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Sharing an olfactory experience: The impact of oral communication

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A B S T R A C T

The way odors are verbally coded in many languages is not very efficient for successful intersubjective communication. Nevertheless, some types of verbalization seem to facilitate the sharing of an olfactory experience. The experiment reported here was aimed at gaining a better understanding of how successful oral communication in the domain of olfaction works. It was hypothesized that oral description of odors enhances the recognition of olfactory stimuli that match the description. The experimental situation involved two participants, one of whom (sender) smelled and orally described an odorant to the other person (receiver) who had to recognize it. Qualitative analyses (verbal) from the communication phase and quantitative analyses (recognition rate) from the recognition phase were made. The line of study of the participants (18 chemistry students and 18 humanities students) and the type-of-odorant used had no effect on the recognition rate. On the other hand, as the number of trials increased, a slight but still statistically significant interaction between participant sex and odor-recognition rate was observed. The qualitative analysis showed that the oral communication revolved mainly around five types of description - known source, odor intensity, hedonistic valence, odorant property, and odorant effect – and that the use of too many of these descriptors reduces performance. Descriptions were based on associations and fuzzy categories, they were related to the body, occasionally contained references to other senses (sight, touch, and taste), and could exhibit considerable self-confidence, even on trials that ended in a recognition failure. These findings support the idea that one and the same scent-bearing substance can be subject to highly diverse cognitive processing.

1. Introduction

According to a number of psycholinguistic studies, odor perception is an individual phenomenon, highly encapsulated in the subjectivity of autobiographical memory (Chu & Downes, 2000). It seems, in Western societies at least, that odors – unlike colors – were not constructed collectively via negotiation of a shared meaning during verbal interaction (Dubois & Rouby, 1997). According to Schaal (2004), it is as if "the acquisition of chemical sensory knowledge were the random outcome of personal experiences". Does this mean that this object escapes all intersubjectivity? The literature on this topic refutes this claim. First, because the olfactory system is highly phylogenetically programmed (Kratz, Dugas, & Ngai, 2002), some olfactory perceptions can be shared by all humans. Secondly, numerous publications have demonstrated the existence of differences in olfactory perception across groups (Candau, 2004; Chrea et al., 2004; Classen, 1993, 1997; Classen, Howes, & Synnott, 1994) and even across countries (Gilbert & Wysocki, 1987), sometimes with slight variation (Chrea, Valentin, Sulmont-Rossé, Hoang Nuguyen, & Abdi, 2005). Not only odor-related processes such as hedonistic evaluation, naming, and memory storage (Candau, 2001) but also olfactory tolerance thresholds are determined socially, culturally, and historically (Corbin, 1986), notably in the food-related odor register. Accordingly, different ways of sharing olfactory experience are beyond doubt.

However, much more still than in the general field of shared cognition – finding out "how two minds shape each other mutually through reciprocal interactions" (Frith & Wolpert, 2004) – the true nature of olfactory cognition remains mysterious. The overly

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general explanations given in many theories that bring "social frameworks" or "cultural influences" to bear do not provide a concrete understanding of exactly how and to what extent individuals are able (or unable) to share an olfactory experience: is it by way of identical reactions to the same stimuli, reliance upon a shared terminology, similar meanings assigned to descriptors, and so forth? We contend that by studying the verbal coding of olfactory experience, we will be able to improve our understanding of how such experiences are shared. This assumption is not trivial, given the characteristics of this verbal coding.

Clearly, coding of odors poses a genuine cognitive challenge, for a number of reasons. First of all, the French language, like many of others, does not have a precise, unchanging vocabulary for odors as it does for colors (lack of "basic terms": Berlin & Kay, 1969). Secondly, our olfactory perceptions, just like our other sensory perceptions, fall along a continuum that is not easy to describe in a language made up of discrete units. Moreover, the categorization system of odors is a fuzzy one, at least as far as its linguistic description is concerned. Not only is the distinction between category and exemplar poorly defined – we often find the same name being proposed for "type" and "token" responses (David, 1997) – but we also frequently see the meaning of the term "odor" overlapping with that of the scent-bearing object. The odor, which is the cognitive representation of the odorant, is usually confounded with the odorant itself, which adds to the imprecision of the description. What we call the "odor of a rose", for instance, is in fact the effect of the odoriferous mixture of chemical substances on a person who smells it. In this case, while the olfactory descriptor refers explicitly to the scent-bearing source, what really is described is the subjective quality of this substance. This is certainly true for other perceptual systems as well. Most people take the internal representation of the outside world (perception) to be the same as the outside world (stimuli). However, what is specific in olfactory perception is the very usual confusion in the internal representation between *two* different entities of the outside world: the direct origin of stimuli (the odoriferous volatile molecules emitted by the source and transported to the olfactory epithelium by the inhaled air flow) and their indirect origin (the scent-bearing source). It would be more accurate indeed to speak of "the odor of the odoriferous molecules emanating from the rose". This shift in meaning questions what the common sense sees as obvious: that words refer directly to the things they name. This idea underlies Dubois and Rouby's remark that "whether or not and how these two entities (material and mental) overlap remains one of the important questions (if not *the* question) for olfactory research" (Dubois & Rouby, 2002). In the end, given the instability of the natural language of odors, speakers trying to communicate their subjective representations of scent-bearing molecules "make do with what's available" (Dubois & Rouby, 2002), even professional perfumers and flavorists, despite their efforts to optimize this kind of communication. Although written up by trained specialists, the descriptions found in specialized publications or in catalogues of chemical products are highly inconsistent. In a recent study, Pintore et al. (2006) compared the odorous characteristics of various common compounds found in two major databases deemed to be the authorities in the field (Arctander, 1960, 1969; PMP, 2001), each containing about 2600 compounds. Based on a comparison of the 923 compounds present in both databases, the authors noted that 40% were described by totally different olfactory profiles, 58% shared at least one descriptor, and a mere 2% were described in exactly the same way.

