Chem. Senses 26: 267–280, 2001

Implicit Learning and Implicit Memory for Odors: the Influence of Odor Identification and Retention Time

Joachim Degel, Dag Piper[1] and Egon Peter Köster

University of Utrecht, The Netherlands and [1]Institut Européen des Sciences du Goût, Dijon, France

Correspondence to be sent to: Egon Peter Köster, University of Utrecht, Jan Van Scorelstraat 5, NL-34583 CK Utrecht, The Netherlands. e-mail: ep.koster@wxs.nl

Abstract

One hundred and fifty-two subjects, divided into eight groups, were exposed to a room with a low concentration of either orange or lavender and to an odorless room. In a careful double-blind procedure, neither the subjects nor the experimenters were made aware of the presence of the odors in the experimental conditions. Later they were asked to indicate how well each of 12 odor stimuli, including the experimental and control odors, befitted each of 12 visual contexts, including the exposure rooms. At the end of this session they rated the pleasantness and the familiarity of the odors, and identified them by name. Finally they were debriefed and asked specifically whether they had perceived the experimental odors anywhere in the building. The results of four subjects who answered positively to the latter question were omitted. The results confirm the earlier finding that non-identifiers implicitly link odor and exposure room, whereas identifiers do not show such a link. It is suggested that episodic information is an essential constituent of olfactory memory and that its function is comparable to that of form and structure in visual and auditory memory systems.

Introduction

According to the practical distinction made by Buchner and Wippich (Buchner and Wippich, 1998), *implicit learning* refers to 'the [incidental] acquisition of knowledge about the structural properties of the relations between [usually more than two] objects or events'. Since the acquisition is incidental and non-intentional—subjects are not informed about the existence of the relations, let alone instructed to search for them—implicit learning is often described as 'phenomenally unconscious', even if the test situation may require intentional retrieval in some cases. *Implicit memory*, in contrast to implicit learning, refers to 'situations in which effects of prior experiences can be observed despite the fact that the participants are not instructed to relate their current performance to a learning episode' (Buchner and Wippich, 1998). Therefore, implicit memory is also described as phenomenally unconscious.

In an earlier study Degel and Köster (Degel and Köster, 1999), using a method already tentatively explored (Degel and Köster 1998), combined both implicit learning and implicit memory in a paradigm for the study of implicit odor memory. Participants were subjected to three short psychological tests in a room that either was odorized with a barely perceptible concentration of one of two odors or was not scented at all (control). Neither the subjects nor the persons who administered the tests were informed about the possible presence of an odor or about any relationship of the experiment to odor. After completing the tests, the subjects took part in an experiment on the taste of cookies that was carried out in a sensory laboratory and lasted 30 min. At the end of this experiment, they were invited to still another room where they sat in front of a screen on which the pictures of 12 rooms, including the room in which they had made the psychological test, were shown one by one. For each of these pictures the subjects were asked to indicate on a rating scale how well each of a set of 11 odors and one non-odor control would fit to that room. In all cases subjects who had been exposed to a given odor in a given test room rated the fit of that odor to that room higher than subjects who had not been exposed to odor in that room. At the end of the final session, the subjects were asked to rate the pleasantness and familiarity for each of the odors in the set in front of them and to indicate where and when they had smelled the odor before entering the room in which they were at present. Even after insistent and rather suggestive questioning, only one of the subjects remembered having smelled the experimental odor in the laboratory. Finally, they were asked to identify the 12 odors in the set in front of them by name. The subjects were subsequently divided into two groups: those who could identify the odor by its name and those who could not, and the data were reanalyzed for each of these groups. Thus, it was accidentally shown that those who could identify an odor by name did not show any implicit memory effect, whereas those who did not know the name did. In fact the rating of fit of the odor to the test room by the identifiers was even slightly (though not significantly) lower than by the group who had never been in that room. Since this striking finding was accidental and occurred only for one odorous substance (the other one being identified by name by only one subject), it was decided to repeat this experiment with the same odor but with different subjects and with another odor that was also recognized by name by ~50% of the population. Furthermore, it was decided to measure the effects more directly by comparing the exposure to one of the experimental odors with that to the non-odorous control condition with a within-subjects design.

An earlier attempt to study implicit memory for odors (Schab and Crowder, 1995) has been critically discussed by Degel and Köster (Degel and Köster, 1998). It was argued that Schab and Crowder, who used odors and their names explicitly in the learning phase, did not really investigate implicit odor memory at all. In fact, even for what they considered to be implicit memory for odors they found almost no evidence. Also in 1995, Olsson and Cain published a short note on a priming experiment (Olson and Cain, 1995). Six odors were presented monorhinally in a priming session in which the subjects were asked when they had last smelled these odors. Then, in a subsequent session, they received these odors again among six other (distractor) odors and were asked to 'press a button when they "realized" what they were smelling, but not to give names for the stimuli'. Shorter reaction times (positive priming effects) were found for the primed odors, but only if they had been presented to the left nostril. In a separate odor (explicit) recognition experiment with monorhinal presentation no such left-nostril advantage was found. Rightly, no mention of implicit memory was made, although the priming results were opposed to the results of the test of explicit memory (recognition). If the study of implicit memory was intended [as later implied (Olsson, 1999)], the choice of the priming procedure (asking to search memory for the last encounter with the odor) was a very odd choice which, by its emphasis on remembering, most probably prevented truly implicit measures of memory in the final phase.

Since then, Olsson, using the same priming procedure, reported the outcome of a repetitive priming experiment based on latency of identity rejection, which showed a clear and positive priming effect for odors that could not be identified and a smaller, but significant, negative priming effect for identified odors (Olsson, 1999). Although Olsson does not discuss this possibility, it seems that in his case there is also evidence that knowing the name of an odor has seriously interfered with the establishment, retention or retrieval of an (implicit?) odor memory. Nevertheless there are essential differences between the two types of experiments. Contrary to Degel and Köster, Olsson used clearly perceptible odors in the priming phase of his experiment, and in the test phase he asked his subjects to distinguish between odors among which were the previously presented ones, whereas Degel and Köster (Degel and Köster, 1998, 1999) asked the subjects to rate the fit of hitherto unnoticed odors to images of rooms and other contexts. Furthermore, in Degel and Köster's experiment the retention interval was probably longer, since the subjects performed another experiment between the two phases, thus imposing a filled retention interval of 60 min, although Olsson also allowed for (unspecified) retention time by asking his subjects to fill out a questionnaire and giving them experience with two comparison stimuli.

In the present experiment, the retention time is varied by submitting half of the subjects to a non-odorous control condition before the priming phase and the other half after the priming phase. In this way a systematic difference in retention time of an additional hour is introduced.

Materials and methods

Participants

A total of 152 subjects, citizens of Dijon, France, comprising 77 men (average age ± SD 23.0 ± 2.64 years) and 75 women (22.9 ± 2.49 years), participated in the study. The subjects were recruited by an independent agency by telephone. They were invited to participate in psychological tests and to take part in an experiment on basic taste appreciation. (For details of the double-blind design, briefing, debriefing and execution of the test see Procedure below). The agency was also asked to provide interviewers with experience in psychological testing. These interviewers were also left unaware of the presence of odors. The subjects were paid FF 150 for their participation by the external agency and were randomly split into eight groups according to the test design displayed in Table 1. Some of these groups were not filled, because a few people did not appear (see Table 1).

After the experiments, four subjects were omitted from the analysis of the main data set, because an extensive debriefing at the end of the experiment revealed that they had been aware of the fact that there was an odor in the test rooms. All others remained unaware of the presence of an odor even after extensive questioning. The distribution of the remaining 'unaware' group is also given in Table 1.

Test rooms

Three rooms were used as test rooms. Rooms A and B were used for the odor exposures and were laboratory rooms different in form, appearance and furniture. Room C, a circular conference room with large windows, was used in the odor-free control condition. The differences between the rooms were necessary to make them recognizable for the third phase in the experiment where the implicit memory of the odor–room combinations was tested.

