with main effects of Association. IAT effects are defined as the differences in mean latency between compatible blocks and incompatible blocks (Greenwald et al. 1998). Because we expected to find a dominant odor–illness association, the odor and sick block was considered a compatible block, whereas the odor and healthy block was considered an incompatible block. Consequently, we expected that the mean latency of the compatible block would be shorter compared with the mean latency of the incompatible block, as reflected by positive IAT effect scores (incompatible block minus compatible block). A main effect of Order would indicate that one order (first odor and healthy and then odor and sick vs. first odor and sick and then odor and healthy) would be easier to complete compared with the other order. It was expected that both orders would be equal in terms of their difficulty. A significant interaction effect between Order and Association would demonstrate that switching from one block to the other block would be easier for one order as compared with the other. Here, it was expected that switching from an incompatible block to a compatible block (Order 1) would be easier compared with switching from a compatible block to an incompatible block (Order 2).

IAT effects were additionally calculated with the improved D600 scoring algorithm as proposed by Greenwald et al. (2003; e.g., better resistance to artifacts associated with the speed of responding and to procedural influences). Following their formula, practice blocks were now included in the analyses, error penalties (600 ms) were given, and results were standardized at the level of the subject. The D600 measure was calculated such that higher scores indicated faster performance during odor and sick blocks as opposed to odor and healthy blocks.

The alpha level was set at 0.05. Post hoc tests were conducted after significant interactions between Order and Association. Bonferroni corrections were applied, and alpha levels were set at 0.025. As an indication of effect size, the partial eta square (η_p^2) is reported along with all significant main and interaction effects.

Results

Experiment 1

Data reduction

Following Greenwald et al. (1998), reaction times below 300 ms were recoded to 300 ms ($n = 1$; 0.01%), and reaction times above 3000 ms were recoded to 3000 ms ($n = 36$; 0.30%). Reaction times of incorrect trials were excluded for further reaction time analysis ($n = 715$; 5.93%). This did not apply for the calculation of the D600 measure, where reaction times and incorrect trials were not recoded or excluded. Box plots depicting the distribution of individual mean latencies on the odor and sick block and on the odor and healthy block showed that one subject was a significant outlier on both blocks. Data of this subject (Order 1) were excluded from all analyses.

Reaction times

For the 2 combined blocks (3b and 5b), mean reaction times are shown separately for Orders 1 and 2 in Table 1. A main effect of Association was found: $F_{1,64} = 25.51$, $P < 0.01$, $\eta_p^2 = 0.29$, showing that reaction times were shorter during odor and sick

Table 1 Mean reaction times in milliseconds (SDs between parentheses) for Orders 1 and 2 during phases of Experiment 1 where the concept odor had to be associated with the concepts healthy and sick

Order	Blocks	Reaction times
Order 1[a] (*n* = 34)	Odor and healthy	797.99 (162.27)
	Odor and sick	822.94 (150.98)
Order 2[b] (*n* = 34)	Odor and sick	704.83 (124.27)
	Odor and healthy	875.92 (181.53)

[a]Subjects in Order 1 first had to complete the odor and healthy block and then the odor and sick block.
[b]Subjects in Order 2 first had to complete the odor and sick block and then the odor and healthy block.

blocks, compared with odor and healthy blocks ($mean_{healthy}$ = 836 ms, SD = 175 ms; $mean_{sick}$ = 766 ms, SD = 150 ms, IAT effect = 70). Additionally, a significant interaction effect between Association and Order effect was found: $F_{1,64} = 45.91$, $P < 0.01$, $\eta_p^2 = 0.42$. Post hoc testing demonstrated that subjects in Order 1, who first completed the odor and healthy block, did not show more difficulty after switching to the new combined task where they had to associate odor and sick: $t(33) = -1.13$, $P = 0.27$ (Order 1: $mean_{healthy}$ = 798 ms, SD = 162 ms; $mean_{sick}$ = 823 ms, SD = 151 ms). However, subjects in Order 2 who first completed the odor and sick block, and then the odor and healthy block, demonstrated more difficulty with the new task, $t(31) = 9.31$, $P < 0.025$ (Order 2: $mean_{healthy}$ = 876 ms, SD = 182 ms; $mean_{sick}$ = 705 ms, SD = 124 ms). There was no main effect of Order, $F < 1.0$.

