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Graded structure in odour categories: A cross-cultural case study

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Abstract. The existence of graded structure in fruit and flower odour categories and its stability in different cultures is examined. Groups of students from France, the United States, and Vietnam performed a typicality rating task, a similarity judgment task, a membership verification task, a recognition memory task, a familiarity rating task, and a free identification task using a set of 40 odorants (20 fruit odorants and 20 flower odorants). Overall, our results demonstrate that fruit and flower odour categories possess graded structure. Moreover, principal component analyses of the data revealed the implication of typicality in a variety of cognitive tasks where typical odours receive a preferential processing compared to atypical ones. Finally, our results suggest that typicality can be predicted to a certain extent by experiential knowledge but that other determinants play a role in odour category structure. Altogether, this study confirms that graded structure is a universal property of categories and suggests that universals and cultural specifics can both constrain the emergence of odour category structures.

1 Introduction

Since the 1970s, it has been theorised that possessing graded structure characterises natural categories (Rosch 1975). Instead of being all equivalent, some members of a category are more representative or more typical of the category than others. For instance, robins are better *birds* than penguins, and some 'reds' are better 'reds' than others (Rosch 1973). More recent work has confirmed that graded structure is a universal property of categories but that the resulting typicality gradient differs from one culture to another as a function of cultural familiarity with the various exemplars of the category (Bailenson et al 2002; Lynch et al 2000; Schwanenflugel and Rey 1986). The research on graded structure has been devoted to a broad variety of categories including natural taxonomic categories such as fruit, furniture, or animal species (eg Burnett et al 2005; Lynch et al 2000; Storms et al 2001), colour categories (eg Jameson and Alvarado 2003; Roberson et al 2000), artificial categories (eg Johansen and Palmeri 2002; Smith and Minda 2002), or goal-derived categories (ie abstract categories that people construct to serve goals) such as things to eat on a diet, things to pack in a suitcase, etc (eg Ratneshwar et al 2001).

While graded structure constitutes a powerful framework to better understand how people from different cultures perceive and organise information about the world, one can wonder to what degree this approach can be extended to all types of perceptual objects. Here we investigated whether graded structure can provide a plausible framework to better understand how odours are represented in memory. In other words: are odours perceived as members of a category, in which some members are more representative or more typical of the category than others? This question has important implications for how people conceptualise information from their olfactory environment. Indeed, until recently, research has pointed to the idiosyncratic and variable nature of odour perception and to the importance of cultural experience in shaping it (Distel et al 1999). Some authors came to the conclusion that odours might resist categorisation because they are perceived as unique events integrating the olfactory information with its surroundings and are furthermore difficult to describe in terms of a feature list (Engen 1982; Holley 1996).

However, a growing literature brings argument for the existence of mental representations for odours. For example, Lawless (1989) asked two groups of participants to sort citrus, woody, and ambiguous odours (partly woody-like and partly citrus-like). One group of participants could make as many categories as they wanted, while the other group was restricted to sorting the odours into only two categories. In the restricted condition, multidimensional scaling (MDS) analysis of the data revealed a configuration with only two clusters (woody and citrus), with ambiguous odours on the edges of each cluster. But in the unrestricted condition, a configuration with four clusters emerged, with ambiguous odours falling to a central cluster between the woody and citrus clusters. In a subsequent study, Lawless et al (1991) investigated a contrast effect at the boundaries between the citrus and woody categories: Lawless et al found that after exposure to a citrus odour, an ambiguous odour was rated as more woody, and after exposure to a woody odour, the same ambiguous odour was rated as more citrus.

The work of Lawless and his collaborators strongly suggests that, rather than being perceived as 'unitary perceptual events', odours are organised into categories which possess graded structure. More recent work shows that, in addition, odour categories may vary with cultural environment. For instance, Ueno (1993) found that Japanese and Sherpa participants (Sherpa is an ethnic group of Nepal) agreed on how to sort 20 artificial Japanese aromas on the basis of their perceptual similarity, with the exception that the Japanese classification revealed a 'fishy' category that did not emerge in the Sherpa classification. Ueno hypothesised that this difference might be due to the fact that fish odours are rarely encountered by Sherpa people. More recently, and along the same lines, Chrea et al (2004) asked participants of American, French, and Vietnamese cultures to sort freely 40 everyday odorants. MDS analyses showed some fine cultural differences which have been again attributed to differences in cultural habits. For example, the same odour of wintergreen was associated with a candy by Americans and with a traditional medicine by Vietnamese.

One possible explanation of Ueno's (1993) and Chrea et al's (2004) findings is that odour categories are more likely formed on the basis of the function associated to specific odours in a given culture rather than on universal properties of the odours. This is quite reminiscent of the idea that cognitive categories possess a graded structure that reflects both universal and cultural constraints (Bailenson et al 2002; Lynch et al 2000; Schwanenflugel and Rey 1986).

While the literature suggests that graded structure may constitute a plausible framework to better understand the organisation of odours in memory and its variability among different cultures, no attempt has been made yet to directly test this hypothesis, even though this has been demonstrated for visual categories. Confirming the graded-structure hypothesis could be valuable for the understanding of the cognitive mechanisms underlying odour perception as well as for understanding the more general problem of how culture shapes our perception of the world.

Using experimental paradigms borrowed from studies on visual and semantic categories, we aimed in the present paper to answer the following questions. Are odours perceived as members of a category in which some members are more representative or more typical of the category than others? And if a graded structure exists, is it stable among different cultures? To address these questions, we decided to use fruit and flower odours because previous work showed that these odours seem to be organised in two categories with boundaries that may be culturally dependent (Chrea et al 2004, 2005). Moreover, it seems that these two categories function as each other's contrast category, in that some fruit odours could be considered as floral and some flower odours as fruity (Chrea et al 2004, 2005). Finally, we were able to select a large variety of fruit and flower odours whose familiarity was culturally dependent.

We designed an experiment including six tasks using odorant samples from these two categories. The different tasks were performed by groups of students from French, American, and Vietnamese cultures because similarities and differences in odour perception have already been reported between these three cultures (Chrea 2005; Chrea et al 2004, 2005). Below is an outline of the six different tasks.

The first task was designed to evaluate directly the existence of a graded structure and consisted of a *typicality rating* task. According to Barsalou (1987), graded structure refers to a continuum going from the most typical members of a category and continuing through its atypical members to those non-members least similar to category members. In accordance with Barsalou's statement, we evaluated the degree to which each odour was judged a good example (ie typical) of a fruit odour and a flower odour.