Odors

Orange (sweet orange, Brasilia, *Citrus aurantium dulcic*) and

Table 1 Experimental groups and conditions with the average age and number of subjects in each gender group

Group	Learning condition 1	Learning condition 2	Mean age (*n*)		Remaining subjects (*n*)	% identification (*n*)	
			Male	Female		Lavender	Orange
1	RaLa	RcCo	24.2 (10)	24.3 (10)	20	55.0 (11)	30.0 (6)
2	RaOr	RcCo	24.1 (10)	24.1 (10)	20	45.0 (9)	15.0 (3)
3	RbLa	RcCo	21.8 (9)	21.7 (10)	18	66.7 (12)	33.3 (6)
4	RbOr	RcCo	23.4 (8)	23.1 (9)	17	64.7 (11)	41.2 (7)
5	RcCo	RaLa	22.4 (12)	22.1 (8)	18	61.1 (11)	27.8 (5)
6	RcCo	RaOr	21.7 (9)	22.0 (10)	19	57.9 (11)	52.6 (10)
7	RcCo	RbLa	23.8 (8)	23.9 (10)	18	50.0 (9)	44.4 (8)
8	RcCo	RbOr	22.9 (11)	22.0 (8)	18	50.0 (9)	55.6 (10)
Total			23.0 (77)	22.9 (75)	148	56.1 (83)	37.2 (55)
Total *n*			152		148	138	

Ra, Rb, Rc = room A, room B, room C; O = odor; La = lavender; Or = orange; Co = control (no odor). The percentage of the subjects in each group that identified the experimental odors at the end of the last session and the number of remaining subjects after the results of the four subjects who had detected the odor in the test rooms were omitted from the data are given (see Procedure and Results).

Lavender (Lavender, Mont Blanc, France, *Lavandula angustifolia*) were chosen as the odors in the experimental rooms. According to Degel and Köster (Degel and Köster 1999) and Sulmont *et al*. (submitted for publication), both odors can be identified by just over half of the French population. The concentrations chosen were just above detection threshold to make sure that only very few of the subjects would consciously notice them. This was checked by extensively debriefing eight people immediately after they had been in the odorized rooms for normal business for at least 10 min. None of them had noticed the odor. The odors were injected into the ventilation system of the room with short pulses at regular 5 min intervals in order to prevent complete adaptation to them. After each session the rooms were aired and when necessary the odor was changed according to the schedule. This took 5 min and when the new groups entered after 30 min odor equilibrium was re-established.

For the rating of fit, pleasantness and familiarity, 12 jars, equal in size and color marked by a random three-digit code, were presented at the end of the experiment. Of these jars, 11 contained an odor in a weak, but suprathreshold concentration and one jar contained no odor at all (see Table 2). Subjects were told that each jar contained an odor, although sometimes in such a weak concentration that they might not smell anything. The positions of the jars in the presentation series for the rating were systematically varied over all subjects.

Table 2 Odors used in the rating of fit between odor and environment

Odor name	Pleasantness[a]		Familiarity[a]		Correct identification[b] (%)
	Mean	SD	Mean	SD	
Lavender	57.0	30.1	69.1	29.9	57.2
Aftershave	55.4	22.3	64.9	25.6	9.9
Cedarwood	34.2	25.7	45.7	32.7	2.6
Jasmine	30.5	27.5	34.5	30.8	2.6
Coffee	38.7	33.8	66.9	36.1	63.2
Laundry	52.9	25.6	50.1	31.9	21.7
Leather	26.0	25.0	37.1	32.6	17.1
Sandalwood	37.3	26.7	32.5	28.7	2.6
Thyme	25.2	27.1	34.2	31.5	5.9
Orange	72.1	22.6	71.1	26.3	38.2
Peach	73.0	24.6	63.6	28.6	8.6
Control	62.4	23.2	67.7	30.1	75.7

[a]Pleasantness and familiarity as judged by the subjects at the end of the experiment (maximum = 100).

[b]Correct identification of the odor at the end of the experiment, $n = 152$.

Visual materials

In the rating of fit phase, 12 pictures were used showing the three test rooms and different surroundings from everyday life (the counter hall of a bank, an office with an empty desk, the women's department of a clothing store, experimental room A, a canteen room, a train lavatory, a kitchen, experimental room B, an office with a crowded desk, a large train compartment, a bank advisory room and the control room C). None of them contained a visual cue for an odor. The above sequence of the pictures was kept constant for all subjects and had been chosen at random with the restriction that the pictures of the test rooms were at the same distance from each other (positions 4, 8 and 12).

Test material

During the odor exposure a letter-counting concentration test and then a mathematical test were administered. In the two sessions in which the subjects participated, different versions of these tests were used. Since the results have been combined with those of the subjects in another, very similar experiment and will be submitted for publication separately, they will not be described here.

Procedure

A double-blind procedure was used. An independent agency recruited both the subjects and the interviewers that administered the psychological tests in the first phase of the experiment. The agency was told that we wanted to calibrate two versions of two psychological tests in order to be able to use them later as pre- and post-experimental measurements in research on the long-term effects of different health foods on mental capabilities. Furthermore, we informed them that there would be a taste experiment with unflavored yogurts varying in sweetness and asked them to explain to the subjects that it was an experiment about the role of basic tastes. Odor was never mentioned. The interviewers were told the same story and were instructed to keep a rigorous time schedule because, in view of the calibration, it was important to keep the circumstances of testing exactly the same for the two versions. The order of these two versions was systematically varied.

The interviewers were never told anything about odor. During their debriefing at the end of the experiments, it became clear that they were convinced of the proposed aim of the study (calibration of test versions) and that even they, who had been in and out of the experimental rooms during all six days of the experiment, had not noticed the odors or the change of odors in the rooms over the days. When then confronted with the odorized rooms after debriefing, they nevertheless could perceive the odors and indicate which odor was in which room.

In the intervals between sessions the interviewers returned with their subjects to the spacious main hall of the institute, where they waited for new subjects or for the subjects interviewed by another experimenter. They never entered any other part of the building and had no contact with any of the other experimenters. During the period between test sessions one of the authors immediately aired the rooms and changed the odor when necessary (see Odors above).

When they arrived, the subjects of a group were assigned for performance testing to a room that was scented with either an ambient odor [lavender (La) or orange (Or)] or no odor [control (Co)] respectively (learning condition 1; see Table 1). The subjects were not told that odors played a role in the study or that odors were present in the rooms. They were, however, told that the psychological tests for which they had been invited were divided over two equivalent sessions to check their reliability and that they would participate in the experiment on basic taste appreciation between these two sessions and after the second session.

The subjects participated in groups with a maximal size of 10. After meeting the interviewer, the group was taken to the test room and had to wait for 5 min before the interviewer gave an instruction and started the test. The next test started exactly 5 min after completion of the first one. The total duration of the tests, including the initial 5 min waiting time and the two instructions (2 min each) as well as the 5 min break between the two tests, was 30 min.

After the first part of the psychological tests the subjects were collected in the hall by another experimenter (not one of the authors) and brought to the (odor-free) sensory analysis facility with separate booths, where they took part in the yogurt-tasting experiment. Here they had to indicate their liking for the sweetness of a series of the same yogurts which were just noticeably different in sweetness. In this procedure there was nothing (neither in the food nor in the environment) that drew the attention to odor or flavor. After the experiment, they were brought back to the hall by the same experimenter who had collected them from there. In the hall they met their interviewer for the second part of the psychological test (learning condition 2; Table 1). In order to control for interviewer effects, the three interviewers were rotated systematically over the subjects in the eight experimental groups. Thus, each interviewer saw an almost equal number of men and women in each group and in each test room.

The same procedure took place after the second part of the psychological test, but when the subjects returned after the second taste experiment, they were collected by yet another experimenter, who took them to another floor of the building, where they were told that there was a trend in the market for the use of odors in different environments and asked to help 'finding odors that would fit well to different environments' (12 pictures among which were those of the two rooms they had been in during the two phases of the psychological testing experiment). For this rating the subjects were seated in groups of maximum 10, separated by side walls in front of a screen on which the images of different contexts were projected. They each had a set of 12 jars in front of them. The subjects were instructed to rate how well each odor fitted in each of the contexts shown. The rating was made on a 100 mm visual analog scale with the end labels 'does not fit' and 'fits'. After rating the fit of all odors to a given context, a new context was shown on the screen. To neutralize the odor perception and cause a temporal delay between the ratings of fit, the subjects were told to smell at the inside of their own arm after each rating. In order to reduce olfactory adaptation there was a 45 s interval before the next visual context was shown.