A positive D600 IAT effect was calculated (0.20), demonstrating that subjects associated the concept odor significantly more with the concept sick than with the concept healthy, $t(65) = 3.11$, $P < 0.01$.

Explicit ratings

Explicit ratings of the subjects who completed the experiment differed from the ratings made by the independent student sample preceding the construction of the IAT with regard to the exemplar categories house and odor, $t(65) = -6.01$, $P < 0.01$, showing that odor words were rated as healthier than house words ($mean_{odor}$ = 3.34, SD = 0.42; $mean_{house}$ = 3.10, SD = 0.30). The concept words were rated as equal in terms of healthiness, $t(65) = 1.23$, $P = 0.22$, indicating that both concept names were rated as equally neutral in terms of healthiness ($mean_{odor}$ = 3.42, SD = 0.68; $mean_{house}$ = 3.33, SD = 0.51).

Conclusion

Subjects showed lower reaction times during blocks where they had to associate the concept odor with the concept sick, compared with blocks where they had to associate the concept odor with healthy, reflected by a positive (and significant D600) IAT effect score. Additionally, they demonstrated more difficulty when switching to the odor and healthy block than when switching to the odor and sick block. Thus, subjects were quicker to associate odor with illness than odor with health, which implies a stronger association for the former pairing than the latter.

Although the concept word odor was rated equally neutral as house in terms of its healthiness, the odor exemplar words were rated as healthier compared with the house exemplars. Explicit odor and health associations are apparently different from implicit odor and health associations.

Experiment 2A and 2B

Data reduction

Reaction times below 300 ms were recoded to 300 ms ($n = 1$, 0.01% [Experiment 2A]; $n = 0$ [Experiment 2B]), and reaction times above 3000 ms were recoded to 3000 ms ($n = 6$, 0.05% [Experiment 2A]; $n = 73$, 0.63% [Experiment 2B]). Incorrect trials were excluded for further reaction time analysis (n = 740, 6.32% [Experiment 2A]; n = 838, 7.19% [Experiment 2B]). Box plots depicting the distribution of individual mean latencies on the odor and sick block and on the odor and healthy block showed that one subject was a significant outlier on both blocks. Data of this subject (Order 1, Experiment 2A) were excluded from all analyses.

Reaction times

For the 2 combined blocks (3b and 5b), mean reaction times are shown separately for Orders 1 and 2 and Experiment 2A and 2B in Table 2. For Experiment 2A, a main effect of Association was found, $F_{1,62} = 9.85$, $P < 0.01$, $\eta_p^2 = 0.14$, showing that reaction times were shorter during odor and sick blocks, compared with odor and healthy blocks ($mean_{healthy}$ = 868 ms, SD = 168 ms; $mean_{sick}$ = 809 ms, SD = 183 ms, IAT effect = 59 [Experiment 2A]). During Experiment 2B, reaction times were also lower for the odor and sick combination ($mean_{sick}$ = 946 ms, SD = 263 ms) than for the odor and healthy combination ($mean_{healthy}$ = 962 ms, SD = 212 ms, IAT effect = 16). However, this main effect did not reach significance, $F < 1.0$ (Experiment 2B). A significant interaction effect between Association and Order was found for both experiments, $F_{1,62} = 9.89$, $P < 0.01$, $\eta_p^2 = 0.14$ (Experiment 2A), and $F_{1,62} = 6.47$, $P = 0.01$, $\eta_p^2 = 0.09$ (Experiment 2B). Post hoc testing demonstrated that subjects in Order 1 who first completed the odor and healthy block did not show more difficulty after switching to the new combined task where they had to associate odor and sick, Experiment 2A: $t(32) = -0.01$, $P = 1.00$ (Order 1: $mean_{healthy}$ = 822 ms, SD = 137 ms; $mean_{sick}$ = 822 ms, SD = 163 ms), and Experiment 2B: $t(32) = -1.22$, $P = 0.23$ (Order 1: $mean_{healthy}$ = 943 ms, SD = 214 ms; $mean_{sick}$ = 988 ms, SD = 265 ms). However, subjects in Order 2 who first completed the odor and sick block and then the odor and healthy block demonstrated more difficulty with the new task, Experiment 2A: $t(30) = 4.03$, $P < 0.025$ (Order 2: $mean_{healthy}$ = 918 ms, SD =185 ms; $mean_{sick}$ = 794 ms, SD = 204 ms), Experiment 2B; $t(30) = 2.48$, $P < 0.025$