The three following tasks were designed to evaluate if we could find any link between graded structure and performances in diverse cognitive tasks. Indeed it has been widely established for common taxonomic categories that graded structure has an important influence on a wide range of cognitive tasks in which typical exemplars receive preferential processing compared to atypical instances. For example, typical exemplars of a category are more likely to be rated as similar to all other exemplars of this category and different from exemplars of contrasting categories (Rosch and Mervis 1975; Smith et al 1974; Tversky 1977). Another example is that experimental participants are faster and more accurate in verifying category membership for typical exemplars as opposed to atypical exemplars (Hampton 1979; Kiran and Thompson 2003; Rosch 1973; Smith et al 1974; Storms et al 2001; Ward and Scott 1987). As a last example, typical exemplars are easier to acquire than, and thus better remembered, atypical exemplars (Heider 1972; Mervis and Pani 1980; Mervis et al 1976). In order to evaluate whether similar effects can be shown in odour categories, we investigated the relationship between typicality and (i) the similarity among the odours using a *similarity judgment* task; (ii) the accuracy to categorise odours in their category using a *membership verification* task; and (iii) the ability to memorise odours using a *recognition memory* task.

Finally, as we were interested in the stability of graded structure among different cultures, the purpose of the last two tasks was to assess the role of experiental knowledge in generating variations in typicality gradient across cultures. Indeed, for common taxonomic categories, it seems that the availability or familiarity of the exemplars partially predicts a category's typicality gradient and accounts for cultural variations in category knowledge (Ashcraft 1978; Hampton and Gardiner 1983; Lin et al 1990; Lin and Schwanenflugel 1995; Lynch et al 2000; McCloskey 1980; Malt and Smith 1982; Schwanenflugel and Rey 1986). In the same vein, codability, which refers to the ease and degree of agreement with which people can name a referent, has been found to predict how representative or typical an exemplar is in its category (Heider 1972). Therefore, two groups of participants from the same three cultural groups performed a *familiarity rating* task and a *free identification* task on the odorant set in order to extract two measures of experiental knowledge with the odours.

If fruit and flower odours possess graded structure, then we expect participants of all three cultures to make clear typicality distinctions among the different fruit and flower odours. Moreover, as graded structure should vary cross-culturally, differences should be found in the way odours are ordered among the three cultural groups. Another way to confirm the existence of graded structure is to demonstrate the implication of typicality in similarity, categorisation accuracy, and recognition memory performances.

Specifically, typical exemplars should be more similar to other exemplars of their category, more accurately classified, and better recognised than less typical exemplars. Finally, we expect typicality and experiential knowledge measured through familiarity rating and identification performances to be related: more familiar and better identifiable exemplars should be rated as more typical than less familiar and less identifiable exemplars of a category.

2 Experiment

2.1 *Methods*

2.1.1 *Participants.* 115 students of the University of Bourgogne in Dijon, 108 students of the University of Texas at Dallas, and 113 students of the University of Technology in Ho Chi Minh City participated in the experiment. In each culture, five groups participated in the typicality rating, similarity judgment, membership verification, familiarity rating, and recognition memory tasks, respectively. Groups who performed the free identification task were those who performed the recognition memory task, one week apart. Table 1 presents participants' repartition in all different tasks and all three cultural groups. All participants were born and raised in the studied countries. They were naive to the purpose of the experiment and most of them were not familiar with olfactory testing. Furthermore, none of them spontaneously reported any problem with their sense of smell. In the USA and in Vietnam, the students received course credit for their participation and in France they received a token in the form of sweet consumables.

Table 1. Mean age (±SD) and number of participants (*n* of males, *n* of females) in each cultural experimental group.

Task	Mean age of cultural group/years		
	France	USA	Vietnam
Typicality rating task	20.3 ± 1.9 (2, 23)	24.2 ± 6.1 (4, 18)	21.7 ± 0.8 (9, 20)
Similarity judgment task	24.4 ± 2.1 (7, 13)	23.2 ± 3.7 (7, 14)	21.6 ± 0.5 (3, 17)
Membership verification task	20.2 ± 1.0 (2, 20)	29.7 ± 7.7 (7, 13)	21.1 ± 0.6 (3, 18)
Recognition memory task + free identification task	20.8 ± 1.3 (0, 28)	24.7 ± 6.4 (6, 15)	21.4 ± 0.7 (6, 17)
Familiarity rating task	22.3 ± 1.5 (3, 17)	24.0 ± 6.3 (3, 21)	21.9 ± 1.0 (3, 17)
Total $n = 336$			

2.1.2 *Materials.* A preliminary set of 9 fruit and 9 flower odorants were selected from a set of 56 odorants for which previous research provided information about familiarity and identification of the odorants as well as frequency with which the fruit and flower odorant sources are encountered in all three cultures (Chrea 2005). To this initial set, for the present experiment, we added 10 fruit and 10 flower odorants in order to constitute the final set composed of odorants thought to be characteristic of a given culture (eg carnation or lily of the valley for France; wintergreen or Concord grape for the USA; and tamarind or durian for Vietnam) and others thought to be international (eg banana, rose).

Odorants were diluted in odorless mineral oil and the concentrations were adjusted so that the subjective intensity was evaluated by a small group of people working in the Centre des Sciences du Gôut as: (i) well perceived without being too strong and (ii) without any notable difference in perceived intensity among all of the odorants. In addition to these 38 odorants, we created artificial prototypes of fruit and flower odours. To do so, we prepared one fruity mixture made from an equal volume of all the diluted fruit odorants and one floral mixture made from an equal volume of all the diluted flower odorants. Thus the entire odorant set was composed of 40 odorants. 10 m of the diluted odorant were applied to a piece of absorbent tissue, filled to reach saturation, and placed in a capped 60 ml amber glass jar. Each odorant was coded by a random three-digit code.

2.1.3 *Design and procedure.* All tasks took place in a well-ventilated room in each of the three universities. Participants took part individually in each task. The forty glass jars were presented on a tray. All the participants' answers were recorded using a Macintosh computer running the PsyScope data-acquisition software (Cohen et al 1993), except for the similarity judgment task and the free identification task. In each of the six tasks, odorants were presented in a random order, different for each participant. In all tasks, if a participant perceived no odour when smelling an odorant, he or she did not perform the task for this odorant. The specific instructions for each of the six tasks are listed below:

(i) *Typicality judgment task*. The degree to which each odour was judged a good example (ie typical) of flower and fruit odour categories was evaluated in the same task. Participants were asked to smell a first odorant and to respond on a 7-point rating scale to the two following questions: "How typical is this odour of a fruit odour?" and "How typical is this odour of a flower odour?" (where 1 was not typical at all and 7 was very typical). To ensure that participants understood the notion of typicality, they were given the following instructions before beginning the task: "Imagine that you are explaining to an extraterrestrial what a 'fruit' (flower) odour is. Would you choose this odour to illustrate the concept of a 'fruit' (flower) odour?" The question presentation order was counterbalanced across participants, but, for a given participant, the presentation order was the same for all odorants.