At the end of this session and after an interval of 5 min, the subjects were asked to rate the 12 odors for pleasantness and familiarity on a 100 mm visual analog scale with the end labels 'very unpleasant' and 'very pleasant' or 'very unfamiliar' and 'very familiar' respectively.

They were next asked to identify the odors and then debriefed extensively. For odor identification only an exact definition of an odor's name (lavender, orange or no odor) was counted as a correct answer. Near-veridical labels (tangerine or citrus for orange, bed linen for lavender) were not accepted. This did not pose a real problem, because such labels were very rare (<2%) in the case of the rather well-known experimental odors, probably due to the fact that the subjects had smelled them already 12 times before being asked to identify them. Furthermore, it is unclear whether a near-veridical label does not leave the subject with the same amount (or even more) of uncertainty as a truly non-veridical or no label.

In the debriefing subjects were asked explicitly 'When and where did you smell this odor last?' and 'Did you not smell it today elsewhere in this building?'. After this debriefing, the subjects filled out a questionnaire about the vividness of their odor imagination and then left the building via a separate exit to avoid the experimental area and the other groups of subjects.

Statistical analysis

The analysis was performed with SPSS for Windows, Version 6.1.3 (SPSS, Inc., 1994).

For the rating of fit, normalized means were calculated. Normalization was performed by dividing the rating of fit for each individual odorant-context combination by the mean of the 12 contextual ratings for that same odor by the same subject. Thus, values below 1.00 express a rating below the average rating for that odor and values above 1.00 express a rating above the average. The normalization served two purposes. In the first place, it reduced the variance in the data that was due to the different scaling behavior of the subjects, some of whom used the high end of the scale, whereas others used only low values. Secondly, and related to the first point, it gave an equal weight to each of the participants irrespective of their use of high or low numbers. By expressing the individual ratings in units based on their mean, the relative position of the judgements remains unaffected. Nevertheless, since this type of normalization has the disadvantage that people who on average give high ratings are less likely to get normalized ratings that deviate strongly from 1.00 than people who frequently give low ratings, the average rating levels of the identifier group and the non-identifier group were compared as a control measurement. No significant differences between the mean rating levels or the SDs of these two groups were found. For the ratings of pleasantness and familiarity the means per odor were calculated over all subjects. As indicated above, for identification the number of veridical labels was counted and the percentage of correct identifications calculated. An additional analysis, in which the few persons who produced near-veridical labels were moved to the identifier group, showed no difference in the results.

In the analysis of the ratings of fit, analysis of variance (ANOVA) was used. In order to check whether the results confirmed the findings of the previous experiment (Degel and Köster, 1999), first of all a 2 × 2 × 2 × 4 × 2 ANOVA [room (A, B) × odor (La, Or) × identification (identifier, non-identifier) × exposure condition (RaLa, RaOr, RbLa, RbOr) × learning session (1, 2)] was carried out on the rating of fit for the experimental odors, with a special interest in the three-way interaction between room, exposure condition and identification. If odor was not a main factor and if this three-way interaction was significant—the non-identifiers showing higher ratings of fit for the rooms in which they were exposed than to the other rooms, and the identifiers not showing such a dependence on exposure condition—then the results of the previous experiment would be confirmed with a new group of subjects and for both odors. ANOVA was also used in the analysis of the pleasantness and familiarity data. When effects were found further analysis was made using Bonferroni tests. Correlation (Pearson) was used to show the relationships between pleasantness, familiarity and ratings of fit.

Results

Pleasantness

The ratings of pleasantness in Table 2 show peach and orange to be the most pleasant odors in the set. Of the experimental odors, orange was judged to be more pleasant than lavender [$T(151)=5.53$, $P < 0.001$] and the control odor [$T(144) = 3.50$, $P = 0.001$]. The non-odorous control occupied a middle position between orange and lavender. Significant gender differences were found for the pleasantness ratings of the control odor [$T(143) = -2.06$; $P < 0.05$] and marginally for those of leather [$T(150) = 1.89$; $P < 0.06$]. The latter was judged to be slightly more pleasant by men. The odor-free control was more pleasant to female subjects. Exposure had no influence on the pleasantness of the odors, i.e. there was no difference in the pleasantness judgements for an odor (lavender or orange) between the groups who had been exposed to the odor during the first phase of the experiments and those who had not. This was also true for both the identifiers and the non-identifiers of that particular odor.

Familiarity

Orange was the most familiar odor, followed by lavender and the control odor, although none of the differences was significant. No significant gender differences in the familiarity ratings were found. As in the case of pleasantness, exposure had no significant influence on the familiarity of the odors. This was again true for both the identifiers and the non-identifiers of that particular odor, although for the non-identifiers higher ratings of familiarity were always found in the exposed groups (lavender: exposed = 53.4 ± 35.2, non-exposed = 48.1 ± 31.2; orange: exposed = 69.0 ± 30.1, non-exposed = 61.3 ± 26.0) than in the non-exposed groups, whereas this was not the case for the identifiers.

Pleasantness and familiarity

Correlation analysis over all subjects ($n = 152$) and odors ($n = 12$) showed a positive correlation between pleasantness

Table 3 Differences in pleasantness and familiarity ratings for the two experimental odors and the control odor given by the identifiers and non-identifiers of these odors

Odor	Non-identifiers		Identifiers		Significance main effect ANOVA	
	Mean	SD	Mean	SD	*F* (*df*)	*P*
Lavender						
Pleasantness	39.2	27.2	70.3	24.9	53.1 (1,148)	<0.001
Familiarity	50.6	33.0	82.7	17.9	56.2 (1,147)	<0.001
Orange						
Pleasantness	68.0	22.9	78.7	20.6	8.50 (1,148)	<0.01
Familiarity	65.2	28.1	81.0	19.7	14.1 (1,147)	<0.001
Control (no odor)						
Pleasantness	58.8	21.4	63.6	23.8	1.56 (1,141)	n.s.
Familiarity	53.8	32.7	72.3	27.8	10.7 (1,140)	<0.01

and familiarity for each of the odors (range r = 0.277–0.634 all P < 0.02; median = 0.46). Subsequent analysis showed the median of the correlation to be somewhat higher for women (median = 0.51) than for men (median = 0.43).

Identification

The odor of coffee was identified correctly by 63.2% of the subjects, followed by lavender (57.2%) and orange (38.2%) (see Table 2). The control odor was correctly identified as 'no odor' by 75.7% of the subjects. There was no relationship between gender and odor identification. Furthermore, exposure to the odors of lavender or orange during the first phase of the experiments had no significant influence on the identification of these odors in the last phase, i.e. the numbers of identifiers did not differ between the exposed and the non-exposed groups for either of the two odors (lavender: χ^2 = 0.108, df = 1, P > 0.70; orange: χ^2 = 0.455, df = 1, P > 0.50).

Identification and pleasantness

A 2 × 2 ANOVA [gender (male, female) × identification (non-identifier, identifier)] was carried out on the pleasantness data for all odors. A significant main effect was found for the factor identification [F(1,1808) = 187.1; P < 0.001 (12 missing values); non-identifiers = 41.5 ± 30.1; identifiers = 63.3 ± 27.9]. No gender effect or interaction was found. A 2 × 2 ANOVA (gender × identification) was also carried out specifically on the pleasantness for the experimental odors lavender and orange. Here also, only main effects for identification were found (see Table 3). A similar ANOVA on the pleasantness of the non-odorous control odor did not show any significant effect or interaction.

Identification and familiarity

A 2 × 2 ANOVA (gender × identification) was also conducted on the familiarity data for all odors. Again a significant main effect of identification was found [F(1,1801) = 368.2; P < 0.001 (19 missing values); non-identifiers = 44.9 ± 32.8; identifiers = 77.1 ± 24.4]. No gender effect or interaction was significant.