Table 2 Mean reaction times in milliseconds (SDs between parentheses) for Orders 1 and 2 during phases where the concept odor had to be associated with the concepts healthy and sick, shown separately for Experiment 2A and 2B

Order	Blocks	Reaction times
Experiment 2A (N = 64)		
Order 1[a] (n = 33)	Odor and healthy	821.90 (136.53)
	Odor and sick	822.03 (162.92)
Order 2[b] (n = 31)	Odor and sick	794.47 (203.71)
	Odor and healthy	917.59 (184.81)
Experiment 2B (N = 64)		
Order 1[a] (n = 33)	Odor and healthy	942.50 (213.78)
	Odor and sick	988.40 (265.10)
Order 2[b] (n = 31)	Odor and sick	901.05 (258.19)
	Odor and healthy	983.31 (212.00)

[a]Subjects in Order 1 first had to complete the odor and healthy block and then the odor and sick block.
[b]Subjects in Order 2 first had to complete the odor and sick block and then the odor and healthy block.

(Order 2: $\text{mean}_{\text{healthy}} = 983$ ms, SD = 212 ms; $\text{mean}_{\text{sick}} = 901$ ms, SD = 258 ms). There was no main effect of Order, $F < 1.0$ (Experiment 2A and 2B).

A positive D600 IAT effect was calculated (0.24 [Experiment 2A]; 0.10 [Experiment 2B]), demonstrating that subjects associated odor significantly more with the concept sick than with the concept healthy, Experiment 2A: $t(63) = 4.50$, $P < 0.01$, and Experiment 2B: $t(63) = 2.07$, $P = 0.04$.

Explicit ratings

For Experiment 2A, explicit healthiness ratings of the word exemplars did not differ between the odor words and the clothes words, $t(63) = 0.03$, $P = 0.97$ ($\text{mean}_{\text{odor}} = 3.19$, SD = 0.40; $\text{mean}_{\text{clothes}} = 3.19$, SD = 0.43). The same was true for Experiment 2B, $t(63) = -0.66$, $P = 0.51$ ($\text{mean}_{\text{odor}} = 3.14$, SD = 0.46; $\text{mean}_{\text{sound}} = 3.18$, SD = 0.41). Mean ratings for the concept words did not differ either, $t(63) = 0.80$, $P = 0.43$ ($\text{mean}_{\text{odor}} = 3.27$, SD = 0.63; $\text{mean}_{\text{clothes}} = 3.19$, SD = 0.65 [Experiment 2A]), and $t(63) = 0.59$, $P = 0.56$ ($\text{mean}_{\text{odor}} = 3.39$, SD = 0.70; $\text{mean}_{\text{sound}} = 3.33$, SD = 0.67 [Experiment 2B]).

Conclusion

In both experiments, subjects showed lower reaction times during blocks in which they had to associate the concept odor with sick, compared with blocks where they had to associate odor with healthy, which was also reflected by positive (and significant D600) IAT effect scores. This main effect reached significance during Experiment 2A, but not during Experiment 2B. However, both during Experiment 2A and 2B, subjects demonstrated significantly more difficulty with switching from the odor and sick block to the odor and healthy block than the other way around. These results again suggest an implicit association between the concepts odor and sick: The odor–illness association turns out to be a robust one.

Explicit evaluation of the exemplar and concept words revealed no differences between the categories. These results demonstrate that explicit, intentional evaluations do not reflect implicit ones.

Remarkably, we observed a difference in reaction times between the IAT using the concept sound as a neutral contrast category (Experiment 2B) and the other 2 experiments that used house and clothes as contrast categories (Experiments 1 and 2A). Reaction times in general were approximately 100 ms higher during Experiment 2B compared with the other 2 experiments. This is surprising because experimental hardware and procedures were exactly identical in all experiments. It could be argued that Experiment 2B was harder to complete because the 2 concepts that had to be associated with the health dimension related both to sensory modalities, whereas in the other 2 experiments the control concepts (house and clothes) were not sensory modalities. This would imply that the sensory modality exemplar words are conceptually closer, leading to higher decision times during the categorization process of the exemplar words. Despite this complicating factor, a significant D600 IAT effect was observed for Experiment 2B, indicating a stronger odor–sick association than an odor–healthy association.