In spite of these characteristics of the verbal coding of odors, all of which appear to be obstacles to successful intersubjective communication, it is nevertheless generally acknowledged, both in daily life and in experimental settings, that there exists a "process of fitting to the perceptual representation" at the individual level, and also an intersubjective negotiation for "sharing subjective experiences" (David, 1997). It is the elaboration of these shared cognitive representations that we will study here via the experiment described below. Our hypothesis is that oral description of odors enhances the recognition of olfactory stimuli that match the description. The aim of the work is to gain a better understanding of linguistic factors that contribute to the success of an oral communication in the domain of olfaction. This goal is pursued on the basis of the analysis of recorded dialogues between sending and receiving participants. In these dialogues, we try to identify the types of verbalizations which facilitate the recognition and hence the sharing of a sensory experience.

2. Methods

2.1. Participants

Thirty-six volunteer participants (11 men and 25 women, mean age 24) were recruited at the University of Nice-Sophia Antipolis, France. Subjects gave written informed consent. The experiment was not intrusive and was considered by the ethic committee on human experimentation as not requiring formal approval. Sex was not taken into account in the experimental design, however it was considered a posteriori to check whether some individual differences due to sex may explain the identification rate.

Subjects were divided into two groups according to their line of study (18 chemistry majors, 18 humanities majors). The rationale for choosing two groups was the following. The substances used in the experiment are "pure chemical substances" including representative substances of chemical families such as esters, amines, and sulfides that "chemistry" students have probably being exposed to during their laboratory work, while this possibility is very low for "humanities" students. Since it is generally considered that familiarity to an odorant is an important factor for its recognition, it was a priori sought that "chemistry" students could perform better than "humanities" students. The participants in each group were asked to choose a partner so that each member of the pair could act alternately as the sender or the receiver.

2.2. Stimuli

The experimental material was comprised of a set of 12 odorants (Table 1) selected on the basis of their spatial location in Jean-Noël Jaubert's classification (Jaubert, Tapiero, & Dore, 1995). According to this classification (generated from the responses of a panel of judges whose sensitivity to odors had been verified), the olfactory space is represented by 45 basic chemical compounds whose smell is considered prototypic of a class of odors. This space has six principal poles (amino, hesperidian, terpenic, sulphurous, pyrogenic, and sweet), that allow positioning of the 45 compounds relative to each other. The olfactory space is multidimensional, but in exchange for certain distortions, it can be represented as a two-dimensional map (called the field of odors) onto which the refer-

Table 1
Odorants used for the experiment.

	Far (Series F)		Close (Series C)
1	Citral (5%)	7	Cyclopentanone (10%)
2	Isobutyl amine (1%)	8	γ-Undecalactone (1%)
3	Coumarin (5%)	9	Benzyl acetate (5%)
4	α-Pinene (10%)	10	4-(4-Hydroxyphenyl)-2-butanone (5%)
5	2-Acetyl pyrazine (0.5%)	11	Methyl anthranylate (1%)
6	Dimethyl disulfide (0.01%)	12	Ethyl phenylacetate (1%)

Test solutions were prepared from pure chemicals diluted to 10% in alcohol and then diluted in water to the concentrations (percentages) given in the Table.

ence molecules are projected. For the experiment reported here, six compounds located far apart in the field of odors, i.e., ones whose odors are considered very different, were chosen for the first group of odorants (the six poles mentioned above), called Series F (F for far). The second group, called Series C (C for close), contained six odorants whose projections onto the field of odors were all close to the same pole. The latter odorants were assumed to smell more alike, and thus to be more difficult to recognize and more likely to be confused.

The test solutions were prepared from pure chemicals diluted to 10% in alcohol and then diluted in water to the concentrations (percentages) given in Table 1 in compliance with the Agence Française de Normalisation (AFNOR) recommendations which has established "standards" for odorants to be used in training panelists in sensory analysis (AFNOR, 1989). Although the possibility that alcohol might interfere with the odor of the compounds in solution cannot be excluded, the concentrations were tested in advance by 12 judges to make sure that the odors would be weak but clearly detectable. Half a milliliter of each test solution was put in an amber-colored glass bottle numbered underneath (3 digit code) containing a piece of cotton batting. The bottles were closed and kept at room temperature for at least 15 min before the experiment started.

2.3. Procedure

The procedure of the experiment proper consisted of two phases: a communication phase and a recognition phase. To begin, the experimenter described the experimental situation: the participants were told that the goal was to recognize odors on the basis of oral description: each participant would play in turn the role of the sender who describes, and of the receiver who needs to recognize the odor. The participants then had to choose a partner and to agree on who first acts as the sender, the other being the receiver. The experimenters presented the odorants (hereafter called target odorants) that were to be described by the senders one at a time, by series (e.g., six far odorants then six close odorants). The presentation order of the odorant series and of the odorants within the series was counterbalanced across participants according to a Latin-Square design.

The experiment was run in a room equipped with booths for the sensory analysis in compliance with AFNOR norm V 09-105 (AFNOR, 1987). In the booth, the sending subjects (S) sniffed the sample via short inhalations while holding the open bottle at a distance of about 5 cm from their nostrils. Thirty seconds was allotted for this phase, after which the senders had to describe their olfactory perception to the receiving subjects (*R*) located on the other side of the partition that separated the booths into two parts.