(ii) *Similarity judgment task*. The overall similarity was measured with a free sorting task as used by Bailenson et al (2002). We chose a free sorting task because it avoids the problems of (a) fatigue observed with large number of pairwise similarity estimates and (b) individual differences in semantic interpretation associated with verbal attribute ratings (Lawless 1989). The participants were presented with the 40-odorant set and asked to sort the odorants on the basis of their perceptual similarity. Participants could make as many groups as they wanted and each group could contain as many odorants as they wished. Once they had finished, the participants had to report on a response sheet the groups they had formed and to give a short description of each of their groups.

(iii) *Category membership verification task*. The ability to categorise an odour in a category was measured with a speeded category membership verification task. Because we did not have access to a precise device for recording reaction time, we limited our present experimental design to classification accuracy with an additional certainty rating on a 3-point scale as used by Storms et al (2001). The participants received two blocks of 40 trials separated by a 10 min break, in which each odorant was presented once in each block. In one block, a given odorant was rated as a member of one category. In the second block, the same odorant was rated as a member of the contrasting category. For each trial, immediately after smelling an odorant, participants were asked to press the space bar on the computer keyboard to display the question.

Questions appeared randomly on the top of the screen as a unique category name: 'FRUIT?' ('FLOWER?', respectively). If participants thought the odour was a member of the category, they pressed the 'yes' button, otherwise they pressed the 'no' button. After each categorisation decision, participants were asked to indicate how sure they felt about their answer on a 3-point rating scale from 1 (not sure) to 3 (sure). Instructions stressed that responses should be made as quickly and as accurately as possible. Within a block, the fruit and flower category prompts appeared equally often.

Block presentations were counterbalanced across participants within a cultural group. The odorants were presented in a different random order in each block.
(iv) *Recognition memory task*. The ability to recognise odours was measured with a standard yes/no recognition task. Participants first rated half of the odorants (10 fruit and 10 flower odorants) for pleasantness on a 7-point rating scale as an incidental learning phase. After a 10 min retention phase, during which participants had to solve a set of logical puzzles, participants smelled the 40 odorants (ie 20 targets and 20 distractors) and had to answer "yes" or "no" to the question: "Did you smell this odour during the first session of this test?". Odorants were blocked in two sets of 20 odorants (10 fruit and 10 flower odorants in each set) and the two sets were counterbalanced across participants to obtain odorants presented equally often as target or distractor.
(v) *Familiarity rating task*. Participants were asked to answer the following question on a 7-point rating scale: "How familiar is this odour?" where 1 is not familiar at all and 7 is very familiar.
(vi) *Free identification task*. This task followed the recognition-memory task. The participants were asked to identify the odours. Participants could provide one word, several words, or even a sentence but they were asked to give the most accurate identification as possible and to avoid hedonic or intensity terms. Participants were given a set of forty pages assembled into booklets. At the top of each page was printed the digit-code number of an odour sample and a box to write down the appropriate identification of the odour.

2.1.4 *Data analyses.* In the whole experiment, the 0.01% of cases in France and Vietnam and 0.03% in the USA in which participants did not perceive a particular odorant were excluded from the data. From the six tasks, nine indices were computed as follows:
Typicality. We averaged across the participants the absolute value of the difference between individual flower typicality score minus individual fruit typicality score for each odorant within each cultural group. This index reflects, for a given group, the typicality of an odour for one category contrasted with its typicality in the other category.
Similarity. We first derived pairwise similarity estimates in each culture by counting the number of times two odorants were sorted into the same group. We then summed the pairwise distances between an odorant and all other odorants of the a priori fruit category. We did the same for the pairwise distances between an odorant and all other odorants of the a priori flower category. Then, for each odorant, we computed the absolute value of the overall similarity of this odorant in the a priori fruit category minus the overall similarity of this same odorant in the a priori flower category in order to obtain a unique similarity index. This index—akin to family resemblance (Rosch and Mervis 1975) or central tendency (Barsalou 1985) and calculated as described by Burnett et al (2005)—represents the overall similarity of an odour with both its a priori category members and the contrasting a priori category members.
Categorisation accuracy. All categorisation decisions were transformed into certainty ratings defined on a 6-point rating scale (Storms et al 2001). The scale ranged from -3 (incorrect a priori categorisation decision with a certainty rating of 3) to $+3$ (correct a priori categorisation decision with a certainty of 3). Then, we computed the difference between individual certainty ratings for categorisation into fruit category and flower category. Finally we averaged the absolute values of this difference across participants for each odorant within each cultural group. This index reflects, for a given group, both the inclusion of an odour in a given category and its exclusion from the contrasting category.
Memorability. As we were interested in recognition performance, we relied on signal detection theory to evaluate recognition performances (Abdi 2007; Macmillan and Creelman 1991). The data were collapsed across participants into hits and false-alarm

rates for each odorant within a cultural group. We then calculated a d' as a measure of discriminability and C as a criterion for each odorant in each cultural group.

Familiarity. For each odorant we computed the average familiarity score across participants within each cultural group.

Identifiability. We computed three indices to evaluate the identification performance. Frequency of correct answers—for instance 'rose' for the odour of rose—is the most common identification index used in olfactory literature (Lyman and McDaniel 1986; Rabin and Cain 1984; Sulmont et al 2002). However, this method constrains the correct answer to the expected label, and thus does not take into account the relevance of other labels (Dubois and Rouby 2002). For instance, we may imagine that the label 'toilet freshener' is a relevant label for the odour of lilac if participants use freshener scented with lilac in their toilet. Therefore, we decided to compute an alternative index, called the 'consensual' index, that evaluates the consistency among participants of a cultural group in labeling odours rather than the subjective correctness. It is reasonable to think that the more consistent a label is within a cultural group, the more relevant this label is for the odour. The consensual index was computed as the highest frequency of consistent answers among participants of a cultural group, regardless of the status of the label as expected or not. Two additional indices, adapted from Lesschaeve and Issanchou (1996), were computed to evaluate the precision of the labels. The first index, called the 'precise' index, corresponded to the frequency of specific nouns (eg cherry, candy, toothpaste) given by participants of a cultural group to each odour. The second index, called the 'categorical' index, corresponded to the frequency of category label (eg fruit, flower) or imprecise description (eg sweet, spring-like smell) given by participants of a cultural group to each odour.

The nine indices for all 40 odours are reported in tables 2, 3, and 4 for the French, American, and Vietnamese groups, respectively.

2.2 *Results*

2.2.1 *Graded structure.* As shown in tables 2–4, participants of all three cultures were able to make clear typicality distinctions among the different odours because there was a minimum range of at least 3 points in typicality index across odours in all three cultural groups. This result suggests that, in all three cultural samples, typicality indices for the fruit and flower odours were spread out on the whole typicality rating scale.