Extra analyses to rule out effects of exemplar word selection

The aim of the 3 experiments was to investigate intrinsic odor and health associations. We conducted additional analyses in order to rule out any alternative explanations, related to selection of the exemplar words, which could have accounted for the observed odor–illness association. For example, De Houwer (2001) argues that the IAT primarily measures associations at the level of the categories (in this case: odor, house, clothes, sound, healthy, sick) and that category labels determine IAT effects more strongly than the exemplar words that happen to be selected (i.e., the "label effect"). However, others have argued that exemplar words do in fact influence association strengths (Bluemke and Friese 2006). With this latter argument in mind, we reexamined our exemplar words and found 2 possible confounding factors that could have contributed to the present results. First of all, the sick and healthy exemplar words seemed to differ in terms of their semantic proximity to the concept odor. That is, the sick category consisted of words like fever, flu, and virus, words that seem to have a stronger a priori link to the concept odor than the exemplar words belonging to the healthy category, like fit, well, and vital, which do not have an a priori link to odor. If that is the case, it would explain why we found an implicit odor–illness association rather than an implicit odor–health association. Second, the sick and healthy exemplar words differed in terms of their abstractness: the sick category mostly consisted of concrete words (e.g., flu, headache, virus), whereas the healthy category mostly consisted of abstract words (e.g., well, happy, vital). To account for such influences, reaction time analyses were conducted again, but instead of calculating mean reaction times of all 5 exemplar words per category, only the words "strong" (representing the healthy category) and "weak" (representing the sick category) were included in the analyses because these 2 words are both equal in terms of their semantic proximity to the concept odor (in relation to the first argument), as well as in terms of their abstractness (in relation to the second argument). The same pattern of results appeared. Associations between the concepts odor and weak were stronger compared with associations between odor and strong (Experiment 1: $t(65) = -3.31$, $P < 0.01$; $\text{mean}_{\text{weak}} = 832.02$, SD = 270.76; $\text{mean}_{\text{strong}} = 1008.95$, SD = 427.27; Experiment 2A: $t(63) = 2.36$, $P < 0.05$; $\text{mean}_{\text{weak}} = 864.34$, SD = 389.87; $\text{mean}_{\text{strong}} = 1366.03$, SD = 1610.67; Experiment 2B: $t(63) = 1.76$, $P = 0.08$; $\text{mean}_{\text{weak}} = 1045.20$, SD = 1193.51; $\text{mean}_{\text{strong}} = 1609.30$, SD = 2210.85). In conclusion, after controlling for possible confounding factors, we still found a robust odor–sick association.

Discussion

A robust implicit odor–illness association

Three experiments demonstrated that subjects were quicker to associate odor with sick than odor with healthy and that subjects had more difficulty switching from odor and sick associations to odor and healthy associations than the other way around. Additionally, all 3 experiments showed positive D600 IAT effects, implying a stronger implicit association between the concepts odor and sick than between odor and healthy. This odor–illness association remained visible after controlling for possible confounding factors. It can be concluded therefore that the association between odor and illness is a robust one.

Implicit associations were assessed independently of, and did not match, explicit associations between the concepts. Although the distinction between implicit versus explicit information processing has received attention previously in the odor literature (e.g., Nordin et al. 1995; Degel and Köster 1999; Köster et al. 2002; Dematte et al. 2006), it has not been applied in the context of odors as signals of illness or health (but see: Witthöft et al. 2006).

The finding that people intrinsically associate the concept odor with illness, regardless of self-reported attitudes, raises the question as to the purpose served by such fast and automatic associations between odors and illness, rather than between odors and health.