The sending subjects were free to describe the odorant in any way desired (except for the fact that they were not supposed to disclose the chemical term that only experts may know) and could use whatever linguistic expressions and devices they needed (metaphors, periphrases, and so forth). During the communication phase, the receiving subjects could converse with the senders through a window. Receivers were instructed to prompt the speakers in an attempt to make the description as clear as possible and facilitate recognition of the target odorant. The dialogue, which lasted 1 min, was recorded and included in the linguistic corpus for later analysis.

The odorant recognition phase began immediately afterwards. The receivers were given six bottles all at once (containing either the six Series F odorants or the six Series C odorants). Their task was to state which one contained the target odorant that the senders had just described. The receiving subjects could open each bottle only once, but could smell the odorant as many times as they wanted to. Next they reported the result of the recognition on an answer sheet by writing down the number of the bottle they thought contained the target odorant just described. Finally, they rated their degree of confidence in their answer on a 5-point scale ranging from 1 (not sure at all) to 5 (absolutely sure). No feedback about response accuracy was given.

The experimental procedure was repeated for the 12 target odorants, which were presented in two blocks so the participants could change roles. After the recognition task on one of the two series, the sending subjects became the receiving subjects, and vice versa. The same individual was thus the sender of one series and the receiver of the other, in either the close/far or far/close odorant order.

To be sure that the errors made during the oral communication experiment were not due to an intrinsic difficulty discriminating the odors of the target substances selected, we conducted a control experiment with a group of 10 volunteer subjects (six men and four women, mean age 21.3) who were science majors at the University of Nice-Sophia Antipolis. The stimuli and operating conditions were the same as in the actual experiment. The subjects had 30 s to sniff the odorant presented by the experimenter. One minute later (the communication time in the experiment proper) they had to recognize the odorant among a set of six odorants in bottles presented all at once. As in the recognition phase of the oral communication experiment, the subjects were allowed to smell each bottle only once (no time limit for smelling) before responding. For the odorants in Series F, only one error was made (2-acetyl pyrazine was confused with isobutyl amine). For Series C, there were nine errors (four by the same subject), making for a total of only 10 errors in 120 trials (8.3%). Thus it is reasonable to believe that the high number of errors in the actual experiment (114 in 216 trials, or 52.8%) was not due to an intrinsic difficulty in discriminating the odors of the target substances.

2.4. Analysis

The quantitative analysis mainly concerns the recognition phase, and includes the odorant recognition rate and the receiving subjects' confidence levels in their responses. The recognition rate was defined as a percentage by dividing the sum of correct recognition responses by the theoretically possible number of correct responses for all target odorants (i.e., 6). The mean degree of confidence was calculated by averaging the 5-point scale ratings for all target odorants. Each measure was processed in an analysis of variance (ANOVA), using the participants ($F1$) or the odorant stimuli ($F2$) as the random factor. The ANOVAs were computed with the line of study (chemistry vs. humanities), sex (male vs. female), and odorant distance (far vs. close) as between-subject factors.

3. Results

3.1. Dissimilarity measurement

Tables 2a and 2b show two confusion matrices that cross the subject's record of responses to the odorants presented (stimulus vs. responses). Tallies (responses) on the main diagonal represent correct recognition, and tallies on the off-diagonal represent misrecognitions. From these two matrices, individual differences can be quantified using the OCM (Odorant Confusion Matrix) dissimilarity measure (Kurtz, White, Sheehe, Hornung, & Kent, 2001; Kurtz et al., 2000), which leads to Fig. 1. There was no significant effect of odorant distance, but a significant interaction between the type-of-odorants and their distance (far/close), $F(5,17) = 335.29$, $p < .001$. As shown in Fig. 1, the individual differences as indicated by the dissimilarity index are significantly higher for

Table 2a
Number of responses of each type for Series F compounds.

		Response					
		1	2	3	4	5	6
Stimulus	1	12	0	2	3	1	0
	2	1	4	2	0	3	8
	3	0	2	11	3	2	0
	4	5	1	1	9	1	1
	5	2	4	0	1	8	3
	6	0	5	2	2	6	3

Table 2b
Number of responses of each type for Series C compounds.

		Response					
		7	8	9	10	11	12
Stimulus	7	11	0	1	0	4	2
	8	1	10	2	0	1	4
	9	1	3	10	1	2	1
	10	0	3	1	11	2	1
	11	4	1	3	1	5	4
	12	2	1	3	1	3	8