In order to evaluate the agreement on typicality within each cultural group, we computed Kendall concordance coefficients across the participants for each odour set. As suggested by Barsalou (1983), if categories do possess graded structure, then participants should show good agreement in how they rank odours as a function of their typicality for fruit and flower odour categories. All coefficients were significant but the reliability was higher among French participants than among the two other cultural groups ($w = 0.30$, $p < 0.001$ for the French group; $w = 0.22$, $p < 0.001$ for the American group; and $w = 0.14$, $p < 0.001$ for the Vietnamese group). The reliability appeared to be lower than that obtained for ad hoc categories by Barsalou in 1983 ($w = 0.87$) but remains comparable to those reported in a recent work evaluating the typicality of Chardonnay wine aromas (Ballester 2004) and are much higher than the values reported recently for face typicality (Peskin and Newell 2004).

2.2.2 *Cross-cultural stability in typicality gradient.* To evaluate cross-cultural variation in typicality gradient for fruit and flower odour categories, we performed on the typicality index a two-way analysis of variance with cultural group (American, French, and Vietnamese) as a between-participants independent variable and odour (all 40 odours) as a within-participants independent variable. When the odour $\times$ culture interaction was significant, a Duncan test was performed. An α value of 0.5 was taken as the significance level throughout. This analysis showed no main effect between the three cultural groups

Table 2. France. Values of the nine indices calculated for each odour: typicality (TYP), categorisation accuracy (CA), similarity (SIM), d', criterion (C), familiarity (FAM), consensual identification (CONS), precise identification (PREC), categorical identification (CAT), and proportion of people who declared having encountered the odorant object sources sometimes or often in their life (FREQ). The most typical odours within each odour category are in bold. The least typical odours within each odour category are underlined.

Odours	TYP	CA	SIM	d'	C	FAM	CONS	PREC	CAT	FREQ[a]
Flowers										
<u>anise</u>	2.48	3.10	8	2.14	0	6.20	85.19	85.19	0	70
carnation	3.18	3.45	99	1.43	−0.35	3.25	11.11	0	3.70	–
geranium	3.17	3.25	71	−0.18	−0.09	4.15	14.81	11.11	14.81	–
<u>grapefruit blossom</u>	2.17	3.00	21	0.36	0	5.65	18.52	7.41	0.00	–
honeysuckle	4.33	3.95	96	1.76	−0.59	3.85	11.11	44.44	7.41	31
hyacinth	3.33	2.95	69	0.89	0.62	3.65	11.11	0	11.11	–
jasmine	4.92	4.45	119	0.57	−0.28	3.60	28.00	20.00	28.00	31
lavender	5.21	4.70	62	1.36	−0.11	5.50	81.48	85.19	3.70	79
lilac	4.67	4.95	114	0.47	−0.33	4.05	22.22	44.44	29.63	64
lily of the valley	5.33	4.05	77	0.29	−0.15	4.40	29.63	44.44	7.41	90
mimosa	2.74	2.45	34	0.64	−0.42	3.30	7.69	19.23	7.69	–
mixflower	3.13	2.70	67	−0.47	−0.33	3.90	7.41	0	7.41	–
narcissus	3.13	3.70	54	1.07	0.53	3.30	11.11	0	7.41	–
orange blossom	3.54	3.85	65	0.28	−0.93	4.90	40.74	48.15	0.00	46
orchid	5.08	5.10	82	0.20	−0.47	3.85	7.41	14.81	7.41	–
rose	4.61	5.20	75	0.50	−0.82	4	7.41	14.81	18.52	80
tuberose	3.83	3.85	60	0.75	−0.19	3.60	7.41	3.70	14.81	–
violet	3.58	4.10	49	1.29	0.82	4.50	23.08	34.62	3.85	42
<u>wintergreen</u>	2.14	3.10	50	1.63	0.25	4.40	40.74	0	0	4
ylang ylang	4.50	4.35	121	0	−0.57	3.90	11.11	18.52	14.81	10
Fruits										
apricot	3.13	3.68	78	1.13	0	22.22	44.44	0	3.13	92
banana	3.54	4.65	123	3.43	−0.25	40.74	59.26	7.41	3.54	97
<u>blackcurrant</u>	2.45	2.40	42	1.07	0.53	8.00	4.00	4.00	2.45	87
cherry	3.48	4.05	73	1.25	0.44	33.33	37.04	0.00	3.48	–
coconut	3.38	3.95	85	2.26	−0.34	48.15	51.85	0.00	3.38	71
cranberries	3.26	4.40	92	0.36	0	18.52	25.93	11.11	3.26	–
<u>durian</u>	1.45	1.85	17	2.33	0.80	11.11	3.70	0	1.45	–
granny smith	2.96	3.70	76	0.93	−0.10	19.23	42.31	3.85	2.96	–
grape	2.96	2.45	19	2.53	−0.70	18.52	25.93	7.41	2.96	–
grapefruit	4.17	3.25	106	1.43	0.71	44.44	62.96	14.81	4.17	–
lime	3.38	4.40	40	1.65	0.64	37.04	40.74	3.70	3.38	–
lychee	3.87	4.30	29	0.28	0.04	14.81	14.81	7.41	3.87	58
mango	3.87	3.10	3	1.36	−0.11	37.04	18.52	3.70	3.87	53
melon	3.54	4.16	110	1.43	−0.35	30.77	50.00	11.54	3.54	95
<u>mixfruit</u>	2.48	2.20	60	1.65	−0.64	25.93	18.52	14.81	2.48	–
peach	4.22	5.60	98	1.36	−0.11	48.15	74.07	25.93	4.22	–
pineapple	2.92	3.25	120	1.25	0.44	37.04	44.44	18.52	2.92	89
raspberry	3.21	2.80	16	0.66	−0.23	11.11	22.22	3.70	3.21	–
strawberry	3.92	3.50	114	0.74	−0.37	33.33	48.15	18.52	3.92	100
tamarind	2.63	3	22	0.79	0.40	7.41	29.63	7.41	2.63	–

[a] The data come from a questionnaire anterior to this study and administrated to 100 respondents from each of the three cultures. The data concerned only 20 out of the 40 odorants used in this study.

Note: mixflower=artificial prototype of flower odours made from an equal volume of all the diluted flower odorants; mixfruit=artificial prototype of fruit odours made from an equal volume of all the diluted fruit odorants.

Table 3. USA. Values of the nine indices calculated for each odour: typicality (TYP), categorisation accuracy (CA), similarity (SIM), d', criterion (C), familiarity (FAM), consensual identification (CONS), precise identification (PREC), categorical identification (CAT), and proportion of people who declared having encountered the odorant object sources sometimes or often in their life (FREQ). The most typical odours within each odour category are in bold. The least typical odours within each odour category are underlined.

