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Verbal coding in olfactory versus nonolfactory cognition

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Two paired-associate memory experiments were conducted to investigate verbal coding in olfactory versus nonolfactory cognition. Experiment 1 examined the effects of switching/not switching odors and visual items to words between encoding and test sessions. Experiment 2 examined switching/not switching perceptual odors and verbal-imagine versions of odors with each other. Experiment 1 showed that memory was impaired for odors but not visual cues when they were switched to their verbal form at test. Experiment 2 revealed that memory was impaired for both odors and verbal-imagine cues when they were switched in format at test and that odor sensory imagery was not accessed by the instruction to imagine a smell. Together, these findings suggest that olfaction is distinguished from other sensory systems by the degree of verbal coding involved in associated cognitive processing.

The first cognitive interpretation we have for any sensory item is a determination of what it denotes. That is, we label to ourselves in words what the item we are perceiving is called. For the purposes of the present research, this process will be called *verbal coding*. In certain cases of perceiving very unfamiliar or ambiguous experiences, verbal coding may not readily occur, but when we are confronted with familiar visual, auditory, or tactile stimuli, verbal coding normally occurs effortlessly. By contrast, when confronted with an odor, the word to denote it may not be available even when the smell is highly familiar (Cain, 1979; Cain & Potts, 1996). This experience is called the *tip of the* nose state and differs dramatically from its *tip of the tongue* cousin, in that, in the former, one has no lexical access whatsoever for the odor name in question, such as first letter, general word configuration, or the number of syllables.

Neurological studies suggest that olfaction is less connected to linguistic processing areas than are other sensory systems. In comparing naming ability for visual, tactile, auditory and olfactory stimuli among aphasics, it was found that naming ability was worse for olfactory items than for items in other modalities, even though olfactory perception was unimpaired (Goodglass, Barton, & Kaplan, 1968). In odor-associated memory research, it has been shown that episodic memories to odors can be accessed without the subject being able to provide any name for the eliciting odor (Herz, 1998b; Herz & Cupchik, 1992). Additionally, a number of odor recognition studies have demonstrated that access to verbal labels has no effect on subsequent odor recognition memory performance (Ayabe-Kanamura, Kikuchi, & Saito, 1997; Engen & Ross, 1973; Lawless & Cain, 1975) and that incorrectly labeled odors can be recognized significantly above chance levels (Lehrner, 1993; Rabin & Cain, 1984). Still, other experiments report that recognition memory for odors can be improved with semantic techniques (Larsson & Bäckman, 1993; Lyman & McDaniel, 1986, 1990; Walk & Johns, 1984). On balance, however, it appears that odors are more experientially and neurologically distant from language than perception through the other senses is.

The question regarding what role verbal codes play in olfactory cognition has not been satisfactorily resolved. To date, no experiments have directly assessed the extent to which verbal coding occurs during olfactory perception, and what role it plays in higher levels of olfactory cognition. Specifically, are verbal odor labels (words) readily activated upon smelling an odor? And do these words form part of the memory trace associated to odor cues? The main goal of the present research was to address these questions and provide new insights into the verbal aspects of olfactory cognition. These issues have general theoretical relevance to students of human cognition, because if olfactory cognition does not necessarily involve verbal mediation, then a functional difference between olfaction and the other senses would be shown.

A further distinguishing feature of olfaction is our generally deficient ability to perceptually imagine smells. In a recent survey study conducted on 140 undergraduates (Herz, 1996), subjects reported that their ability to conjure an odor sensation (e.g., chocolate) was poor and significantly worse than their ability to conjure the sensa-

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tion of visual, touch, or auditory stimuli. Crowder and Schab (1995) compared olfactory and visual imagery instructions on subjects' ability to subsequently recognize, identify, and detect odors—tasks for which imagery in other sensory modalities have produced positive outcomes. However, no effects of odor imagery on olfactory performance were found across three different experiments. Engen (1982) has suggested that what may seem like odor imagery is actually a confusion between imagery in other modalities.