A 2×2 ANOVA (gender × identification) was also carried out specifically on the familiarity data for the experimental odors lavender and orange. Again, only main effects for identification were found (see Table 3). A similar ANOVA on the familiarity of the non-odorous control odor showed only a significant identification effect (see Table 3).

Table 4 Main effects and interactions of the 2 × 2 × 2 × 4 × 2 ANOVA [room (A, B) × odor (La, Or) × identification (identifier, non-identifier) × exposure condition (RaLa, RaOr, RbLa, RbOr) × learning session (1. 2)

Main effect or interaction	*F* (*df*)	*P*
Room	27.1 (1,528)	<0.001
Learning session	7.84 (1,528)	<0.01
Identification	5.82 (1,528)	<0.05
Exposure condition	2.29 (3,528)	<0.08
Room × odor	8.16 (1,528)	<0.01
Room × exposure condition	3.81 (3,528)	<0.05
Room × exposure condition × identification	5.69 (3,528)	<0.001

Ratings of fit in the experimental groups

In order to test implicit memory, the results obtained in conditions in which the subjects were confronted with a given odor–room combination were selected. Thus the rating of fit values for the groups 1–8 were analyzed with a 2 × 2 × 2 × 4 × 2 ANOVA (room × odor × identification × exposure condition × learning session). The results are shown in Table 4.

Main effects were found for room (room A = 0.62 ± 0.66; room B = 0.94 ± 0.88), identification (identifier = 0.70 ± 0.73; non-identifier = 0.85 ± 0.84) and learning session

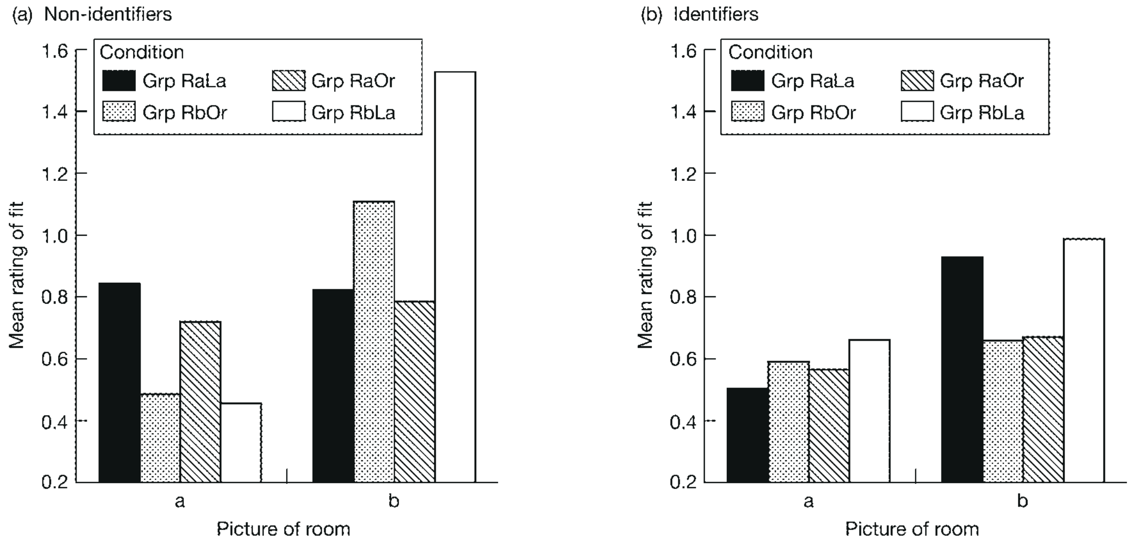

Figure 1 Three-way interaction of the factors condition, identification and room and their influences on the rating of fit of the experimental odors to the experimental rooms.

(session 1 = 0.70 ± 0.79; session 2 = 0.87 ± 0.79). The factor exposure condition showed only a marginal effect. Odor was not a significant main factor, but a clear two-way interaction between room and odor was found. Lavender (mean = 0.72 ± 0.75) showed a better fit to the picture of room A than orange (mean = 0.52 ± 0.54), while the reverse was true for the picture of room B, where lavender (mean = 0.87 ± 0.85) had a lower fit than orange (mean = 1.01 ± 0.91).

However, by far the most important result in the context of this study (see statistical analysis) is the three-way interaction between room, exposure condition and identification, which is illustrated in the Figure 1a,b.

From this figure it can be seen that the non-identifiers showed a larger fit to the pictures of the rooms in which they had been exposed to the odor (exposure condition RaLa and RaOr in room A and conditions RbOr and RbLa in room B) than to the other rooms, indicating that implicit memory for the odor–room combination did take place, whereas such a systematic relationship between the degree of fit to a room and the exposure condition was not found for the identifiers.

In view of this difference between identifiers and non-identifiers, two separate 2 × 2 × 4 × 2 ANOVAs (room × odor × exposure condition × learning session) were carried out for these two groups.

Non-identifiers

For the non-identifiers the factor room was a significant main effect [$F(1,284) = 16.98$, $P < 0.001$]. The picture of room B attracted higher ratings of fit than that of room A. Most importantly, there was a clear interaction between room and exposure condition [$F(3,284) = 8.73$, $P < 0.001$] and an additional one between room, odor and condition [$F(3,284) = 3.79$, $P < 0.05$]. No significant effect of learning session was found for the non-identifiers (session 1 = 0.79 ± 0.88; session 2 = 0.92 ± 0.79).

Identifiers

For the identifiers the main effects were of room [$F(1,244) = 10.88$, $P < 0.01$], with the picture of room B again attracting the highest fit, and learning session [$F(1,244) = 6.38$, $P < 0.05$], with the second session (mean = 0.81 ± 0.79) showing higher ratings of fit than the first one (mean = 0.59 ± 0.64). Most importantly, there was no interaction between room and condition in this case, but there was a two-way interaction between room and odor [$F(1,244) = 4.99$, $P < 0.05$]. This interaction is clearly illustrated in Figure 1b. Pre-exposure to lavender gives a higher rate of fit of this odor to the picture of room B than pre-exposure to orange, irrespective of the room in which the pre-exposure took place. For the picture of room A no such difference in rating of fit is found.

In Tables 5 and 6 the detailed results for the the non-identifiers and the identifiers are given for the four types of exposure condition, irrespective of session. For this purpose groups with the same condition, but in different sessions, were combined into new groups (W, X, Y, Z). The most important results in these tables are given in the diagonal from the top left to the bottom right, where the ratings of fit are shown for the groups (W, X, Y, Z) that were exposed to the same odor and the same room as the one for which the ratings of fit (RaLa, RaOr, RbLa or BbOr) were made. In these cells of the table the results of the non-identifiers and the identifiers are given. These can be compared with the ratings of fit to the same odor and the same room for the groups that were exposed to another odor or another room by looking at the results in the same column of Table 5. The significances of difference between these groups in the same column of Table 5 are given in Table 6 for the non-identifiers. Since no significant differences were found

Table 5 Ratings of fit of the two experimental odors (La and Or) to the two experimental rooms (Ra and Rb) for the groups that were exposed to each of the four conditions (room–odor combinations) in either session 1 or 2

Exposure condition	Ratings of fit (significance of differences within columns)							
	RaLa		RaOr		RbLa		RbOr	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group W: RaLa (groups 1and 5)								
Non-identifiers	1.49	1.45	0.48	0.54	0.74	0.80	0.89	0.64
Identifiers	0.61	0.64	0.32	0.40	0.92	0.78	0.96	0.99
Group X: RaOr (groups 2 and 6)								
Non-identifiers	0.59	0.55	0.83	0.53	0.84	1.00	0.76	0.72
Identifiers	0.66	0.50	0.44	0.42	0.61	0.50	0.77	0.68
Group Y: RbLa (groups 3 and 7)								
Non-identifiers	0.54	0.40	0.42	0.47	1.68	0.96	1.43	1.24
Identifiers	0.75	0.67	0.54	0.54	0.89	1.11	1.13	1.16
Group Z: RbOr (groups 4 and 8)								
Non-identifiers	0.62	0.43	0.40	0.54	0.89	0.54	1.31	0.82
Identifiers	0.62	0.62	0.57	0.68	0.55	0.52	0.80	0.84

The results are given for the identifiers and non-identifiers of the particular odor involved in the rating of fit.

for the identifiers between the groups represented in the columns of Table 5, these are not shown in Table 6.