Better safe than sorry

The implicit odor–illness association probably has its roots in a predisposition for organisms to primarily attend to negative inputs coming from the environment (Pratto and John 1991). This general propensity for negative information can even be found at preattentive levels (Ogawa and Suzuki 2004). From an evolutionary perspective, survival is obviously better served by automatically scanning the environment for possible danger, so as to always be prepared for a "flight" reaction. This same reasoning could be applied to the perception of odors. It is a safer strategy to quickly signal an odorant coming from a potentially poisonous food source or a predator, and thus prevent death, than to signal an odorant coming from a wholesome and nutritious source or a potential mate and thus extend life. From the point of view of signal detection theory (Swets 1964), the criterion for detecting danger should be lower than that for detecting safety, so as to increase one's chances of survival. The present results may reflect such a perceptual strategy.

Besides the tendency to (implicitly) focus attention on negative information in general, certain stimuli or objects seem to have, even in the absence of actual danger, a strong innate association with possible harmful consequences. This biological "preparedness" indicates that certain stimuli which once posed serious threat to our early ancestors are still easily classified as harmful today (Öhman and Mineka 2001). This is reflected by the fact that fears and phobias for spiders, snakes, and water are far more common compared with fears for cars or even guns (Seligman 1971). Because one of the ancient functions of olfaction is to signal possible danger, odors can also be considered such "prepared stimuli," having an innate association with danger and illness, as was demonstrated in the present study (Although it is difficult to determine whether certain odor–illness associations are truly innate or actually based on learned associations: embryo's are already exposed to various chemicals in the womb through food ingestion by the mother and might "learn" in this stage which chemicals should be approached or avoided later on [Mennella et al. 1995].) As a result of this innate odor–illness connection, "newly" learned associations between odors and adverse health effects are in turn more easily established (based on Garcia and Koelling 1966).

Miasma theory: "All smell is disease"

The implicit odor–illness association shown here may have been strengthened by the belief that odors themselves can influence health in a negative way. A theory that has presumably contributed to the spreading and persistence of these beliefs is the Miasma theory. This theory is based on beliefs of Hippocrates (460–377 BC) who suspected a relation between illness and places "where the air is dank and foul." The malodors he referred to were called "miasma." The notion of miasma triggered the theory that diseases may originate due to the inhalation of vapors emitted by rotting animal and vegetable materials (Miller 1962; Bloom 1965; Franco and Williams 2000). Hundreds of years later, in the 19th century, the miasmatists helped to improve health care and living conditions by stating that "all smell is disease,'' consequently motivating people (including governments) to tackle malodor sources and thereby unintentionally improving sanitation (Collins 2006). Although the miasma theory has been abandoned by scientists for quite some time—it has been accepted that bacteria were directly responsible for causing disease with odors being produced as by-products—the belief that odors negatively influence health still seems to resonate today (Dalton 2007).

A dual-processing perspective

As already stated in the introduction of this paper, the distinction between an automatic, effortless, and unconscious information processing system on the one hand and a more controlling, voluntary, and conscious system on the other hand plays a central role in recent models of cognitive information processing in psychopathology (e.g., Mathews and Mackintosh 1998; Brown 2004; Bar-Heim et al. 2007). With respect to olfaction, automatically activated odor–illness associations could facilitate olfactory information processing by giving it a ''jump start.'' Still, bottom-up processing of odor characteristics and contextual influences can suppress or rectify reactions based on such initial associations. This distinction seems useful as an extension of the information-processing model of chemosensory perception mentioned earlier (Dalton and Hummel 2000; Smeets and Dalton 2005). From such a dual-processing perspective, it could be hypothesized that the foundation for the development and maintenance of odor-induced health symptoms—referring to the symptoms that cannot be clarified by toxicological models—should be searched in an imbalance between the 2 information processing systems. Based on the analog with signal detection theory introduced earlier, classifying harmless odors as dangerous could be equated with the false alarms that unavoidably accompany low criteria. Alternatively, it is possible that controlled cognitive processes are insufficiently capable of suppressing automatic avoidance associations or reinforce them. This perspective may foster interesting new hypotheses for future research to improve our understanding of unexplained illness from exposure to environmental odors, as in people suffering from MCS or IEI. For example, it could be hypothesized that individuals who suffer from IEI have stronger implicit associations between odors and sick than healthy individuals, that individuals with strong odor–illness associations interpret ambiguous/unknown odors as more threatening compared with individuals with less strong associations, or that those who have stronger odor–illness associations produce or report more adverse health effects than controls.