Other researchers have argued that odor imagery is equivalent to imagery in other modalities (see Elmes, 1998, for discussion). Carrasco and Ridout (1993) used multidimensional scaling techniques to determine whether common elements underlie olfactory perception and imagery. Depending on how many dimensions the solution space accounted for, similarities in olfactory imagery and perception were more or less apparent, though a high degree of variance was found as a function of the factor and dimension considered. In another study, Algom and Cain (1991) found little variation in the pattern of judgments made to perceptual and mental mixtures of banana and grass odors. However, Schifferstein (1997) criticized these effects on statistical grounds and also showed that perceived taste mixtures differed from imagined taste mixtures. Cain and Algom (1997), however, point out that memory for odors must be based on an internal representation of the odor, which is certainly true. Yet whether this representation is perceptual or semantic is not currently known. The most compelling evidence for odor imagery comes from EEG research. In a study aimed at examining how the contingent negative variation (CNV) wave was related to the psychological and physiological effects of some odors, Lorig and Roberts (1990) found similar brain wave activity for real and imagined smells. However, their experiment was not directly aimed at assessing odor imagery, and it is also not clear whether the changes in brain wave indicated semantic or perceptual representations; therefore, this finding should be interpreted judiciously.

In sum, there is, at best, weak support for the existence of odor imagery. One reason for the deficiency of olfactory imagery relative to other forms of sensory imagery may be because odors are not necessarily translated into verbal codes during perception. Thus, a secondary aim of the present research, addressed in Experiment 2, was to examine the generation of olfactory perceptual codes when given the instruction to "imagine the smell" of a particular odor.

The central goal of the present research was to examine the degree of verbal coding in olfactory cognitive processing in comparison with sensory cognition in other modalities (e.g., vision). This goal was met by two aims: (1) by investigating whether verbal codes are readily activated during odor perception and become part of and function in the odor-associated memory trace as they do in visual object perception/cognition, and (2) by examining whether odor perceptual images could be invoked by the instruction to "imagine a smell" and function equivalently to the olfactory percept. To address these aims, two experiments were conducted in which very familiar stimuli ("source objects") were presented in olfactory, visual, or imaginal form at the encoding session and were then switched or not switched to their verbal or sensory form at the test session. Experiment 1 examined the effects of switching/not switching both odors and visual items to words. Experiment 2 examined the effects of switching/not switching odors to verbal-imagine versions of the smells and these imaginal versions to actual odors.

Previous work on odor-associated memory has shown that it is distinguished from memories cued through other modalities by its emotional potency (Herz, 1998a, 1998b; Herz & Cupchik, 1995). For these reasons, both accuracy and emotional components of memory were examined in the present research. In both experiments, source objects were paired with emotionally evocative paintings as to-be-remembered (TBR) items at the encoding session, and memory accuracy and emotionality were evaluated at a cued recall test session 48 h later.

EXPERIMENT 1

The degree of verbal coding in olfaction and visual cognition was compared. It was anticipated that if verbal codes were activated, they would form part of the memory trace associated to the source object in question. From prior research and experience, it was presumed that presentation of familiar visual items would activate verbal codes, whereas verbal coding of olfactory items was not necessarily expected to occur (Herz & Engen, 1996). It was hypothesized that switching odor stimuli to their verbal form (odor→word) would compromise memory relative to switching visual stimuli to their verbal form (visual→word).

Method

Subjects. Thirty-six student volunteers (24 male, 12 female) from the University of Pennsylvania participated as subjects. Only individuals without formal training or experience in visual art and who were nonsmokers with a self-reported normal sense of smell were selected. The subjects were paid $20 at the end of the test session.

Stimuli. The stimuli assessed in this experiment were 12 highly familiar and pleasant source objects represented in either olfactory or visual form during the encoding session and represented verbally for half of the cases during the test session (see Appendix A). Because these stimuli were used as recall cues, they are referred to as *odor*, *visual*, or *verbal* cues, respectively.