Odours	TYP	CA	SIM	d'	C	FAM	CONS	PREC	CAT	FREQ[a]
Flowers										
anise	2.36	2.94	10	1.09	0.29	4.95	68.18	0	4.55	10
carnation	3.59	3.55	51	0.84	−0.42	2.95	15	20	10	–
geranium	3.77	3.65	57	−0.14	−0.18	3.84	13.64	13.64	4.55	–
grapefruit blossom	3.32	3.00	36	1.92	−0.84	4.70	27.27	0	0	–
honeysuckle	4.67	4.79	98	0.96	−0.36	3.83	15.79	36.84	10.53	41
hyacinth	3.27	4.68	80	2.64	−0.48	3.15	13.64	9.09	9.09	–
jasmine	4.09	5.20	92	0.49	−0.60	4.05	13.64	4.55	27.27	47
lavender	2.91	3.74	3	0.08	0.56	5.05	22.73	4.55	0	64
lilac	4.50	5.55	90	0.05	−1.31	4.95	9.52	23.81	14.29	47
lily of the valley	4.86	5.15	85	0.91	−0.45	4.10	13.64	9.09	18.18	19
mimosa	3.41	3.00	11	0.68	−0.94	4.10	15	5	15	–
mixflower	3.59	3.78	91	0.08	−0.56	3.85	15	10	20	–
narcissus	3.55	4.37	78	2.18	−0.25	3.58	9.52	0.00	9.52	–
orange blossom	4.77	4.00	82	0.38	−0.72	3.53	21.05	15.79	15.79	25
orchid	4.68	5.40	97	−0.07	−0.88	3.89	9.52	4.76	28.57	–
rose	5.05	5.25	100	0.07	−0.88	3.50	25	30	15	80
tuberose	3.68	4.65	72	1.20	−1.20	4.30	9.09	9.09	27.27	–
violet	2.95	3.27	45	1.75	0.03	4.90	13.64	4.55	9.09	37
wintergreen	2.05	2.43	4	0.60	0.30	5.00	15.79	47.37	0	81
ylang ylang	4.18	4.20	78	0.07	−0.88	3.39	14.29	0	14.29	10
Fruits										
apricot	2.95	4.75	27	0.54	0.16	3.22	10	10	5	63
banana	4.50	4.05	128	1.75	0.03	5.15	31.82	45.45	13.64	96
blackcurrant	1.86	3.30	18	0.10	0.30	2.45	13.64	9.09	22.73	15
cherry	3.95	4.53	96	0.64	−0.21	4.90	45.45	59.09	9.09	–
coconut	4.05	4.35	81	1.13	−0.04	5.80	57.14	61.90	0.00	73
cranberries	2.77	4.00	105	0.24	−0.72	4.55	15	30	30	–
durian	1.45	3.78	45	1.40	0.58	2.10	25	10	10	–
granny smith	3.77	4.55	113	0.91	−0.45	5.35	9.09	40.91	22.73	–
grape	4.64	4.75	98	1.75	0.03	6.10	45.45	68.18	0.00	–
grapefruit	2.23	4.11	73	1.16	0.33	5.90	33.33	42.86	9.52	–
lime	3.91	3.25	65	1.40	0.58	5.80	31.82	54.55	9.09	–
lychee	4.20	3.57	18	1.19	−0.25	3.65	20	5	0	6
mango	3.68	3.70	35	0.08	−0.56	4.70	18.18	9.09	9.09	59
melon	4.05	5.16	89	1.19	−0.25	5.40	27.27	36.36	18.18	93
mixfruit	2.71	3.30	53	−0.08	−0.56	3.95	9.52	28.57	14.29	–
peach	4.59	4.80	58	0.60	−0.30	5.26	27.27	68.18	9.09	–
pineapple	3.82	4.26	111	1.03	−0.77	5.25	13.64	45.45	9.09	95
raspberry	3.36	3.55	79	0.49	−1.09	4.70	9.52	33.33	23.81	–
strawberry	4.50	4.50	46	0.35	−0.17	4.60	23.81	52.38	19.05	99
tamarind	4.00	3.68	100	1.17	−0.70	3.79	18.18	40.91	13.64	–

[a] The data come from a questionnaire anterior to this study and administrated to 100 respondents from each of the three cultures. The data concerned only 20 out of the 40 odorants used in this study.

Note: mixflower=artificial prototype of flower odours made from an equal volume of all the diluted flower odorants; mixfruit=artificial prototype of fruit odours made from an equal volume of all the diluted fruit odorants.

Table 4. Vietnam. Values of the nine indices calculated for each odour: typicality (TYP), categorisation accuracy (CA), similarity (SIM), d', criterion (C), familiarity (FAM), consensual identification (CONS), precise identification (PREC), categorical identification (CAT), and proportion of people who declared having encountered the odorant object sources sometimes or often in their life (FREQ). The most typical odours within each odour category are in bold. The least typical odours within each odour category are underlined.