As can be seen from Table 6, for the non-identifiers there was only one case in which the rating of fit of the exposed group is not significantly higher (P = 0.717) than that of a non-exposed group and one case in which the difference is in the same direction but remains marginal (P = 0.063). As stated above, for the identifiers none of the differences between the exposed groups and the other groups was significant.

In order to check whether the differences found between the identifiers and non-identifiers of lavender and orange respectively were not the result of general differences in rating of fit, a comparison was made between their ratings of fit of the experimental odors to each of the pictures of the other (non-experimental) contexts. In no single case was a difference between lavender identifiers and lavender non-identifiers found in the rating of fit of lavender to any of these other pictures. The same was true for the ratings of fit of orange of the identifiers and non-identifiers of that odor, although in one case—the rating of fit of orange to the canteen—significance was approached (P = 0.06). In this case, the non-identifiers made a slightly higher rating of fit than the identifiers.

Further analysis also showed that identification or non-identification of either lavender or orange or the non-odorous control had no significant effect on the ratings of fit found for the other nine odors to the pictures of the nine rooms that were not used in the experimental or control conditions. In none of the three (identification of lavender, orange or control odor) sets of 81 cases (fits of nine non-experimental odors to nine non-experimental contexts) were more significant (P < 0.05) differences between identifiers and non-identifiers of these odors found than might be expected by mere chance [lavender, 1/81 (P = 0.027); orange, 2/81 (P = 0.036 and P = 0.050); control, 1/81 (P = 0.028)].

Table 6 Significant differences between the non-identifiers in exposed groups and non-exposed groups for the ratings of fit of the experimental odors to the experimental rooms

Rating of fit	Exposed group (mean)	Other group (mean)	*T* value	*df*	*P* =
RaLa	W (1.49)	X (0.59)	2.52	33	0.017
RaLa	W (1.49)	Y (0.54)	2.50	29	0.020
RaLa	W (1.49)	Z (0.62)	2.22	29	0.034
RaOr	X (0.83)	W (0.48)	2.42	51	0.019
RaOr	X (0.83)	Y (0.42)	2.83	46	0.007
RaOr	X (0.83)	Z (0.40)	2.66	42	0.011
RbLa	Y (1.68)	W (0.74)	2.95	29	0.006
RbLa	Y (1.68)	X (0.84)	2.48	32	0.019
RbLa	Y (1.68)	Z (0.89)	2.78	28	0.010
RbOr	Z (1.31)	W (0.89)	1.91	43	0.063
RbOr	Z (1.31)	X (0.76)	2.32	42	0.025
RbOr	Z (1.31)	Y (1.43)	–0.37	38	0.717

It can be concluded that the identifiers and non-identifiers of each of the two experimental odors showed no differences in rating behavior with regard to the pictures of contexts that were hitherto unknown to them. In order to see whether this was also true for the control room, in which they all had been but without exposure to an odor, the ratings of fit of the experimental odors to this room were checked. Only in one case—the rating of fit of lavender to the control room (RcLa) in group X—was there a significant difference [$T(37) = 2.664$; $P = 0.011$] in the same direction as in the experimental contexts (non-identifiers = 3.10 ± 2.05; identifiers = 1.57 ± 1.51). In order to check the uniqueness of this latter difference, the differences between identifiers and non-identifiers in their rating of fit of the experimental odor (RcLa or RcOr) to the control room were reviewed in all separate subgroups.

Only in one case (group 6 RcLa) was a difference in the same direction as the differences for the ratings of fit of the experimental odors to the experimental rooms found (non-identifiers: $n = 8$, mean = 3.18 ± 2.17; identifiers $n = 11$, mean = 1.13 ± 0.98; $T = 2.79$; $df = 17$; $P = 0.013$). Not only was this the only significant difference in all 16 measurements, but in exactly half of the measurements the identifiers made equal or higher ratings of fit of the experimental odor to the control room (RcLa or RcOr) than the non-identifiers. Furthermore, group 6 was a group that had not been exposed to lavender in the experimental condition. The rating of fit (RcOr) of orange (the odor to which this group was exposed) to the control room proved to be slightly higher for the identifiers than for the non-identifiers. In contrast, separate inspection of the rating of fit of the orange odor to the experimental exposure room (RaOr) in this group showed that the non-identifiers (mean = 1.00 ± 0.59) gave higher ratings of fit than the identifiers (mean = 0.54 ± 0.43). The one significant difference in group 6 can therefore be considered to be an accidental result.

Session effects

As indicated in Table 4, an overall session effect was found. The ratings of fit were lower for the groups in which the experimental odor had been presented in the first session than in the groups where it was presented in the second session. Table 7 gives a more detailed account of these effects for the two experimental odors and their identifiers and non-identifiers.

When special attention was given to the distinction between identifiers and non-identifiers, it became clear that the session effect was to be ascribed mainly to the identifiers of lavender, who showed a much lower rating of fit in the first session than in the second (see Table 7). Nevertheless, other differences between the sessions also point in the same direction and will also have contributed to the main effect.

Identification and session effects of the non-odorous control

The non-odorous control was treated in the same way as the experimental odors in order to check whether the same results would be obtained. As can be seen from Table 2, the control odor was correctly identified as 'no odor' by 75.7% of the subjects.

A 2 × 2 ANOVA (identification × learning session) was carried out on the ratings of all subjects for the fit of the control odor to the control room. Only weak and marginally significant main effects were found. In the case of identification [$F(1,144) = 3.74$, $P = 0.055$], the non-identifiers (mean = 2.95 ± 2.36) had a lower rate of fit than the identifiers (mean = 3.80 ± 2.37), which is contrary to the difference obtained with the experimental odors. For learning session [$F(1,144) = 3,19$, $P = 0.076$], the first session (mean = 3.05 ± 1.91) shows a somewhat lower rate of fit than the second (mean = 4.12 ± 2.69), which is in the same direction as the results obtained with the experimental odors. Further inspection shows that this effect is almost completely due to the identifiers (session 1 = 3.12 ± 1.81, session 2 = 4.48 ± 2.67; $T = 3.16$, $df = 110$, $P < 0.01$). For the non-identifiers (session 1 = 2.84 ± 2.23, session 2 = 3.05 ± 2.52) no significant difference was found.

Relationship between rating of fit, pleasantness and familiarity

None of the 16 (identifiers and non-identifiers of the rated experimental odor in each of the eight groups) correlations between pleasantness or familiarity and rate of fit was significant. The correlation coefficients ranged from –0.37 to +0.24 (minimal group size = 29), with exactly half of them being negative. Inspection of the scatter plots showed no abnormalities that might account for this lack of correla-

Table 7 Session effects for the two experimental odors split by identifiers and non-identifiers of these odors

Session	Odor	Rating of fit				*T* (*df*)	*P*
		Non-identifiers		Identifiers			
		Mean	SD	Mean	SD		
First	Lavender	1.49	1.48	0.53	0.54	2.853(36)	<0.01
Second	Lavender	1.66	0.95	1.00	1.16	1.838 (34)	=0.075
Difference		$T = -0.392$ (29); $P = 0.698$		$T = -1.770$ (41); $P = 0.084$			
First	Orange	0.94	0.68	0.45	0.90	1.761 (35)	=0.087
Second	Orange	1.17	0.72	0.74	0.58	2.027 (35)	=0.050
Difference		$T = -1.087$ (42); $P = 0.283$		$T = -1.048$ (28); $P = 0.303$			

tion. All correlated variables showed good, if not always normal, distributions (see also SDs in Tables 3 and 5).