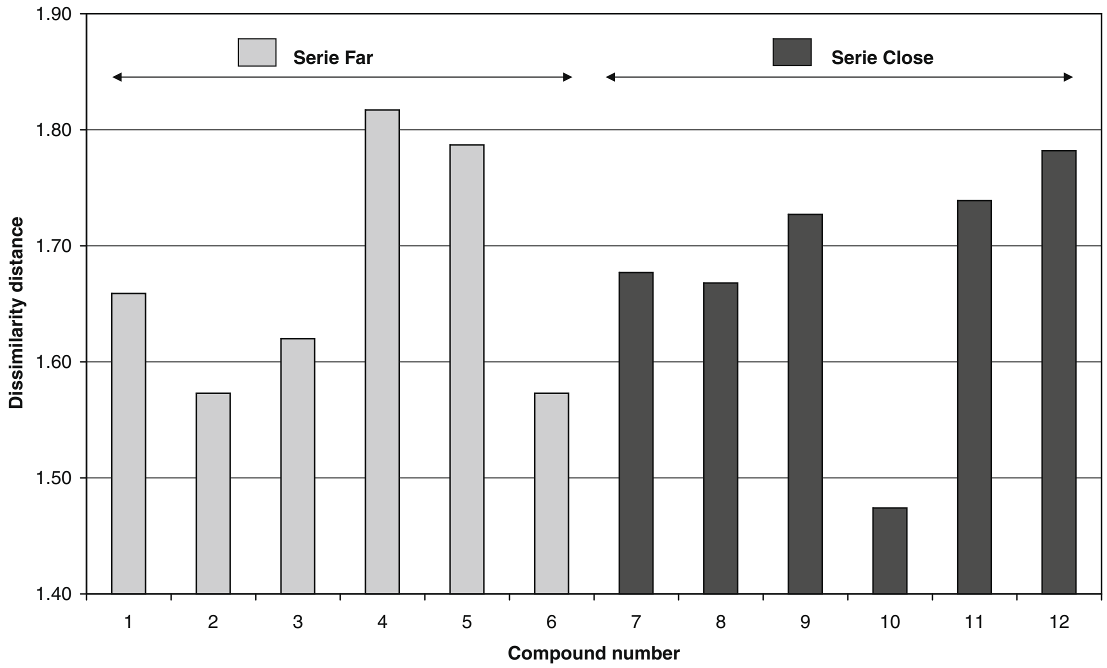

Fig. 1. Dissimilarity distance for the 12 components distributed by series far (light gray) and close (black).

alphapinene, 2-acetylpyrazine (far components), $F(1,34) = 1257.29$, $p < .001$, and for methyl anthranylate and ethyl phenylacetate (close components), $F(1,34) = 522.1$, $p < .001$.

3.2. Characterization of the verbal descriptions

We checked to see whether the recognition was significantly correlated with the description length. No correlation was found for the total duration: the mean dialogue length was 52 s for dialogues with recognition and 56 s for dialogues without recognition. There were no significant correlations either when the total description length was divided into 10-s intervals.

The qualitative analysis showed that the dialogues between senders and receivers revolved around five types of description. We took into account only the most frequent types in our corpus, which are also those that are most often quoted in the relevant literature: reference to a known source that was supposed to be a possible origin (mentioned in 91.2% of the dialogues), odor intensity (70.8%), hedonistic valence (50.0%), intrinsic odor property (37.5%), and odorant effect on the smelling subject (27.3%). The origin is usually expressed by means of nouns (Ça sent la *menthe*./It smells like *mint*) or adjectives (Ça fait un peu *boisé*, j'ai trouvé./I think it's rather a *woody* scent), the intensity by means of adjectives and adverbs (Ça sent *fort*./It smells *strong*), the hedonistic

Table 3
Wrong and correct recognition categorized with respect to the presence of five descriptive items in the dialogs.

	Descriptive items					
	Dialogs	Source	Intensity	Hedonistic	Property	Effect
Wrong recognition	114	107	85	57	51	34
Correct recognition	102	90	68	51	45	25
Total	216	197	153	108	96	59
	Percentage	0.91	0.71	0.50	0.44	0.27
	Chi-square	2.12	1.62	0.00	0.01	0.77
	p	0.15	0.20	1.00	0.93	0.38

valence also by means of adjectives and adverbs (Ça sen*t bon, mauvais*…/It smells *good, unpleasant*…), the intrinsic odor properties by means of adjectives (Une odeur *lourde, légère*…/A *heavy, light*… scent), whereas the effect on the smelling subject is almost always described by verbs (*Ça prend le nez/It grabs your nose*).

3.3. Recognition rate

A putative difference between successful recognition and the presence in the verbal description of either type of descriptions was evaluated by calculating of the chi square index. Results are given in Table 3. None of the categories proved to be a statistically significant factor for success. On the other hand, a significant negative correlation between the number of descriptive elements (known source, odor intensity, hedonistic valence, odorant property, and odorant effect) that is used by the sender in the verbal description and the recognition rate was observed. ($r = -0.113$, $p = 0.05$). That is, the recognition rate was lower when participants used a greater number of descriptive elements.

The line of study, the odorant distance and sex did not have a significant effect on the recognition rate. The recognition rate was neither correlated along trials. From trial 1 to 6, the correlation coefficients were, respectively: trial 1–2 ($R(36)=-0.09$ ns); trial 2–3 ($R(36) = 0.05$ ns); trial 3–4 ($R(36) = 0.35$; $p < .05$); trial 4–5 ($R(36) = -0.06$ ns); trial 5–6 ($R(36) = 0.06$ ns). Even though trials were realized by the same participants and with a limited set of odorants, this absence of correlation (except for trial 3–4) showed a striking independence of responses given by participants. As a consequence, we included the number of trials as within-subjects factor into the ANOVA. There was a significant interaction between sex and trials on correct-odor-recognition $F1(5,14) = 2.70$, $p < .025$. Fig. 2 uses trend lines to illustrate this interaction, and planned comparisons of this interaction showed that the recognition rate increased significantly for women as a function of the trial number ($F1(5,24) = 3.49$, $p = .01$), while the difference was not significant for men ($F = 1.26$ ns).