Odours	TYP	CA	SIM	d'	C	FAM	CONS	PREC	CAT	FREQ[a]
Flowers										
anise	2.00	3.76	17	1.03	0.87	5.20	13.64	4.55	9.09	9
carnation	3.57	4.19	57	−0.48	−0.67	4.70	18.18	9.09	27.27	–
geranium	2.96	3.95	42	0.70	−0.56	5.70	13.64	0	18.18	–
grapefruit blossom	3.00	3.86	18	0.07	−0.64	5.15	18.18	0	0.00	–
honeysuckle	3.61	4.95	57	0.35	−0.43	5.10	22.73	40.91	27.27	6
hyacinth	3.31	3.60	86	0.56	−0.07	2.75	9.09	9.09	9.09	–
jasmine	3.46	4.14	43	0.79	−0.28	3.45	19.05	19.05	19.05	45
lavender	2.59	3.43	24	1.34	0.24	4.50	9.09	4.55	4.55	4
lilac	4.00	4.95	72	1.37	−1.12	4.10	9.09	27.27	40.91	3
lily of the valley	4.21	5.14	55	0.91	−0.45	4.70	18.18	45.45	22.73	0
mimosa	1.93	3.26	35	0.84	0.42	3.05	9.09	13.64	31.82	–
mixflower	3.62	4.48	54	0.48	−0.67	5.70	22.73	9.09	40.91	–
narcissus	3.39	3.19	77	1.88	0.03	2.85	13.64	4.55	13.64	–
orange blossom	3.41	3.81	60	0.35	−0.17	3.95	22.73	18.18	22.73	29
orchid	3.07	4.05	82	−0.61	−0.98	3.70	9.09	22.73	40.91	–
rose	3.93	4.33	74	0.30	−0.76	5.05	9.09	27.27	31.82	86
tuberose	4.52	4.00	45	1.99	−0.39	5.25	18.18	40.91	18.18	–
violet	1.73	3.37	51	1.77	0.45	2.80	9.52	0	9.52	17
wintergreen	1.43	2.90	28	0.56	0.07	3.63	18.18	4.55	13.64	0
ylang ylang	3.69	3.95	74	1.02	−0.40	4.55	13.64	27.27	27.27	10
Fruits										
apricot	2.21	4.00	97	0.70	−0.56	4.50	13.64	40.91	31.82	66
banana	3.21	3.52	63	0.54	−0.16	4.65	13.64	22.73	13.64	95
blackcurrant	2.57	3.79	98	0.79	−0.28	4.50	13.64	13.64	13.64	0
cherry	2.93	2.67	104	0.85	−0.54	4.40	16.34	18.18	27.27	–
coconut	2.14	3.57	67	1.77	−0.45	6.45	36.36	18.18	4.55	90
cranberries	3.14	3.43	95	0.00	−0.60	4.30	13.64	27.27	36.36	–
durian	2.69	4.40	83	1.73	0.52	5.55	13.67	27.27	4.54	–
granny smith	3.48	3.43	90	0.78	0.04	5.65	27.27	50	4.55	–
grape	3.59	3.43	105	0.62	−0.66	5.55	18.18	54.55	22.73	–
grapefruit	3.36	4.57	107	1.49	−0.22	6.15	45.45	63.64	18.18	–
lime	3.21	3.14	77	0.54	0.16	5.50	45.45	50.00	0.00	–
lychee	2.82	4.71	9	−0.14	−0.28	4.90	13.64	31.82	9.09	88
mango	2.93	3.10	52	1.59	−1.01	5.75	18.18	36.36	13.64	96
melon	3.79	3.71	115	0.85	−0.54	5.55	22.73	50.00	31.82	22
mixfruit	3.36	3.62	107	0.47	−1.57	5.35	22.73	36.36	22.73	–
peach	3.48	3.95	114	−0.08	−0.39	5.75	18.18	59.09	36.36	–
pineapple	3.82	4.24	107	1.51	0.15	6	22.73	36.36	31.82	90
raspberry	3.03	2.95	61	0.39	−0.41	5.20	22.73	18.18	18.18	–
strawberry	2.76	4.52	88	0.90	−0.88	3.95	13.64	31.82	22.73	21
tamarind	3.66	5.00	94	1.92	−0.84	6.60	45.45	72.73	13.64	–

[a] The data come from a questionnaire anterior to this study and administrated to 100 respondents from each of the three cultures. The data concerned only 20 out of the 40 odorants used in this study.

Note: mixflower=artificial prototype of flower odours made from an equal volume of all the diluted flower odorants; mixfruit=artificial prototype of fruit odours made from an equal volume of all the diluted fruit odorants.

($F_{2,\,2762} = 2.35$, MSE $= 73.88$), whereas the effect was highly significant between odours ($F_{39,\,2762} = 10.81$, MSE $= 32.27$, $p < 0.0001$). The interaction between odour and culture was also highly significant ($F_{78,\,2762} = 2.71$, MSE $= 8.08$, $p < 0.0001$). The results of the Duncan test showed cultural differences for four fruit odours—durian, coconut, Concord grape, and strawberry—and four flower odours—lavender, violet, orange blossom, and orchid. Among these odours, some were expected to elicit cross-cultural differences because of differences in the availability of the related odorant sources: for instance the odour of durian, a characteristic South-East Asian fruit (Chiva 1993), was rated as more typical by Vietnamese participants ($M = 2.41$, SD $= 1.97$) than by French participants ($M = 1.45$, SD $= 1.63$) or American participants ($M = 0.09$, SD $= 2.11$); Concord grape, a grape variety growing exclusively in the USA (Pangborn 1975), was rated as more typical by American participants ($M = 4.00$, SD $= 1.59$) than by French participants ($M = 2.96$, SD $= 1.73$) and Vietnamese participants ($M = 2.41$, SD $= 1.78$); and lavender, a frequently encountered flower in France (Chrea 2005), was rated as more typical by French participants ($M = 5.02$, SD $= 1.50$) than by participants of the two other cultural groups (USA: $M = 1.82$, SD $= 1.82$; Vietnam: $M = 1.48$, SD $= 2.10$).

To confirm that availability of the odorant object sources may account for the differences in typicality ratings between the three cultural groups, we calculated, in each cultural group, Pearson product moment correlation between the typicality index and the frequency of encountering odorant object sources among the 20 odorants for which we had the relevant data (cf table 2). Correlations were all non-significant at the α level of 0.05 ($r = -0.01$, $r = 0.13$, $r = 0.06$ for participants from France, the USA, and Vietnam, respectively).

Beside few cultural differences, the ANOVA highlights a high consistency in typicality ratings among the three cultural groups. In fact, no difference in typicality was found for 32 odours. To confirm this finding, we calculated Pearson product moment correlation between cultural typicality ratings. We found a strong correlation between French and American typicality ratings ($r = 0.61$, $p < 0.0001$), between American and Vietnamese typicality ratings ($r = 0.55$, $p < 0.001$), and to a lesser extent between French and Vietnamese typicality ratings ($r = 0.40$, $p < 0.05$). This latter analysis confirms the large overlap in typicality gradients between the three cultures. Moreover, it reveals a greater similarity between French and American typicality gradients than each of them with Vietnam typicality gradients.

To have a closer look at the category structure in the three cultural groups, we focused on highly typical and highly atypical odours by extracting within fruit and flower categories odours that were outside the range of ± 1 SD around the typicality index mean for each cultural group. Seven highly typical and six highly atypical odours were extracted for the French group, nine and six respectively for the American group, and five and seven respectively for the Vietnamese group. As shown in tables 2–4, one odour was rated as highly typical (ie lily of the valley) and three odours as highly atypical (ie wintergreen, anise, and blackcurrant) in all three cultural groups. Beside this overall agreement, some odours were rated specifically in one culture as highly typical (lavender, jasmine, and grapefruit in France; honeysuckle, rose, orange blossom, banana, and Concord grape in the USA; tuberose, melon, pineapple, and tamarind in Vietnam) or highly atypical (grapefruit flower and the fruity mixture in France; lavender and grapefruit in the USA; violet, coconut, and apricot in Vietnam). Finally, we found more similarity in the composition of highly typical and atypical odours between the American and French cultures than each of them with the Vietnamese culture (orchid, peach, and strawberry were rated as highly typical and durian as highly atypical in the French and the American cultures).