Other odor associations

In closing, we of course acknowledge that the function of the sense of smell goes beyond warning for possible danger and that associations between the concept odor and concepts other than illness may well be of an approach kind. With respect to food or eating, odors signal nutritious and appealing food products, and IATs will probably also reveal positive associations with the concept odor in such contexts. In animals, odors play a significant role in demarcation of territory or drive mating behavior, which predict avoidance and approach, respectively. Unfortunately, it is still very hard to conduct IATs among animals (but for exciting new IAT possibilities, see Bones and Johnson 2007).

Funding

Netherlands Organization for Scientific Research (NWO 452-03-334 to M.A.M.S).

Acknowledgements

The authors would like to thank Martin Laverman for his technical contribution to this research and Jantine Slotboom, Rik Vos, and Margreet Worm for their contribution to the data acquisition phase of Experiment 1.

References

Bargh JA. 1989. Conditional automaticity: varieties of automatic influence in social perception and cognition. In: Uleman JS, Bargh JA, editors. Unintended thought. New York: Guildford Press. p. 3–51.

Bar-Heim Y, Lamy D, Pergamin L, Bakermans-Kranenburg M, IJzendoorn MH. 2007. Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychol Bull. 133:1–24.

Bloom BL. 1965. The "medical model", miasma theory, and community mental health. Community Ment Health J. 1:333–338.

Bluemke M, Friese M. 2006. Do features of stimuli influence IAT effects? J Exp Soc Psychol. 42:163–176.

Bones AK, Johnson NR. 2007. Measuring the immeasurable: or "could Abraham Lincoln take the Implicit Association Test? Perspect Psychol Sci. 2:406–411.

Brown RJ. 2004. Psychological mechanisms of medically unexplained symptoms: an integrative conceptual model. Psychol Bull. 130:793–812.

Bulsing PJ, Smeets MAM, van den Hout MA. 2007. Positive implicit attitudes towards odor words. Chem Senses. 32:525–534.

Cavalini PM, Koeter-Kemmerling LG, Pulles MP. 1991. Coping with odour annoyance and odour concentrations: three field studies. J Environ Psychol. 11:123–142.

Collins C. 2006. Causes of fevers: miasma versus contagion. Biomed Sci [Internet]. [cited 2007 Sep 13]. Available from: http://www.ibms.org/index.cfm?method=science.history_zone&subpage=history_fevers.

Dalton P. 2007. What is the "Mal" in malodor? In: Rankin K, Christensen C, (Chair). Human axillae: why? Symposium conducted at the XXIXth annual meeting of the association for chemoreception sciences, Sarasota, FL. April 25–29, 2007.

Dalton P, Hummel T. 2000. Chemosensory function and response in idiopathic environmental intolerance. Occup Med. 15:539–556.

Dalton P, Wysocki CJ, Brody MJ, Lawley HJ. 1997. The influence of cognitive bias on the perceived odor, irritation and health symptoms from chemical exposure. Int Arch Occup Environ Health. 69:407–417.

Das-Munshi J, Rubin G, Wessely S. 2007. Multiple chemical sensitivities: a systematic review of provocation studies. J Allergy Clin Immunol. 188:1257–1264.

Dayal HH, Baranowski T, Li Y, Morris R. 1994. Hazardous chemicals: psychological dimensions of the health sequelae of a community exposure in Texas. J Epidemiol Community Health. 48:560–568.

Degel J, Köster EP. 1999. Odors: implicit memory and performance effects. Chem Senses. 24:317–325.

De Houwer J. 2001. A structural and process analysis of the implicit association test. J Exp Soc Psychol. 37:443–451.

De Houwer J. 2002. The implicit association test as a tool for studying dysfunctional associations in psychopathology: strengths and limitations. J Behav Ther Exp Psychiatry. 33:115–133.

De Houwer J. 2006. What are implicit measures and why are we using them? In: Wiers RW, Stacy AW, editors. The handbook of implicit cognition and addiction. Thousand Oaks (CA): Sage Publishers. p. 11–28.

De Jong P, Pasman W, Kindt M, van den Hout MA. 2001. A reaction time paradigm to assess (implicit) complaint-specific dysfunctional beliefs. Behav Res Ther. 39:101–113.