Fig. 3 illustrates the differences between the recognition rates of the various odorants. The type-of-odorant ANOVA ($F2$) indicated extensive recognition variability across odorants, with a significantly higher recognition rate for the following compounds: citral (No. 1, 66.7%) which was best recognized, coumarin (No. 3, 61%), cyclopentanone (No. 7, 61%), 4-(4-hydroxyphenyl)-2-butanone (No. 10, 61%), γ-undecalactone (No. 8, 56%), benzyl acetate (No. 9, 56%), α-pinene (No. 4, 50%), 2-acetyl pyrazine (No. 5, 44%), and ethyl phenylacetate (No. 12, 44%), $F(5,80) = 2.73$, $p < .025$. By contrast, the recognition rate was not significantly above chance for methyl anthranylate (No. 11, 28%), isobutyl amine (No. 2, 22%), or dimethyl disulfide (No. 6, 17%), $F < 1$.

3.4. Degree of confidence in responses

Although in 37.5% of the dialogues the sender made explicit mention of his/her doubt or incapacity to find the words to describe the odor, he/she manifested considerable self-confidence in many cases (20.8%), even on trials that ended in a recognition failure (42.3% of these cases).

The confidence-level analysis yielded no main effects of the factors tested. However, there was a significant two-way interaction between line of study, odorant distance, and participant sex, $F1(1,28) = 4.9$, $p < .05$: the confidence level of the male chemistry students was significantly higher for the far odorants (Series F) than for the close ones (Series C), $F1(1,28) = 6.81$, $p < .025$.

Finally, there was a relationship between recognition rate and confidence level: the confidence levels were significantly higher

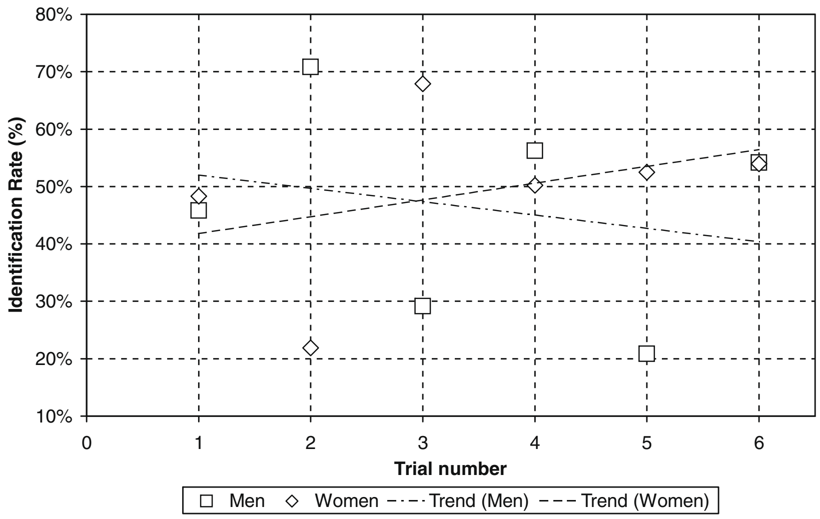

Fig. 2. Mean recognition rate (with trend curves) by trial number and participant sex.

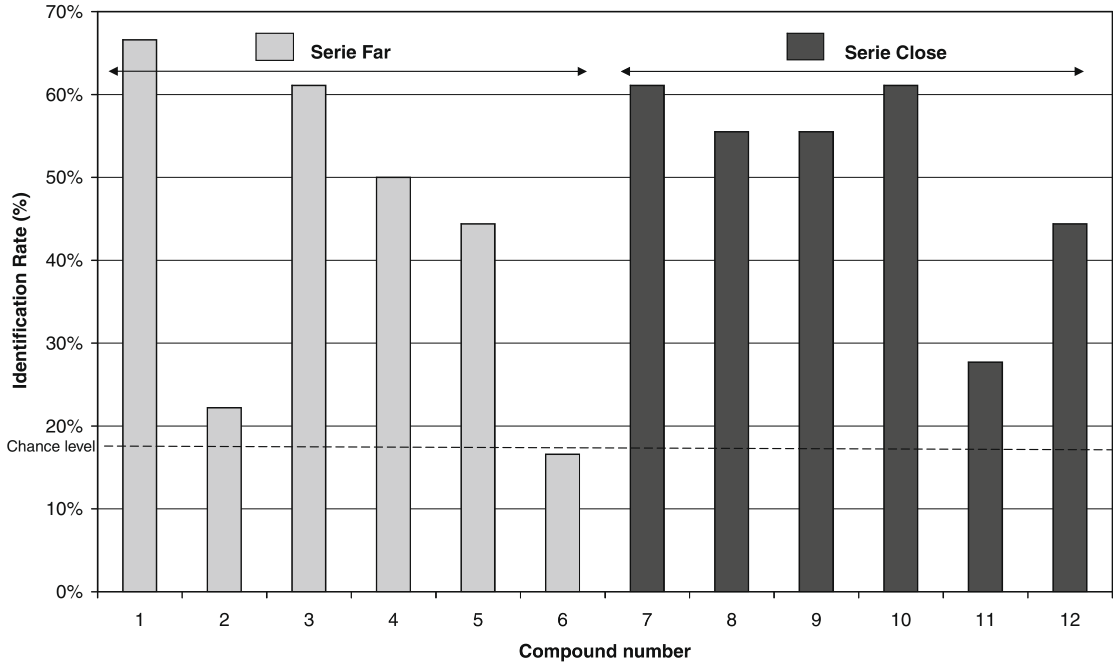

Fig. 3. Mean recognition rate, by type of olfactory stimulus. The grey section corresponds to the area where the responses did not differ significantly from the chance level, set at 17% (1 of 6).

when the participants recognized the odorants than when they failed to do so, $t(10) = 4.11$, $p < .01$.