2.2.3 *Relation between graded structure and performance in cognitive tasks.* To analyse the relation between typicality similarity, categorisation accuracy, and recognition memory, we followed a procedure used in a previous work dealing with structural aspects of face recognition by Vokey and Read (1992). In their study, Vokey and Read applied a principal components analysis (PCA) followed by a VARIMAX rotation to a set of faces rated for several facial characteristics (memorability, familiarity, attractiveness, and likableness) to evaluate how these characteristics were interrelated with rated typicality of the faces. In the present study, we applied a PCA to typicality, categorisation accuracy, similarity, d', and C indices in each cultural group. Using the rule that only principal components with an eigenvalue larger than 1 are retained, we extracted two principal components for all three cultural groups. These first two principal components were then orthogonally rotated with a VARIMAX rotation in order to facilitate the interpretation of the 2-D configurations (see figure 1). The loadings for these VARIMAX rotated components and the percentages of variance explained by each component are reported in table 5.

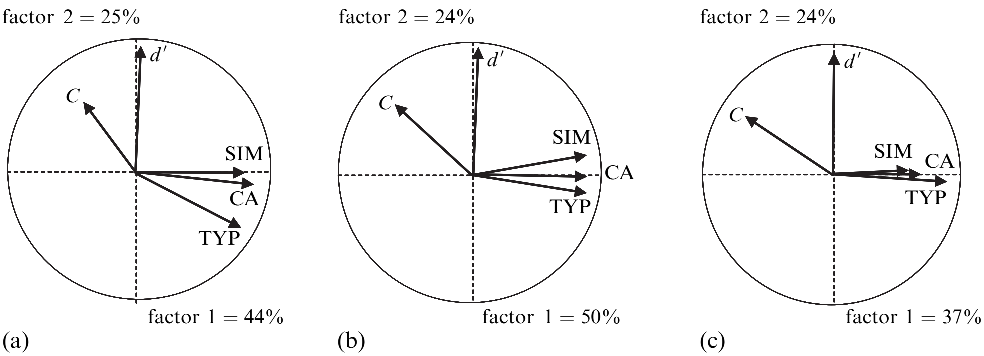

Figure 1. Indices of typicality (TYP), similarity (SIM), categorisation accuracy (CA), and recognition represented on the first factorial space of the principal component analyses computed for (a) France, (b) the USA, and (c) Vietnam.

Table 5. Matrix of correlation between typicality, verification accuracy, similarity, d', and C variables and the first two principal components for the French, the American, and the Vietnamese samples, respectively. Loadings that are predominant are in bold.

	French		USA	Vietnamese		
	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Typicality	**0.81**	**−0.40**	**0.83**	−0.15	**0.85**	−0.08
Verification accuracy	**0.88**	−0.13	**0.83**	−0.03	**0.64**	0.01
Similarity	**0.80**	0.00	**0.86**	0.14	**0.58**	0.06
d'	0.03	**0.90**	0.06	**0.94**	0.01	**0.94**
C	**−0.30**	**0.55**	**−0.59**	**0.50**	**−0.63**	**0.54**
Percentage of variance accounted for by axis	44	25	50	24	37	24

Note: axis 1 = typicality; axis 2 = recognition discrimination.

As an arbitrary threshold, only loadings greater than, or equal to, the absolute value of 0.50 have been considered as important in interpreting the rotated principal components—they are typeset in bold in table 5.

The main point emerging from figure 1 is the global similarity in the patterns of liaison of the five indices between the three cultural groups. First, the amount of variance explained by each factor is roughly similar for the three cultural groups.

Second, in all three cultural groups, the first axis could clearly be interpreted as a positive combination of typicality, categorisation accuracy, and similarity variables, and this combination is somewhat opposed to the criterion C. The second axis could clearly be interpreted as a positive combination of d' and the criterion C. These results suggest that among fruit and flower odours some are more typical than others. It seems that this differential processing affects category membership and similarity judgment in a way that most typical odours are also categorised the best and are most similar to other members of the category. Surprisingly, we did not find an effect of typicality on discriminability as d' loaded only on factor 2 and the typicality measure only on factor 1. But we found that typicality was affecting the strategy of the participants as indicated by the loading of C on the first factor: typical odours triggered a liberal strategy (response "yes" more likely and therefore more false alarms) while atypical odours triggered a conservative strategy (response "no" more likely and therefore fewer false alarms).

2.2.4 *Influence of experiential knowledge on graded structure.* As the first factor of the PCA seems to reflect the relation between typicality, similarity, and categorisation accuracy, we used the scores of the odours on the first factor of the PCA as a more relevant and complex measure of odour typicality than our typicality index. We computed the correlation between the odour factor scores on the first factor of the PCA and the familiarity and identifiability indices, respectively, for each cultural group. We found that familiarity and typicality were not correlated in any of the three cultures ($r = 0.07$, $r = 0.18$, $r = 0.29$, ns, for France, the USA, and Vietnam, respectively). We did not find any correlation between typicality and consensual identification index either ($r = 0.13$, $r = -0.01$, $r = 0.18$, ns, for France, the USA, and Vietnam, respectively). In contrast, for France and Vietnam, but not for the USA, we found a positive correlation between typicality and both categorical identification and precise identification indices (France: $r = 0.33$, $p < 0.05$ and $r = 0.47$, $p < 0.01$ for precise identification and categorical identification, respectively; Vietnam: $r = 0.48$, $p < 0.01$ and $r = 0.35$, $p < 0.05$ for precise identification and categorical identification, respectively). The results of this latter analysis suggest that the ability to name an odour can predict typicality in at least two cultures but that rated familiarity does not influence the typicality of category members.

3 Discussion

Olfactory perception has often been regarded as more difficult to study than other senses and therefore mechanisms underlying odour perception have been much less documented than for other modalities. It was the aim of the present paper to evaluate the possible applicability of general concepts on categorisation to the specific domain of odours. Specifically, we explored the existence of a graded structure in the fruit and flower odour categories and its stability among the American, French, and Vietnamese cultures.

We first demonstrated that, in all three cultural samples, odours are perceived as members of categories, in which some members are more representative or more typical of their category than others. Even though odour perception is often described as more idiosyncratic than other sensory modalities, our results stress the importance of considering odour stimuli as category members rather than as unique events. In other words, this implies that we do not need to identify uniquely the odour of a rose to know that it is a flower odour; we just need to know that this odour belongs to the category of flower odours. Moreover, our findings lend support to the view that, as for other stimuli, we respond to odours in terms of 'representativeness' in category membership and this is consistent with the claim that the process of differentiating typical from atypical category members functions as a cognitive universal (Rosch 1978).