Design and Procedure. A 2 × 2 within-subjects design with cue type (odor, visual) and test condition (stay, switch) as within-subjects variables was followed. The experiment was divided into two sessions (encoding and test) separated by 48 h. Cue–painting learning was incidental during the encoding session and involved pairing 12 cues presented in either olfactory or visual form (see Appendix A) with 12 pleasant emotionally evocative paintings as TBR items (see Appendix B). When the cue was presented as an odor, the subjects unscrewed the lid of an opaque jar and sniffed at the odor-scented cotton inside. The odorant was beneath the cotton, and no visual or other sensory information was available to the subject. When the cue was presented as a visual item, it was placed on a table approximately 70 cm in front of the subject, and no olfactory or other sensory contact with the visual cue occurred. Thus, for each cue type, sensory information came only from the specific modality under investigation.

During the encoding session, the subjects were seated in a semi-darkened windowless room. Painting slides were projected approximately 2 m in front of the subject onto a screen covering 110 × 100 cm. Random cue–painting pairing orders were generated for each subject. Cues of a particular sensory type were presented together in blocks of six; whether odors or visual cues came first alternated between subjects.

At the start of each trial, the subject was presented with a cue to perceptually assess. Immediately following cue presentation, an experimental painting title appeared on the screen for 4 sec, followed by the corresponding painting for 60 sec. During the entire cue–painting trial, the subject either smelled or looked at the cue. At the end of the trial, the cue was removed, and the slide screen went blank. A 2-min incidental encoding task then ensued, during which the subjects provided a written description of the painting just seen and a visualization rating, as well as descriptions and ratings of their concomitant emotional experiences. The subjects were never told that the experiment concerned memory; rather, it was explained that the purpose of the study was to examine the effect of sensory cues on the appreciation of artwork.

At the test session, 2 days later, the accuracy of painting memory and the emotions evoked by the cues and emotionality of memory were assessed by cued recall. However, for half of the trials at test, the format of the eliciting cue was switched from what it had been during encoding (switch condition) to its verbal form, and, for half of the trials, the format of the cue stayed the same as during encoding (stay condition). That is, of the six original odor cues, three were presented as odors again and three were presented as words, and of the six original visual cues, three were presented as words again and three were presented as visual items. When the cue was switched to word format, the experimenter spoke the word aloud (e.g., "rose") and repeated it three times at approximately 30-sec intervals.

After the experimenter first presented the cue to the subjects, either verbally or sensorily, the subject began to answer a sheet similar to the ones they had completed during the encoding session. The recall sheet instructed the subjects to try to describe what the painting associated to the original cue had been and to list and rate their emotional responses to the current cue and their memory of the painting. The duration of recall trials was subject-paced and determined by how long it took the subject to respond to the questions. The average length of recall trials was approximately 2 min. Cue order within the cue blocks was different from what it had been at the encoding session, and specific *stay* and *switch* cue conditions within cue block were randomly generated for each subject. No paintings were seen during the test session.

Accuracy dependent measures were the following: (1) painting description accuracy (evaluated as 0 for incorrect/no description, or 1 for correct description; accuracy ratings were scored by two judges using a strict criterion, who were blind to the purposes of the experiment), (2) the number of words written in the memory description, and (3) rated ability to visualize the painting (1 = *not at all*, 9 = *extremely well*). Emotionality dependent measures were the following: (1) how many emotions were evoked by the cue (max = 4), (2) the rated intensity of these emotions (1–5 scale), and (3) rated emotionality of the memory experience (1 = *not at all*, 9 = *extremely high*). The dependent measures for the test session are listed in Table 1. Responses on very similar dependent measures (omitting accuracy) as a function of cue type were also obtained at the encoding session (see Table 2).