4. Discussion

4.1. Chancy communication and recognition

Humans are not poor smellers (microsmats) but rather relatively good, sometimes even excellent smellers (macrosmats) (Ditzen, Pellegrino, Leslie, & Vosshall, 2008; Porter et al., 2007; Shepherd, 2004). But it does not mean they are able to describe their olfactory sensations (Cain & Potts, 1996; Hughson & Boakes, 2002; Lehrner, Glück, & Laska, 1999; Solomon, 1991). Furthermore, prior research has shown that if "expertise" in ability to recognize odors (Chollet, Valentin, & Abdi, 2005; Lawless, 1984) is often paired with a superior skill to name them, this is not always the case (Parr, Heatherbell, & White, 2002). In the following examples, our data show the unexpected character of some of the descriptions made by the participants, no matter what their major line of study (chemistry or humanities). Many of the recognition failures mentioned can be ascribed to these unexpected descriptions.

Among the substances that were used in the experiment, citral is undoubtedly the most interesting case, because it has almost the same odor as lemon and is therefore easy to recognize. With 12 correct answers out of 19 (63.2%), it was indeed – besides coumarin – the best-recognized substance. In all 12 cases where citral was correctly recognized, the sender mentioned the expected French descriptor *citron* (lemon) or a cognate of it such as *citronné* (lemony) or *citronnelle* (lemon balm). In the seven cases of misrecognition, the word *citron* occurs only once. In 3 of the 6 other dialogues where citral was not correctly recognized, the sender mentions a *fruity* scent and says the substance smells like chewing-gum. This description may be correct, but is visibly too vague and therefore causes the misrecognition. In the three remaining cases, the descriptions are obviously unexpected. In one case, for instance, citral was qualified as an unpleasant odor. For this sender, it evoked odors of feet, animals, Camembert cheese, and a field of cows. It would certainly be off the mark to say that the sender correctly recognized citral, but did not find the relevant descriptive terms. The error lies obviously in the unexpected perception of the substance by the sender. Moreover, the description by the sender surprisingly led the receiver to choose α-pinene, the substance that is generally associated with a resinous odor. These observations regarding citral are compatible with the conclusions of Cain and Potts (1996). That is, recognition failure can be due to inadequate description as well as to perceptual errors either by the sender or by the receiver. However, citral is a very particular substance, because it has a very familiar odor. The other substances used in our experiment are not so easy to recognize and to describe. In these cases, it is therefore more difficult to know whether a failure is due to unexpected perception or to inadequate description.

For instance, in a dialogue where the stimulus was 2-acetyl pyrazine, the sender communicated the odor in the following way: "It smells like a good smell before eating... yeah the smell of a dish before eating", which could have led the receiver to the recognition (the smell of something grilled or cooked, considered characteristic of 2-acetyl pyrazine). It is hard to understand why then, based on this description, the receiver chose α-pinene, even if the qualifier "good smell" might be misleading. Moreover, in the sixty descriptions obtained for the odor of α-pinene, only two referred explicitly to a food-related smell, namely, "*bonbon*" (candy) and "*melon*" (melon).

The loose and volatile nature of the language of odors was further confirmed in nearly every dialogue by the use of conditional phrases like "I'd say", and especially by recourse to expressions like "a little" and "a little bit", sequences such as "no no, yes, perhaps", the high frequency of "not too much", "it's more like", "a touch of", "a kind of", "it might be", "slightly", and so forth. All of these rhetorical tools – conditional assertions, modifying lexemes that narrow down the description, recasts to take back and correct what was said – illustrate how difficult it is to describe and communicate these odorants. Another indication of this complexity was the use of very personal, often detailed images and highly specific memories such as "slightly old, grated Parmesan cheese", "the smell of old metal" or "a wet towel", "rain that's hit the ground, when it's a little hot and all...", "it smells like waking up in the morning", "those black rain worms", "little vanilla perfumes, I mean, little perfumes... but not vanilla; those little perfumes they make sometimes where you smelled moss", a smell "that's not human at all", or "more like having to do with love", and so forth. As was mentioned above, the recognition rate was lower for these very detailed metaphors.

4.2. Communication and recognition around familiarity, intensity, and hedonistic valence

It is reasonable to consider that the substances which are the most easily recognized are those whose odors are (i) the most familiar (Cain, 1979), (ii) the strongest, and (iii) explicitly situated in the hedonistic space, and that any combination of these three factors might further increase the likelihood of correct identification. It is trivial to recall that usually, habitual stimuli are more easily recognized than rare ones. Actually, among the substances used for the experiment, the only one that can be considered familiar is citral, a food odor which, as we have seen, was the top-recognized substance. On the other hand, while the hypothesis that the chemistry majors might be more accustomed to the stimuli than the social science students seems plausible, no difference was found in the performance of these two groups other than the fact that the former made greater use of technical terminology than the latter.

Concerning the other two criteria – strength (strong vs. weak odors) and hedonistic valence (pleasant vs. unpleasant odors) – they are not always easy to distinguish: being somewhat fuzzy, the associated categories overlap. When a person says that an odor "stings your nose", is he/she talking about its strength or its unpleasantness? Looking solely at the data for the hedonistic criterion, we can see that (i) this criterion was used in 50% of the dialogues, (ii) the list of hedonistic descriptors was limited to relatively few items: "bon" (good), "mal" (bad), "agréable" (pleasant), "désagréable" (unpleasant), "doux" (sweet), "aimer" (to like), (iii) these descriptors were distributed more evenly throughout the corpus than object words were, and (iv) the use of hedonistic descriptors did not have a statistical significant effect on the correct recognition rate (see Table 3).