Dematte LM, Sanabria D, Spence C. 2006. Olfactory-tactile compatibility effects demonstrated using a variation of the implicit association test. Acta Psychol. 124:332–343.

Devriese S, Winters W, Stegen K, Van Diest I, Veulemans H, Nemery B, Eelen P, Van de Woestijne K, Van den Bergh O. 2000. Generalization of acquired somatic symptoms in response to odors: a pavlovian perspective on multiple chemical sensitivity. Psychosom Med. 62: 751–759.

Franco DA, Williams CE. 2000. "Airs, waters, places" and other Hippocratic writings: inferences for control of foodborne and waterborne disease. J Environ Health. 62:9–14.

Garcia J, Koelling RA. 1966. Relation of cue to consequence in avoidance learning. In: Domjan M, Burjhard B, editors. The principles of learning and behavior. Pacific Grove, CA: Brooks/Cole Publishing Company. p. 76–78.

Gawronski B, LeBel EP, Peters KR. 2007. What do implicit measures tell us? Scrutinizing the validity of three common assumptions. Perspect Psychol Sci. 2:181–193.

Greenwald AG, McGhee DE, Schwartz JLK. 1998. Measuring individual differences in implicit cognition: the implicit association test. J Pers Soc Psychol. 74:1464–1480.

Greenwald AG, Nosek BA, Banaji MR. 2003. Understanding and using the implicit association test: i. an improved scoring algorithm. J Pers Soc Psychol. 85:197–216.

Köster EP, Degel J, Piper D. 2002. Proactive and retroactive interference in implicit odor memory. Chem Senses. 27:191–206.

Leventhal H, Meyer D, Nerenz D. 1980. The common sense representation of illness danger. In: Rachman S, editor. Med psychol. New York: Pergamon Press. p. 7–30.

Mathews A, Mackintosh B. 1998. A cognitive model of selective processing in anxiety. Cognit Ther Res. 22:539–560.

Mennella JA, Johnson A, Beauchamp GK. 1995. Garlic ingestion by pregnant women alters the odor of amniotic fluid. Chem Senses. 20: 207–209.

Miller G. 1962. "Airs, waters and places" in history. J Hist Med Allied Sci. 17:129–140.

Nordin S, Monsch AU, Murphy C. 1995. Unawareness of smell loss in normal aging and Alzheimer's disease: discrepancy between self-reported and diagnosed smell sensitivity. J Gerontol B Psychol Sci Soc Sci. 50:187–192.

Ogawa T, Suzuki N. 2004. On the saliency of negative stimuli: evidence from attentional blink. Jpn Psychol Res. 46:20–30.

Öhman A, Mineka S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. Psychol Rev. 108:483–522.

Pratto F, John OP. 1991. Automatic vigilance: the attention-grabbing power of negative social information. J Pers Soc Psychol. 61:380–391.

Reiser BJ, Black JB, Abelson RP. 1985. Knowledge structures in the organization and retrieval of autobiographical memories. Cognit Psychol. 17:89–137.

Ross PM, Whysner J, Covello VT, Kuschner M, Rifkind AB, Sedler MJ, Trichopoulos D, Williams GM. 1999. Olfaction and symptoms in the multiple chemical sensitivities syndrome. Prev Med. 28:467–480.

Schiffman SS, Walker JM, Dalton P, Lorig TS, Raymer JH, Shusterman D, Williams CM. 2000. Potential health effects of odor from animal operations, wastewater treatment, and recycling of byproducts. J Agromedicine. 7:7–81.

Schiffman SS, Williams CM. 2005. Science of odor as a potential health issue. J Environ Qual. 34:129–138.

Seligman MEP. 1971. Phobias and preparedness. Behav Ther. 2:307–320.

Shusterman D. 2001. Odor-associated health complaints: competing explanatory models. Chem Senses. 26:339–343.

Smeets MAM, Dalton PH. 2005. Evaluating the human response to chemicals: odor, irritation and non-sensory factors. Environ Toxicol Pharmacol. 19:581–588.

Swets JA. 1964. Signal detection and recognition by human observers. New York: Wiley.

Witthöft M, Gerlach AL, Bailer J. 2006. Selective attention, memory bias, and symptom perception in idiopathic environmental intolerance and somatoform disorders. J Abnorm Psychol. 115:397–407.

Accepted September 17, 2008