An underlying assumption was that the subjects' verbal representations of the odors were matched to the names given for them in the experiment and that the ability to identify odors was not significantly worse than the ability to identify the visual cues. To validate the matching of odor cues with labels, prior to the study, several volunteers were pretested with a set of cue labels, and where necessary, cue names were modified. Additionally, at the end of the experiment, all subjects were presented with the sensory cues again and asked to generate their own verbal labels to them, and rate the

Table 1
Interaction Between Cue Type and Test Condition in Experiment 1

Dependent Measure	Cue Type	Test Condition	*M*	*SE*	*F*	*p*
Painting recall accuracy	Odor	Stay	1.44	0.14	4.68	<.05
	Odor	Switch	1.11	0.13		
	Visual	Stay	1.58	0.14		
	Visual	Switch	1.77	0.14		
Number of words	Odor	Stay	17.88	1.38	4.61	<.05
	Odor	Switch	14.85	1.35		
	Visual	Stay	17.17	1.36		
	Visual	Switch	18.01	1.20		
Visualization rating	Odor	Stay	5.34	0.28	3.26	.07
	Odor	Switch	4.74	0.30		
	Visual	Stay	5.65	0.29		
	Visual	Switch	5.98	0.26		
Number of cue-elicited emotions	Odor	Stay	1.98	0.11	1.36	.25
	Odor	Switch	1.96	0.11		
	Visual	Stay	1.88	0.11		
	Visual	Switch	2.07	0.10		
Cue-elicited intensity	Odor	Stay	4.44	0.43	3.42	.07
	Odor	Switch	4.48	0.43		
	Visual	Stay	4.28	0.41		
	Visual	Switch	4.63	0.45		
Memory emotional intensity	Odor	Stay	4.72	0.27	4.04	<.05
	Odor	Switch	4.12	0.26		
	Visual	Stay	4.63	0.26		
	Visual	Switch	5.10	0.28		

Note—The maximum score for painting recall accuracy is 3. The maximum score for number of cue elicited emotions is 4. The *df* for *F* values is (1,35).

Table 2
Effect of Cue Type During Encoding

	Experiment 1				Experiment 2			
Dependent Measure	Cue Type	*M*	*SE*	*t*	Cue Type	*M*	*SE*	*t*
Number of words	Odor	28.32	0.87	.58	Odor	20.96	0.60	1.46
	Visual	27.63	0.81		Verbal-Imagine	22.26	0.66	
Visualization rating	Odor	6.84	0.10	.49	Odor	7.34	0.09	1.15
	Visual	6.76	0.11		Verbal-Imagine	7.48	0.08	
Number of cue-elicited emotions	Odor	2.57	0.07	.14	Odor	2.10	0.05	1.46
	Visual	2.59	0.07		Verbal-Imagine	2.21	0.06	
Cue-elicited intensity	Odor	8.88	0.29	.41	Odor	7.25	0.23	.54
	Visual	8.72	0.28		Verbal-Imagine	7.42	0.23	
Painting emotional intensity	Odor	6.16	0.12	1.17	Odor	6.31	0.14	.94
	Visual	6.36	0.12		Verbal-Imagine	6.47	0.10	

cues for *pleasantness* and *familiarity* (1–7 scales). In almost all cases, the labels generated to odors were identical or close approximations to the experimental labels, and all labels generated to visual cues were identical to the experimental labels; cue identification between odors and visual items was not statistically different [$t(17) = 1.80$]. The t tests on the pleasantness and familiarity scales revealed no significant differences between odors and visual cues. Mean pleasantness and familiarity ratings, respectively, were 4.98 and 5.75 for odors and 4.87 and 6.11 for visual cues.

Results and Discussion

Within-subjects analyses of variance (ANOVAs) with cue type and test condition as independent variables were performed on each dependent measure. The interactions between cue type and test condition for each dependent measure are shown in Table 1. It was found that switching odor cues to their word form significantly compromised recall performance and memory emotionality, whereas switching visual cues to word form produced no decrements in memory. Post hoc comparisons (Newman–Keuls, $p < .05$) indicated that when odor cues were switched, subjects' ability to accurately recall the correct painting match to the cue was worse, there were fewer written words in the memory descriptions, and memory emotional intensity was lower than when odor cues stayed in olfactory form. However, subjects' performance on these measures, as well as all others examined, was unaffected by switching or not switching the visual cues to word form at test. These findings show that words do not necessarily become part of the odor-associated memory trace, nor is verbal coding required for recalling memories associated to odors. Rather, when odor cues were perceived, sensory codes dominated olfactory cognition. In contrast, it appears that words were activated and became part of the visual-associated memory traces.