Discussion

The clear reconfirmation of the earlier finding (Degel and Köster, 1999) that being able to identify an odor by its correct name interferes with the establishment, the retention or the retrieval of an implicitly acquired and phenomenally unconscious memory for that odor is undoubtedly the most important outcome of this study. Although both lavender and orange are among the odors that are most liked by and most familiar to the (French) population, and it can therefore be assumed that the odors were not completely unknown to any of the participants, those who were *unable* to mention them by name rated them as befitting the room in which they had been unconsciously exposed to them to a significantly larger degree than people who had never been in that room or than people who had also been unconsciously exposed in it but could mention the name of the odor at the very end of the experiment. It was further shown that this difference between the identifiers and non-identifiers was not due to a general behavioral difference between the two groups, since in all other ratings of fit of (experimental or non-experimental) odors to (experimental or non-experimental) contexts they rated the fit in the same way. Apart from differences in the effect of retention time (see below), the only other difference was that the identifiers indicated that they liked the experimental odors better and judged them as more familiar than did the non-identifiers (see Table 3). Could this explain the rating of fit results or do people who know the name of an odor just rate its pleasantness and familiarity higher than people who know the odor perhaps equally well from experience but cannot name it? There are three arguments in favor of this second interpretation. First, it is hard to understand why liking an odor less or being less familiar with it would lead to a higher rating of fit of that odor to the room. The contrary might be expected. Secondly, it is hard to see why, if it were nevertheless true that liking an odor less or being less familiar with it has this effect, the occurrence of this effect is limited to the one case in which the subjects had been unknowingly exposed to the odor and is not observed in any other case where the fit of the same odor to another context has been rated. Thirdly, if the differences in rating of fit between the identifiers and the non-identifiers were caused by the differences in pleasantness or familiarity provoked by the odors in the two groups (identifiers and non-identifiers), one would suppose that one would also find correlations between pleasantness or familiarity and fit within these groups. This is not the case (see the last section in Results). Thus, the conclusion must be that the differences in liking and familiarity ratings between the identifiers and non-identifiers are the consequence of their different semantic knowledge, rather than the cause of their different rating behavior in the experimental condition. This conclusion is in good agreement with the findings of Zellner *et al*. (Zellner *et al*., 1991), who investigated the influence of color on odor identification and liking and came to a similar conclusion. In view of this, it is surprising that many authors (Knasko, 1993; Dalton, 1996, 1999), when they speak about 'pleasant' and 'unpleasant' odors, do not take identifiability of the odors into account and do not even mention the large SDs they must have obtained in their measurements. In the case presented here, on average lavender was liked by the identifiers and disliked by the non-identifiers.

An argument similar to the one to exclude the influence of liking differences on the rating of fit can be used to exclude the possibility that the difference in rating behavior is due to the explicit semantic recognition of the experimental odor by the identifiers during the rating of fit phase of the experiment. Firstly, it is clear that these differences are the result of changes in rating behavior of the non-identifiers and not of changes in the ratings of the identifiers. As is shown in Table 6, all but one of the differences between the exposed and non-exposed groups in the columns of Table 5 are significant for the non-identifiers (Table 6), whereas none of these differences is significant for the identifiers. As indicated already, the identifiers and non-identifiers of the experimental odors do not differ in any of their other ratings of fit. Even in the case of the control room, to which all subjects were exposed in either the first or the second session, only an accidental significance was found in one out of 16 cases. This would be highly improbable if the effect was only caused by a difference in rating attitude based on the identification or non-identification of the odors. Such a difference in rating attitude would almost surely also influence the ratings of fit of the odors to other contexts, especially to the control room.

If all of this makes it highly unlikely that the difference between the identifiers and the non-identifiers is related to the retrieval of the memory, the question arises whether knowing the name of an odor really blocks the formation of an unconscious episodic memory, as was supposed by Degel and Köster in an earlier study (Degel and Köster, 1999).

As one of the reviewers of this paper pointed out, in this connection it is important to know that the subjects did not notice the odors. This, it is argued, is especially important in the case of the identifiers, because being able to name an odor is known to make that odor more easily recognizable (Rabin and Cain 1984). It should be pointed out, however, that in Rabin and Cain's experiment the subjects had been explicitly confronted with the odors in a learning phase where they were asked to rate their familiarity and to identify them by a label, and then were explicitly asked to recognize these odors among a set of distractors while trying to identify them again. They were also informed beforehand that the investigation entailed memory for odors and would require eventual recognition of the target items. That under such circumstances identifiability influences the recognition results is not surprising, since it provided the subjects with a second, verbal way to remember the presented odors and even practically forced them to use it. In contrast, in the present experiment everything was done to avoid the subjects' explicit awareness of the odors (the use of a double-blind procedure, and of low concentrations which were not noted by the subjects in the pre-experiment) and to hide the purpose of the experiment. It is therefore in no way certain that the findings of Rabin and Cain are applicable here. Nevertheless, the question of a possible awareness remains open and it should be admitted that the overwhelming absence of any knowledge at debriefing during the retention phase alone is not a strong argument to decide about awareness or non-awareness, as has been shown previously (Dawson and Reardon, 1973). However, apart from the fact that even after such extensive debriefing almost all subjects could not remember having smelled the experimental odor that day anywhere in the building, there are a number of other arguments that may indicate that the subjects did not notice the odor. First, the exposure did not influence the number of identifiers in the exposed and non-exposed groups, as might have been expected if the subjects had been aware of the stimuli. Secondly, the exposure or non-exposure did not influence the ratings of pleasantness or familiarity for the experimental odors of both the identifiers and the non-identifiers. If anything, the familiarity of the non-identifiers and not of the identifiers was raised by exposure (another sign of implicit memory?). Thirdly, the identifiers in the exposed groups, who, according to Rabin and Cain, should have been more likely to notice the odor, gave the same rates of fit to the experimental odor as the identifiers in the non-exposed groups. Finally, the identifiers did not differ from the non-identifiers in any other condition. In other words, there is not a single behavioral indication that awareness during exposure influenced the results of the identifiers (or of the non-identifiers in other situations than those implying implicit memory for the experimental odor–room combination).

If the identifiers did indeed remain unaware of the exposure stimuli, this seems to exclude the possibility that explicit odor recognition blocks the formation of implicit memory in the way described by Freberg (Freberg, 1979; Rescorla, 1981), who showed that in rats prior exposure to a component of a flavor mixture disturbed the establishment of the memory link between the mixture components. Rescorla, who holds the view that perceptual associations should not be seen as a link between separate entities, but rather that simultaneously presented stimuli form a perceptual unit, explains Freberg's results by the fact that previous exposure to one single component prevents the perception of the mixture as a unitary structure. Likewise, Graf and Schacter (Graf and Schacter, 1989) show in human experiments that unitization of paired words seems to be a necessary prerequisite for the formation of implicit memory. However, since in the learning phase they deal only with explicitly presented verbal material, and since their idea of unitization is based on conceptual, rather than on perceptual, links, it is doubtful whether their results are of direct relevance to the present discussion. For even in the unlikely case that the subjects consciously perceived the odors in the exposure phase, they could not unitize them with the room in the same way as in Graf and Schacters' experiments. In a previous article Degel and Köster (Degel and Köster, 1999) discussed four possible explanations for the absence of implicit memory in the identifiers. One of these explanations was related to the fact that knowing the name of the odor placed the (conscious or unconscious) experience with it amidst a series of other similar (conscious or unconscious) experiences. If this were the case, it might indeed prevent the perception of the link between the odor and the room as a unitary (and unique) experience in Rescorla's sense and thus disturb the memory for it. Would this mean that it even blocked the formation of the implicit memory itself?