When citral (the top-recognized compound) was the target substance, the pleasantness or unpleasantness of the odor was practically never mentioned, unlike three other compounds, isobutyl amine, 2-acetyl pyrazine, and dimethyl disulfide, which were more difficult to recognize but for which this aspect was omnipresent in all dialogues, where these substances were qualified as unpleasant (Table 4). One can conclude that when there exists a common referent that is sufficiently frequent and easily recognizable – in this case, the lemon – successful communication is achieved via that referent, without the need to rely on the hedonistic value of the odor, and without the need for periphrases. This did not always hold true here, however. For isobutyl amine, only one of the four correct answers resulted from the use of an everyday referent ("dirty socks").

The importance of the hedonistic criterion may have another explanation. Ethnographic surveys (Candau, 2000; Candau & Jeanjean, 2006) suggest that "strong" olfactory stimuli such as the ones described using expressions like "*qui pique*" (that stings), "*accroche*" (is catching), "*prend le nez*" (grabs your nose), "*prend la tête*" (headache-provoking), "*entête*" (goes to your head), and so on, are more readily verbalized (and recognized) than others. And we also have every reason to assume that our sense of smell is naturally (Anderson et al., 2003; Bensafi et al., 2001, 2003; Kosslyn, 2003) inclined to distinguish odors considered "pleasant" from odors considered "unpleasant". This is plausibly an adaptive phenomenon (Hamann, 2003; Shah, Ben-Shahar, Moninger, Kline, & Welsh, 2009). It is in our best interest to rapidly detect bad odors so that we can immediately get away from them in case they are toxic, or emanate from toxic products as, for instance, putrid food (Prescott, 2004). Although the connection we make between stenches and toxicity is not a direct causal link, it is nonetheless real from the statistical standpoint (Holley, 1999). This being the case, it is preferable – as in many other domains of cognition (Sperber & Hirschfeld, 2004) – to overestimate the risk than to underestimate it. In our case, it is better to be overly sensitive to a bad odor than to ignore an ill-smelling signal that is in fact toxic.

4.3. Communication and recognition related to the body

It is highly probable that the experimental context prompted participants to avoid certain words that were felt to be vulgar or too intimate when body odors are at stake. Nevertheless participants have often made use of this categorization. For the subjects in our experiment, the smell of the body was a perceptual anchoring point whenever the stimulus was considered unpleasant. Isobutyl amine, which "doesn't smell good", was said to smell like perspiration and feet, even if for one participant this substance only had "a little foot odor", and so were ethyl phenylacetate, said to smell like "unclean feet", and dimethyl disulfide, which in addition was said to smell "a little" like "shit" or perspiration, along with 2-acetyl pyrazine. In the same body-related odor category, several subjects perceived certain substances (2-acetyl pyrazine, isobutyl amine, and dimethyl disulfide) as smelling like dirty socks, "you know, as if they were two days old". References to bodily smells promoted recognition in some cases (there were many such references, for example, in the eight recognitions of 2-acetyl pyrazine), but this effect was not systematic: recognition failures occurred even when the description suggested that the odor had violent effects on the body. "I felt like vomiting when I smelled it", said one participant in regards to dimethyl disulfide; this description did not help the receiver, however, who erroneously recognized coumarin.

4.4. Communication and recognition based on associations

In quite a large number of cases, the errors can be ascribed to meaning transfer, associations, or evocations, as in the following dialogue about isobutyl amine, incorrectly recognized as 2-acetyl pyrazine. The sender began with a reference to food, "Vaguely, you might say it's a little bit like an oriental dish [...] like an oriental dish with a little rice, a little sauce, you know, a sauce with a weird taste." A possible explanation for this confusion is that the odor of isobutyl amine is often associated with the smell of fish (usually not fresh), which could bring to mind the fish sauce used in oriental cooking. Added to this is the fact that 2-acetyl pyrazine

Table 4
Hedonistic criterion explicitly used by the senders for three compounds.

	Isobutyl amine	2-Acetyl pyrazine	Dimethyl disulfide
Very weak odor or not perceived	3	0	2
Neutral (neither pleasant nor unpleasant)	3	9	4
Unpleasant	10	5	10
Pleasant	1	4	2

Note: these odorants were categorized according to the classic hedonistic dichotomy (pleasant vs. unpleasant) in at least half of the descriptions.

is commonly associated with a slightly grilled smell and, for some subjects, with the smell of cooked rice. Hence the confusion in the communication seems to be largely triggered by references to oriental cuisine.

Associations of ideas could also, on the contrary, promote recognition. For citral, which as we have seen was the compound recognized the best, eleven of the twelve dialogues leading to a recognition contained the word "lemon" or a derivative of it (here, the French derivatives "*citron*", "*citronné*", and "*citronnelle*"). The 12th dialogue did not mention lemon, but did talk about a toilet-air freshener, often scented with a lime-like odor. Given the set of odor choices proposed to the receivers, they may have recognized citral by way an association of ideas, even though the smell of lemon was not actually mentioned.