A main effect was also observed on the visualization rating scale, showing that paintings associated to visual cues were better visualized at test ($M = 5.81$) than paintings associated to odor cues ($M = 5.04$) [$F(1,35) = 8.57$, $p < .01$]. However, the marginal interaction effect on the visualization scale ($p = .07$) suggests a trend for odors to be worse cues when switched and for visual cues to be the same regardless, which likely explains the lower general rating for odors cues on this scale.

Notably, analyses on the dependent measures obtained at the encoding session showed no significant differences as a function of cue type. That is, visual and odor cues did not produce any basic differences in the experience of the paintings during encoding.

EXPERIMENT 2

Experiment 1 demonstrated that when odors were switched to their verbal label, they were weaker memory cues than when they stayed in their olfactory form, whereas switching visual cues to their verbal label had no effect on cue efficacy. The purpose of Experiment 2 was to replicate this finding and to further examine verbal coding in olfactory cognition by assessing subjects' ability to imagine odors and the function of odor imagery in odor associated memory. Olfactory imagery was assessed by presenting the cues at encoding either in perceptual olfactory form or with verbal instructions to imagine the smell of the odor (e.g., "imagine the smell of rose") and then, at test, switching half of the cues to the alternate form (either verbal-imagine or olfactory, respectively) and keeping half of the cues the same (stay condition). Recall was examined as a function of modality and the switch–stay manipulations. In this way, both the reciprocity of mental representations between olfactory and verbal codes for odor stimuli and the ability to perceptually imagine odors could be evaluated. Because the imagine instruction was given verbally ("imagine the smell of rose"), it was presumed that the odor words (e.g., "rose") were coded verbally as well as potentially in a perceptual manner. Experiment 2 also allowed an exploration of why verbal cues were poor substitutes for odor cues in Experiment 1. It is possible that the subjects may have been trying to conjure odor images from the odor words given at the test session in Experiment 1 but were unsuccessful. Thus, Experiment 2 was both a test of odor imagery and a test of verbal coding in olfaction.

As in Experiment 1, it was hypothesized that the switch condition odor→verbal-imagine, would lead to worse performance than the stay condition odor–odor. With regard to odor imagery, it was reasoned that if sensory percepts for odor words were readily accessible, then the switch condition verbal-imagine→odor would yield equivalent performance to the stay condition verbal-imagine– verbal-imagine. However, if verbal imagery instructions did not activate odor sensory percepts, then the switch condition verbal-imagine→odor would lead to worse performance than the stay condition verbal-imagine– verbal-imagine. Because there is some suggestion that women may have greater familiarity with certain common odors and their names than men do (Cain, 1982), sex differences were also considered.

Method

Subjects. Forty-eight student volunteers (24 male and 24 female) from the University of Pennsylvania participated as subjects. Only individuals without formal training or experience in visual art and who were nonsmokers with a self-reported normal sense of smell were selected. The subjects were paid $20 at the end of the test session.

Design and Procedure. A 2 × 2 × 2 mixed design with subject sex as the between-subjects variable and cue type (odor, word) and test condition (stay, switch) as within-subjects variables was adhered to. The dependent measures and experimental procedures were the same as in Experiment 1, except that odor cues were contrasted with verbal-imagine cues. When the cue was presented in verbal-imagine form, the subjects were told to imagine the smell of the cue (e.g., "imagine the smell of coffee"). At the test session, the accuracy and emotionality of painting memory were assessed by cued recall. For half of the odor trials at test, three of the cues were presented as odors again (stay) and three were switched to verbal-imagine form (switch); for half of the verbal-imagine trials at test, three were presented this way again (stay) and three were presented as odors for the subject to smell (switch).