Here the variation of the retention time, which was introduced by varying the order of the experimental and control conditions presented to the subjects, may provide some insight. The interval between the retrieval and the learning phase was ~60 min for those who received the odor in the second session and exactly 60 min longer for those who were exposed to it in the first session. Thus, one can interpret the lines in Figure 2 as approximations of the retention (or forgetting) curves between 60 and 120 min after 'learning'. If one does so, it becomes clear that being able to identify the odor does not completely block the formation of the implicit episodic memory, as Degel and Köster tentatively supposed in their previous article. For if the blocking of the memory was complete and the identifiers

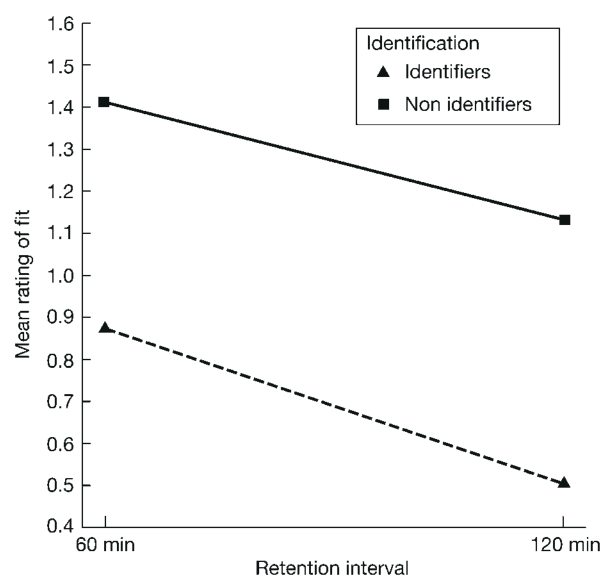

Figure 2 Mean rating of fit for identifiers and non-identifiers of the experimental odors after a 60 and 120 min time interval between psychological testing and rating of fit.

did not build up such a memory, there could not be any forgetting. Thus, the mere fact that identifiers do forget is an indication that the difference between the identifiers and the non-identifiers, if caused by effects of the identification on memory acquisition, is at most a difference of degree and not an absolute one [identifiers: main effect of session for odors, $F(1,244) = 6.38$, $P < 0.05$].

As pointed out in the introduction, efforts to measure implicit memory have been scarce and largely unsuccessful to date. The present experiment explains why the method of Schab and Crowder (Schab and Crowder, 1995) could not produce positive results. In the acquisition phase of their experiments they always compared odors that were identified by their name with a condition in which only the name was presented. According to the results of the present experiment, this alone would prevent the finding of implicit effects. Moreover, in their second phase of three of their experiments they used identification in combination with either reaction time or threshold measurement to verify memory effects. This makes it dubious whether they ever measured implicit odor memory and not just explicit verbal memory. But since in their fourth experiment they used reaction times to pleasantness and familiarity instead of identification in the second phase and found absolutely no memory effect, it seems that using identification in the first phase was enough to annihilate any odor memory effects, just as it might indeed be expected on the basis of the present results.

The results of Olsson and Cain (Olsson and Cain, 1995) on repetition priming effects in the left nostril cannot easily be compared with the present results, because not only did the question used in the priming phase draw the attention unduly to memory (see Introduction), but the meaning of a procedure in which the subjects were asked 'to press a button when they "realized" *what* they were smelling, but were asked not to give names for the stimuli' was unclear. This mysterious and rather naive instruction—could the subjects really stop themselves?—made it impossible to discriminate between the people who could and those who could not identify the odors. When Olsson (Olsson, 1999), using a different method (identity rejection), later separated the identifiers and the non-identifiers, he obtained results that confirm the finding in the present experiment that being able to identify an odor seriously interferes with the implicit memory for it. He found indications of positive priming effects in non-identifiers and significant negative priming effects (longer response latencies to a primed odor than to a non-primed control odor) in identifiers. To explain this latter finding, Olsson invokes two theories mentioned in a review of the negative priming literature (Lowe, 1998) which cites only studies carried out with verbal material. Whether such results are directly comparable with results on odor memory is questionable. Moreover, both these theories are obviously not applicable to the data of Olsson (who presented only one odor at a time) because they are based directly on a paradigm in which *two* stimuli were always presented simultaneously in the priming phase, one to be primed and one to be ignored. In both theories this latter stimulus plays an essential role. Therefore, it is not clear how such theories could explain Olsson's data. If one considers the experiment of Degel and Köster (Degel and Köster, 1999) as a form of repetition priming with an implicit memory response instead of a reaction time as the dependent variable, it is true that, like Olsson, they also found that the identifiers of lavender who had been in the lavender condition showed a somewhat lower (although by no means significant) rating of fit of lavender to the picture of the experimental room than people who had never been in there. This might indicate that (some of) the identifiers who had been in the lavender room had no recollection of smelling the odor in the experimental room and therefore underrated the fit of the odor to the picture. In the present experiment there is no indication that such a process has taken place. The identifiers behave in the same way, whether or not they have been exposed to the odor in an experimental room.

A third theory (Ratcliff and McKoon 1996), which interprets all repetition priming effects as a form of experimental bias, has been supported by a number of small experiments. All of these deal with the priming effects of explicitly presented words or pictures. In Degel and Köster (Degel and Köster, 1999) and in the present experiment the priming stimuli were not explicitly presented and were hidden even to the extent that almost none of the subjects had any recollection of noticing them at all. Thus, it seems response biases of the type invoked by Ratcliff and McKoon are not responsible for the effects of previous exposure to these hitherto unnoticed odors on the ratings of fit.

Another example of the possible negative influence of odor identification on odor memory was incidentally provided by Perkins and McLaughlin Cook (Perkins and McLaughlin Cook, 1990) when, in an effort to prove that their recall data were not influenced by guessing, they correlated the frequency with which odor labels were spontaneously generated by a separate group of subjects with the scores based on the frequency with which an odor was correctly mentioned in immediate or delayed recall or recognition. Although their data set was too small ($n = 15$) to lead to significant correlations, five of their six correlations were negative (range –0.09 to –0.48; mean = –0.26) and only one (+0.01) was positive. This seems to indicate that the better the name of an odor was known, the lower the chance it was recalled or remembered, both immediately after the 'learning' episode or in the delayed condition after an interval of a week.

These results seem to contradict the data of many other authors who find a positive correlation between subjects' capacity to label an odor correctly and their performance on recall or recognition tests (Rabin and Cain, 1984; Lyman and McDaniel, 1986; de Wijk *et al.*, 1995; Larsson, 1997). In all these cases, however, explicit learning and explicit retrieval were involved. As remarked earlier (Degel and Köster, 1999) there is nothing surprising in the fact that when subjects can also make use of the semantic memory system, they perform better than when they have to rely on olfactory information alone. In essence, most of these investigations have studied verbal memory with rather inadequate stimuli. The final question to be asked, then, is what is actually remembered and how the data obtained here fit in general memory theory. Obviously, what is remembered implicitly is the association between the odor and the place where it was smelled, although when asked explicitly, the subjects have no memory of such a connection and do not even remember having smelled the odor previously that day anywhere in the building. Thus, in the strict sense of the term (Tulving, 1985) the memory is not an episodic one. According to Larsson (Larsson, 1997), episodic odor memories presuppose semantic knowledge about the odor and should include explicit recollections of time and place of the original occurrence of the stimulus. Nevertheless, knowing where and when one has smelled an odor seems to be a very prominent feature of olfactory memory. In many cases when one is asked to identify a smell, one first has an impression of where (and often, by deduction, when) one has smelled it. In many cases this then leads to a search for the possible odor sources in that situation and finally to the identification of the true odor source. In any case, the odor and the place or situation where it has been perceived are usually immediately connected. Thus, the memory link between odor and situation seems to belong to the same level as the perceptual representation systems described by Schacter (Schacter, 1994) for visual word form, structural description and auditory word form. The common features of these systems are 'that they operate at a pre-semantic level, that does not involve access to the meanings of words or objects, that they are involved with non-conscious expressions of memory for previous experiences and that they are likely to depend on cortical mechanisms'. Although the latter qualification can thus far not be warranted for the case of odor perception, the other qualifications seem to fit the observed phenomena very well.

In the case of odors, there is no such thing as the form or structure of the examples mentioned by Schacter (Schacter, 1994). Perhaps precisely because odors have no form (spatial as in vision or temporal as in audition) the only pre-semantic form in which we can behold them is through their link with the situation in which we experience them. As discussed above, such a link may even be a unitary experience in the sense of Rescorla (Rescorla, 1981). There are no abstract names for odors as there are for colors or forms; instead they are named after their sources, and these sources are linked to the places and situations where we have encountered them. This might show that the three perceptual representation systems described by Schacter (Schacter, 1994) are only special cases of such systems as vision and audition, and that not only forms and structures, but also situational associations could fulfill such a role. Also, that odors are much more directly linked to the place in which we have experienced them may throw a different light on the relationship between episodic and semantic memory in the case of olfaction.