4.5. Multisensory communication and recognition

Thanks in part to its multisensory attributes (Auvray & Spence, 2008; De Gelder & Bertelson, 2003; Ghazanfar & Schroeder, 2006; Gottfried, Smith, Rugg, & Dolan, 2004; Shepherd, 2006; White & Prescott, 2007) the semantic space of odors offers in terms of evocation what it cannot afford in terms of precision, as noticed long ago by the philosopher Ernst Cassirer. In its attempt to express certain olfactory qualities, language is forced to take a detour by borrowing words "from data provided by sensible intuition" (Cassirer, 1972). In our experiment, the subjects indeed borrowed from other senses to produce their olfactory descriptions. For instance, an odor could be humid, bitter, tart, sweet, light, or heavy; it could sting, make you think of "something flat", and so forth. Some of the descriptions suggest a synaesthetic perception, a concept classically defined as a physical experience that interchanges sensory signals in such a way that the stimulation of one sense arouses another, e.g., when an odor is assigned a color. The following examples illustrate this. For isobutyl amine, one participant said "A sort of green smell anyway, I mean, the smell of greenery." The odorant α-pinene made one participant "think of blue", while coumarin brought "the color green" to mind. The odorant 4-(4-hydroxyphenyl)-2-butanone evoked brown for one participant, pink for another (perhaps because "it's sweet like candy"). Methyl anthranylate was associated with yellow, no doubt because it has "a lemony smell". Finally, ethyl phenylacetate was related to green by one participant, which seems logical since this subject said "it smells like nature, the bush, eucalyptus [...] it smells like grass". This multisensory perception is not surprising. It is well known that sensory integration facilitates the detection and the identification of objects in our environment which are relevant for our species, and hence improve our behavioral responses to stimuli (Prescott, 2004).

5. Conclusion

This study was aimed at gaining a better understanding of how successful oral communication in the domain of olfaction works. The line of study of the participants and the odorant distance had no significant effect on the recognition rate, while sex had a moderate, but still statistically significant bearing. Several studies have confirmed the superiority of women over men on odor-recognition and identification tasks, in addition to a significant rise in women's olfactory acuity upon repeated exposure to various odorants (Brand & Millot, 2001; Choudhury, Moberg, & Doty, 2003; Dalton, Doolittle, & Breslin, 2002; Larsson, Nilsson, Olofsson, & Nordin, 2004; Lehrner, 1993).The analysis of the recorded dialogues between senders and receivers confirms the highly idiosyncratic nature of olfactory-guided behavior (Chu & Downes, 2000). Consequently, it attests to the uncertain nature of the intersubjective communication of olfactory experiences. Even for the recognized substances (e.g., citral), there was no guarantee of success on any given trial. For the other compounds, the descriptions revolved around three fuzzy categories: the odorant's hedonistic valence, its strength, or its familiarity. They were based on associations, were often related to the category of the body smells, occasionally borrowed referents from other senses (sight, touch, and taste), were sometimes highly unexpected, and could exhibit considerable self-assurance, even (Jönsson, Olsson, & Olsson, 2005) on trials that ended in a recognition failure. At this stage of our research, we observe that too many descriptive items reduce performance. We consider this phenomenon as an indirect confirmation of our hypothesis. If, as we argue, oral description of odors enhances the recognition of olfactory stimuli that match the description, it is not surprising that a profuse description impedes the recognition process. That is, the larger part that is occupied by the subjectivity of the participants on the one hand reduces the precision of the description itself, and on the other hand decreases the chances that the description of the sender and the receiver converge. Unfortunately, we cannot say what kind of description facilitates systematically the recognition of an odor. However, our experiment confirms the diversity of cognitive constructions based on the 'same' physical or physico-chemical materials and phenomena, constructions which may not be "reduced to the enumeration of the properties of the substances" (Dubois, 2003). In addition to supporting this diversity, our study prompts three topics for further research.

1. In a very large number of the dialogues, we were surprised by what seemed to be "aberrations" in the subjects' descriptions. Mint, for instance, was mentioned many more times than it should have been, and sometimes in very unexpected cases given the chemical makeup of the compound. These "aberrations", which should pose a fundamental problem for the sensory analyst and for food-odor studies, are worth studying in future experiments. They raise another question too, concerning the effects of language on perception. We all know of this old debate in the sensory sciences, so long organized around what is called the Sapir-Whorf hypothesis (Candau, 2003; Whorf, 1956). The question becomes even more pointed in the light of the "aberrations" just mentioned. Were the receiving subjects' so strongly influenced by peculiar descriptors that they felt compelled to choose a substance that fit the sender's description but was relatively far-removed from their own experience? In an attempt to answer this question, new experimental protocols ought to be envisioned.
2. The study suggests how dependent humans are on shared conceptual, memorial and other culture-specific knowledge when they communicate about smell. The question of the sharing of olfactory experience through language has been studied by one of the authors from an anthropological point of view (Candau, 2000; Candau, 2004). Is has been shown that the lexicon that is shared by perfumers and oenologist is much more effective than the one that nurses, medics or firemen have in common. An obvious direction for further research is to validate these ethnographic results by sensory experiments that vary the amount of shared knowledge. The hypothesis is that if participants do not belong to "similar worlds" (i.e., young, Western, same cuisine, student, senders and receivers knowing each other), the recognition rate will be poorer. Conversely, it is expected to go up if participants are chosen among a population of specialists such as perfumers or oenologists.
3. Another potential research pathway concerns the degree of familiarity with odorants. How can one control familiarity, a particularly vague notion, in order to better assess its effects on recognition (Jönsson, Tchekhova, Lönner, & Olsson, 2005)

and communication? After how many exposures to a stimulus does it become familiar to a subject? Does this number vary across odorants, individuals, the sexes, or with age? Does one become familiar with a particular exemplar of an odorant, or with a family of odorants?

New oral communication experiments should be designed to clarify these issues.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.foodqual.2009.11.001.

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