Results and Discussion

Mixed-design ANOVAs with subject sex as the between-subjects factor and cue type and test condition as within-subjects variables were performed on each dependent measure. Table 3 shows the means for each dependent measure as a function of the interaction of cue type × test condition. As can be seen, no statistically reliable interaction effects were obtained. However, data analyses revealed a significant main effect of test condition for every variable examined (see Table 4). In each case, performance was better when the cue stayed in the same format at test than when the format was switched. That is, regardless of whether the cue was originally in olfactory or verbal-imagine form, it was a superior reminder if presented in the same format again at test. Table 3 also shows that the main effects were due to an equal disadvantage/advantage for odors and verbal-imagine cues when they were switched relative to when they stayed the same. That is, it was equally deleterious for odors and verbal-imagine cues to change format, suggesting that verbal codes were not being generated to odor cues and that olfactory codes were not being generated to verbal cues.

Sex differences were observed on one of the emotionality measures. Females reported more cue-elicited emotions ($M = 1.63$) than did males ($M = 1.27$) [$F(1,46) = 4.39, p < .05$]. However, subject sex did not interact with cue type or test condition. Additionally, as in Experiment 1, analyses of the dependent measures obtained at the encoding session did not reveal any significant differences as a function of cue type (see Table 2).

The results from Experiment 2 replicated the findings from Experiment 1 and showed that the effectiveness of odor memory cues is diminished if odors are presented in verbal (imagine instructions) rather than in perceptual form at the time of recall. This supports the proposition

Table 3
Interaction Between Cue Type and Test Condition in Experiment 2

Dependent Measure	Cue Type	Test Condition	*M*	*SE*	*F*	*p*
Painting recall accuracy	Odor	Stay	1.38	0.07	0.08	.77
	Odor	Switch	1.11	0.08		
	Verbal-Imagine	Stay	1.20	0.07		
	Verbal-Imagine	Switch	0.98	0.08		
Number of words	Odor	Stay	10.74	0.79	0.02	.89
	Odor	Switch	8.73	0.75		
	Verbal-Imagine	Stay	10.24	0.81		
	Verbal-Imagine	Switch	8.07	0.90		
Visualization rating	Odor	Stay	5.55	0.24	0.14	.71
	Odor	Switch	4.63	0.28		
	Verbal-Imagine	Stay	5.54	0.25		
	Verbal-Imagine	Switch	4.39	0.27		
Number of cue-elicited emotions	Odor	Stay	1.51	0.09	2.65	.11
	Odor	Switch	1.43	0.10		
	Verbal-Imagine	Stay	1.61	0.08		
	Verbal-Imagine	Switch	1.25	0.09		
Cue-elicited intensity	Odor	Stay	4.30	0.22	0.31	.58
	Odor	Switch	3.65	0.25		
	Verbal-Imagine	Stay	4.30	0.23		
	Verbal-Imagine	Switch	3.35	0.25		
Memory emotional intensity	Odor	Stay	4.68	0.30	0.48	.49
	Odor	Switch	4.15	0.32		
	Verbal-Imagine	Stay	5.03	0.30		
	Verbal-Imagine	Switch	4.10	0.31		

Note—The maximum score for painting recall accuracy is 3. The maximum score for number of cue-elicited emotions is 4. The *df* for *F* values is (1,46).

Table 4
Main Effect of Test Condition in Experiment 2

Dependent Measure	Test Condition	*M*	*SE*	*F*	*p*
Painting recall accuracy	Stay	1.29	0.05	12.04	<.01
	Switch	1.04	0.05		
Number of words	Stay	10.49	0.57	10.60	<.01
	Switch	8.40	0.58		
Visualization rating	Stay	5.55	0.18	19.12	<.01
	Switch	4.51	0.19		
Number of cue-elicited emotions	Stay	1.56	0.06	6.36	<.01
	Switch	1.34	0.07		
Cue-elicited intensity	Stay	4.30	0.16	11.84	<.01
	Switch	3.50	0.16		
Memory emotional intensity	Stay	4.85	0.21	5.79	<.05
	Switch	4.12	0.22		

Note—The maximum score for painting recall accuracy is 3. The maximum score for number of cue-elicited emotions is 4. The *df* for *F* values is (1,46).

that verbal codes are not necessarily activated during odor perception, nor are they required for elaborated odor-associated memories to ensue.