In fact, the data presented here indicate that a form of implicit episodic memory (a *contradictio in terminis*!) is disturbed by semantic knowledge. For odors the pre-semantic unconscious memory link between the odor and the experimental room is disturbed by knowing the odor's name, because knowing this name places the link of the odor with this special situation amidst a multitude of links with other situations. Thus, episodic reminiscences of an implicit type may be much more common to olfaction than to senses which bring possess form and structure, which are to a large extent independent of the situations in which they are encountered. It is not the sight of the 'madeleine' but its flavor that carries Marcel Proust (Proust, 1962) back to the room of his Aunt Léonie in Combray on Sunday mornings before mass. And it is only after he has realized that it is not the material thing that he can name, the madeleine itself which provokes his feelings of extreme happiness that he immediately experiences the reappearance of the original situation in which he first encountered this particular combination of flavors. Does this mean that in his case too, knowing the name of the madeleine hampered access to the implicitly and unintentionally created olfactory memory link between the flavor and the situation (Aunt Léonie's room before mass)?

One further thing should be made clear: if such a disturbance of the implicit memory by knowing the name took place, it was not due to a phenomenon sometimes described as 'verbal overshadowing' (Schooler and Engstler-Schooler 1990; Melcher and Schooler, 1996). In their experiment the latter authors asked three groups of people—(i) trained wine experts who had a well-established wine language; (ii) wine drinkers who attended wine courses and belonged to local wine societies; and (iii) non-wine drinkers—to take part in a wine-tasting and recognition experiment in which they would first receive two wines and then, after performing another simple task, would attempt to recognize the samples among two sets of four wines, each set containing three different distractor wines. Each of these groups of people were divided into two subgroups, one of which was instructed to describe the target wines as precisely and in as much detail as they could, while the other was required to solve crossword puzzles during the same period. The results showed that whereas the experts performed best throughout, irrespective of the subgroup to which they belonged, the non-wine drinkers without any experience in describing wines performed much better than the amateur wine drinkers under the instruction to describe the wines, but less well than the wine drinkers under the control (crossword) condition. Obviously trying to describe the wines with the limited and inadequate vocabulary of the amateur wine drinker disturbs the olfactory memory of the wine rather than helps it to be retained. The superiority of the verbal condition over the control condition in the non-wine drinkers is tentatively explained by the authors by assuming that these non-wine drinkers only notice some simple characteristics which help them to recognize the wines later and are not confused by trying to grasp the complex tastes that are involved in the descriptions of the other two groups.

It should be clear that the mechanisms involved in verbal overshadowing experiments are of a totally different nature to those involved in the present study and that verbal overshadowing cannot explain the negative influence of knowing the name of an odor on the retention of its unnoticed or at least not remembered presence in a room.

Finally, it should be pointed out that although the results on the influence of odor identification are clear, and although they form a perfect confirmation of earlier results, identification was not explicitly controlled or manipulated in this research. Thus, the possibility that some other differentiating factor between the 'identifiers' and 'non-identifiers' was in fact responsible for the observed effects remains. Research with unknown odors, that are presented without and with different degrees of identification to different groups in a pre-experiment before submitting them to an experiment of the present type, could resolve this problem. Another interesting possibility would be to work with such unknown odors and to introduce identification (e.g. by proposing labels for them) in the different phases (acquisition, retention and retrieval) of the experiment.

Acknowledgements

This study was granted in part by the German Savings Bank Association (Deutscher Sparkassen- und Giroverband), Bonn.

References

Buchner, A. and **Wippich, W.** (1998) *Differences and commonalties between implicit learning and implicit memory*. In Stadler, M.A. and Frensch, P.A. (eds), Handbook of Implicit Learning. Sage Publications, Thousand Oaks, CA, pp. 3–46.

Dalton, P. (1996) *Odor perception and beliefs about risk*. Chem. Senses, 21, 447–458.

Dalton, P. (1999) *Cognitive influences on health symptoms from acute chemical exposure*. Health Psychol., 18, 579–590.

Dawson, M.E. and **Reardon, P.** (1973) *Construct validity of recall and recognition postconditioning measures of awareness*. J. Exp. Psychol., 98, 308–315.

Degel, J. and **Köster, E.P.** (1998) *Implicit memory for odors: a possible method for observation*. Percept. Motor Skills, 86, 943–952.

Degel, J. and **Köster, E.P.** (1999) *Odors: implicit memory and performance effects*. Chem. Senses, 24, 317–325.

De Wijk, R.A., Schab, F.R. and **Cain, W.S.** (1995) *Odor identification*. In Schab, F.R. and Crowder, R.G. (eds), Memory for Odors. Lawrence Erlbaum, Mahwah, NJ, pp. 21 –37.

Freberg, L. (1979) *Evidence supporting a perceptual learning model of the sensory preconditioning of flavours*. PhD Dissertation, University of California, Los Angeles, CA.

Graf, P. and **Schacter D.L.** (1989) *Unitization and grouping mediate dissociations in memory for new associations*. J. Exp. Psychol.: Learn. Mem. Cognit., 15, 930–940.

Knasko, S.C. (1993) *Performance, mood, and health during exposure to intermittent odors*. Arch. Environ. Health, 48, 305–308.

Larsson, M. (1997) *Semantic factors in episodic recognition of common odors in early and late adulthood: a review*. Chem. Senses, 22, 623–633.

Lowe, D. (1998) *Long-term positive and negative priming: evidence for episodic retrieval*. Mem. Cognit., 26, 435–443.

Lyman, B.J. and **McDaniel, M.A.** (1986) *Effects of encoding strategy on long-term memory for odours*. Quart. J. Psychol., 38A, 753–765.

Melcher, J.M. and **Schooler, J.W.** (1996) *The misremembrance of wines past: verbal and perceptual expertise differentially mediate overshadowing of taste memory*. J. Mem. Lang., 35, 231–245.

Olsson, M.J. (1999) *Implicit testing of odor memory: instances of positive and negative repetition priming*. Chem. Senses, 24, 347–350.

Olsson, M.J. and **Cain. W.S.** (1995) *Early temporal events in odor identification*. Chem. Senses, 20, 753.

Perkins, J. and **McLaughlin Cook, N.** (1990) *Recognition and recall of odours: the effects of suppressing visual and verbal encoding processes*. Br. J. Psychol., 81, 221–226.

Proust, M. (1992) In Search of Lost Time: Swann's Way. The Modern Library, New York.

Rabin, M.D. and **Cain, W.S.** (1984) *Odor recognition: familiarity, identifiability, and encoding consistency*. J. Exp. Psychol.: Learn. Mem. Cognit., 10, 316–325.

Ratcliff, R. and **McKoon, G.** (1996) *Bias effects in implicit memory tasks*. J. Exp. Psychol.: Gen., 125, 403–421.

Rescorla, R.A. (1981) *Simultaneous associations*. In Harzem, P. and Zeiler, M.D. (eds), Predictability, Correlation, and Contiguity. John Wiley & Sons, New York.

Schacter, D.L. (1994) *Priming and multiple memory systems: perceptual mechanisms of implicit memory*. In Schacter, D.L. and Tulving, E. (eds), Memory Systems of 1994. MIT Press, Cambridge, MA, pp. 233–268.

Schab, F.R. and **Crowder, R.G.** (1995) *Implicit measures of odor memory*. In Crowder, R.G. and Schab, F.R. (eds), Memory for Odors. Lawrence Erlbaum, Hillsdale, NJ, pp. 71–91.

Schooler, J.W. and **Engslter-Schooler, T.** (1990) *Verbal overshadowing of visual memories: some things are better left unsaid*. Cogn. Psychol., 22, 36–71.

Tulving, E. (1985) *How many memory systems are there?* Am. Psychol., 40, 385–398.

Zellner, D.A., Bartoli, A.M. and **Eckard, R.** (1991) *Influence of color on odor identification and liking ratings*. Am. J. Psychol., 104, 547–561.

Accepted November 11, 2000