On one measure, number of words, the subjects used fewer words in their memory descriptions overall than did the subjects in Experiment 1. This was because in Experiment 1, the subjects were explicitly asked to give detailed written responses, so that a rich coding scheme could be developed. This instruction was not explicitly given in Experiment 2 because the methodology had already been established. As a result, the subjects tended to give briefer descriptions in general. This difference can also be observed at the encoding sessions (see Table 2). However, despite the overall length of descriptions being shorter, the manipulation of switch–stay still had a significant effect on the length of the subjects' responses.

A second important finding from Experiment 2 was that the verbally given imagery instructions did not elicit satisfactory odor perceptual codes, at least to the degree that when the odor itself was presented it was able to elicit recall of the same quality as the original verbal-imagine cue. That is, the instruction to perceptually imagine an odor did not produce the same mental representation as the sensory perception of the odor did. This indicates that in Experiment 1, when the subjects were given the verbal form of the cue at test, perceptual odor codes were not generated and used to access the memories. Rather, it appears that the subjects relied on the verbal form of the cue to access their memories when it was given, and if the verbal form had been part of the initial memory trace, it was an effective reminder (visual cues), but if it were not a part of the original memory trace, it was an ineffective reminder (odor cues). More generally, these findings suggest (1) that odor sensory imagery does not willfully occur and/or (2) that verbal odor imagery codes do not have applicable or accessible overlap with olfactory perceptual representations.

GENERAL DISCUSSION

The data from Experiments 1 and 2 showed that switching odor cues to their verbal form decreased memory accuracy and emotional quality relative to when odors remained as olfactory sensory cues. However, when the same manipulation was done using visual cues, memory performance was unaffected. This suggests that verbal codes are neither automatically activated nor necessary for odor-associated cognition and that olfaction differs from vision in the degree of verbal coding involved in cognition representations.

An accumulating body of work indicates that olfactory processing is not highly compatible with linguistic processing (Ayabe-Kanamura et al., 1997; Engen & Ross, 1973; Herz, 1998b; Herz & Cupchik, 1992; Lawless & Cain, 1975; Lehrner, 1993). Indeed, it has recently been suggested that odor perception may actually interfere with language processing (Lorig, 1999). In several experiments, Lorig and colleagues showed that "odor and language don't seem to work well together" and that there appears to be mutual interference between odor and language-based tasks (see Lorig, 1999, for review). For example, Schott, Krauel, Pause, Sojka, and Ferstl (1994) found that olfactory responses diminished when subjects were required to attend to lyrics in a song. Lorig (1999) explained these findings with evidence suggesting neurological overlap in a region involved in timing and parsing the incoming sensory stream and argued that when the brain is faced with simultaneous olfactory and linguistic signals, interference occurs.

In addition to showing that switching odor cues to their verbal form compromised memory ability, Experiment 2 demonstrated that olfactory perceptual codes were not generated in response to verbal instructions to imagine the smell of a particular odorant. If they had been, the instruction "imagine the smell of rose" should have led the subjects to do as well in the switch condition verbal-imagine→odor, as in the stay condition verbal-imagine–verbal-imagine (viz. the verbal→ visual manipulation in Experiment 1). The fact that the subjects did worse in the switch condition supports previous reports indicating a weak or nonexistent capacity for untrained subjects (e.g., people who are not perfumers or wine experts) to perceptually image odors (e.g., Crowder & Schab, 1995; Herz, 1996) and again demonstrates a contrast with vision where the experiential and neural overlap between perception and imagery has been shown to be quite high (Farah, 1989; see Finke 1989, for a general discussion). There was, however, no baseline condition in Experiment 2 for elaboration of the verbal dimension of an odor word (e.g., "rose") without a potential odor dimension being invoked, as the imagery instructions were aimed at doing. Thus, it is not currently possible to conclusively determine whether any odor imagery was in fact taking place. One way to help disentangle this issue would be to evaluate the differences between odor imagery and the semantic processing of odor words with methods that clearly delineate whether or not odor imagery is accessible.

Notably, odor imagery experiments to date have involved nonexpert subjects. However, it is possible that expert "noses," such as perfumers and wine connoisseurs may have learned to form olfactory sensory representations as a result of training experience and thus may differ from the average person in both their experiential and their neurological representation of olfaction. This supposition is anecdotally supported by claims from experts who say that they are able to conjure perceptual images of smells that are equivalent to their olfactory experiences of the same odors (Ron Winnegrad, Senior Perfumer, Creations Aromatiques, personal communication, May 13, 1999). Brain imaging and implicit memory experiments comparing experts with nonexpert subjects on olfactory imagery tasks would help to determine the veridicality of such claims and would greatly inform the relationship between imagery, perception, and neural representation in olfaction.

The finding in Experiment 2 that females reported more emotions to the cues at test is consistent with literature that females are generally more sensitive to and express more emotion than do males (e.g., Grossman & Wood, 1993; Trobst, Collins, & Embree, 1994; Tucker & Friedman, 1993). However, female responses were not modulated by cue type. More importantly, accuracy/fluency measures of memory and the switch–stay manipulation were unaffected by subject sex. Thus, even though women may be more familiar and better able to name common odorants than males (Cain, 1982; Engen, 1987), this ability did not lead female subjects to be any better at verbally coding odors than males. This lack of effect provides further evidence that odors are processed independently of verbal representations (Lehrner, 1993).

A subtle but important finding was that, in both experiments, the differences that emerged on the dependent measures at the test sessions were unaffected by cue type during the encoding sessions. That is, mere exposure to a particular type of sensory stimulus (odor, visual, verbal) did not influence the subjects' direct experiences of the paintings but did affect the encoding-retrieval process in the generation (or not) of verbal codes.

The argument has been made that olfactory cognition is distinct from cognitive processing mediated through the other senses (Herz & Engen, 1996). The limited and different linguistic representation of olfaction is one of the defining characteristics of this difference (see Herz & Engen, 1996, for review). The present research showed that verbal coding of olfactory experience is both nonintegral and independent of olfactory perceptual processing. This result is even more notable given the favorable conditions for the activation of verbal codes in the present experiments (very familiar stimuli with clear name identities). The present findings substantiate prior evidence that olfaction is not well connected or compatible with linguistic processing especially when compared with other sensory experiences (e.g., vision) and lend further credence to the proposition that olfaction is a unique sensory-cognitive system.

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APPENDIX A
12 Associated Cues

	Odor Cue	Visual Cue	Verbal-Imagine Cue
1	Cinnamon bark (10%)*	Cinnamon spice bottle + stick	cinnamon
2	Coppertone spf4	Coppertone bottle (label removed)	suntan lotion
3	Nestle semi-sweet chips	Bakers Dark Chocolate sq.	chocolate
4	Folgers Aroma Roasted coffee	Coffee beans	coffee
5	Peppermint (10% in DEP)*	White–Red hard candies	peppermint
6	Banana (real fruit)	Plastic banana	banana
7	J & J baby powder	J & J bottle (label removed)	baby powder
8	Ivory soap (bar)	Ivory soap bar	ivory soap
9	Apple (real fruit)	Plastic apple	apple
10	McCormick Pure Anise Extract	Black Twizlers	licorice
11	Jiff Peanut Butter	Peanut Butter jar (label removed)	peanut butter
12	Rose (10%)*	Silk red rose with stem	rose

*Aromachemical supplied by International Flavors and Fragrances.

APPENDIX B
12 To-Be-Remembered Paintings

Artist	Experimental Title	Actual Title
Klimt	The Kiss	The Kiss
Vermeer	The First Encore	Girl with Guitar
Tissot	The Grand Entrance	L'Ambiteuse
Manet	Lazy Days of Summer	House at Rueil
Robson	Winter Wonderland	Heading Home
Renoir	The Garden Party	Luncheon of the Boating Party
Boucher	Breakfast Game	The Breakfast
Miller	Jenny and Her Puppies	Springtime
Ruysdaele	Country Scene in Holland	Landscape with Windmill
Loates	Best Friends	Courtship
Kuck	Mother and Child	Daydreaming
Murrillo	While We Watched	A Girl and her Duena

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