In agreement with the existing literature on typicality, our findings demonstrated the implication of graded structure in a variety of cognitive tasks where typical odours receive a preferential processing compared to atypical ones. Thus, we showed that typical exemplars are judged as more similar to all other exemplars of the category and categorised more accurately than less typical exemplars. However, we failed to demonstrate the influence of typicality on how well exemplars are retrieved from memory, contrary to what was shown in early work on colours (Heider 1972). Nevertheless, if we look at the relation between typicality and recognition memory from a different perspective, our findings are reminiscent of effects found in face processing. Indeed, we found that typicality affects the strategy of the participants in that typical odours induce more false alarms than atypical ones. In the face domain, some authors found that typical faces trigger false alarms whereas atypical faces trigger more hits. This was interpreted as a high confusability of typical faces with other faces because typical faces look more alike (Bartlett et al 1984; Light et al 1979; Vokey and Read 1992). The similarity between our present results and results from the face perception literature supports the recent claim that odours may be encoded as other non-verbal stimuli such as faces (Issanchou et al 2002). Like other non-verbal stimuli such as music or paintings, odours and faces are learned through repeated exposures without explicit intention of learning. Moreover, both types of stimuli share a number of properties: odours, like faces, provide social signals, elicit affects, are difficult to describe but easy to discriminate, seem to be perceived holistically, show context-dependent memory effects, and are quite resistant to forgetting.

On the contrary, colours are processed more analytically and, when categorised, are strongly influenced by language. This difference in terms of processing may explain why we found different typicality effects in face and odour studies on one side and in colour studies on the other side.

This discrepancy between the different studies may also be linked to the paradigm used to measure recognition performances. In Heider (1972), Dani and English participants were presented with a single test colour chip for 5 s, waited for 30 s, and were then shown the entire 160-chip array and were asked to select from it the chip they had seen. In contrast, in face studies, as in our study, recognition discrimination was measured by the classic yes/no recognition task. We speculate that the cognitive processes involved in the two tasks are different and that the graded structure could differently influence the memory processing tapped by the two different tasks. In the context of the task used with colours, typicality may be directly linked to the perceptual saliences of exemplars: typical exemplars may be more perceptually salient and thus more easily retrieved out of a large set of exemplars with a lower salience (Heider 1972). In the context of the task used with faces and odours, typicality is more likely linked to the degree to which category members are similar to each other: typical members, because they are the most similar to all other members of the category, are more often confused with other members, including a bias in how participants answer in a forced-choice task such as the yes/no recognition task. However, we can wonder what makes an odour the most similar to all other members of the category. For natural language categories, this higher similarity of prototypes has been attributed to the structure of attributes within the category, in that typical instances share many attributes with the other members of the category and few with members of other categories (Rosch and Mervis 1975). This categorisation principle, however, is not easily adapted to odour categories. Indeed odours tend to be perceived holistically and are difficult to decompose into a collection of attributes (Holley 1996). Thus, it is probable that odour prototypes are formed on the basis of perceptual similarities rather than on the basis of shared attributes. Contrary to what we hypothesised, the artificially constructed fruit and flower odour prototypes did not emerge as typical.

While the construction of our artificial prototypes relied on a theoretical hypothesis concerning the structural properties of the prototype for common taxonomic or artificial categories (eg as an average of all exemplars of the category or as sharing the most important number of properties with all the other exemplars of the category), one can argue that it is not surprising that these constructed prototypes did not emerge from such new mixtures as the construction was an ad hoc elaboration and did not rely on any theoretical hypothesis on the specific structure of odour prototype. Work is still needed to investigate further the underpinnings of similarity-based typicality for odour categories.

A second point of interest in this paper was the stability of odour-category structures in different cultures. On the one hand, our findings suggest that there are some cultural constraints on how people evaluate the 'representativeness' of odours in their categories. Our findings suggest that these constraints could be linked in part to differences in the availability of the different odorant object sources in the three cultures. More generally, differences in the cultural environment may predict cross-cultural differences as suggested by the greater similarity in the typicality gradient between the two Western cultures compared to the Eastern culture. Indeed, this finding is in agreement with previous work investigating the same three cultures on odour perception (Chrea et al 2004, 2005) and may likely result from greater similarities in the olfactory environment between the two industrial cultures such as the French and the American cultures compared to a more traditional culture like the Vietnamese one (see eg Chrea 2005 for more empirical evidence). It is probable that olfactory environment in the industrialised world is dominated by artificial odours such as the ones we used for our study. Indeed, in most post-industrial cultures, fruit aromas are currently encountered in sweeties, and flower aromas in cosmetic and household products. On the contrary, traditional cultures are still more likely to encounter products with natural aromas (Aubaile Sallenave 2000). Thus, it is possible that the odours we used, more frequently encountered in France and in the USA, matched similarly the odour representation of the French and the American participants and not so much the odour representation of the Vietnamese participants.

Overall, our findings are reminiscent of a common view on category structure arguing that cultural familiarity plays a role in typicality (Schwanenflugel and Rey 1986). However, as suggested by our findings, it seems that rated familiarity can not predict typicality of fruit and flower odours. This finding is in agreement with Barsalou's (1987) findings for common taxonomic categories. According to Barsalou, people's perceptions of how frequently exemplars instantiate their category seem to be the measure of frequency that is the most central for graded structure. In our case, we found that the ability to label the odour with a precise name or its category name seems to be the most central predictor of odour graded structure. This confirms first that typical odours are more likely to be associated with the category to which they belong. Moreover, what plays a role in typicality is not the ability to name consistently an odour among a cultural group, but rather to name it with a precise label even though this label is idiosyncratic. This result contrasts with previous work on colours (Heider 1972) that showed a relationship between typicality and the ability to name a colour consensually within a cultural group (ie codability). This discrepancy may reflect a fundamental difference between colours and odours in their relation with language as suggested earlier in this paper. Indeed, odours are poorly conceptualised in language and refer mostly to the object source (eg 'rose' for the odour of rose) in opposition to colours for which specific terms easily translated among languages (Berlin and Kay 1969) have been abstracted independently from the object sources.

Although our results provide evidence for the influence of experiential knowledge on typicality gradients, this factor is not the only determinant playing a role in the organisation of odour-category structure. Indeed, we found a marked convergence in typicality gradients among the three cultures, even for odours that were not consensually encountered in the three cultures. For example, the odour of lily of the valley has been consensually rated as typical by the three cultural groups but our questionnaire data on frequency of encountering odorant object sources collected from the same populations as our participants indicated that lily of the valley is rarely (if ever) encountered in the USA and in Vietnam (cf tables 2–4 for information on the frequency of encountering odorant object sources in each of the three cultures). Although we cannot be sure that there is no other flower with a lily-of-the-valley-like odour which is encountered more in the USA and in Vietnam (the odour of lily of the valley was identified as rose by 18% of Vietnamese participants in the free identification task), this example suggests that typicality is not strictly based on previously encountered odour instances. This result is reminiscent of a recent finding in folk biology: Bailenson et al (2002) found impressive similarities between the Itza'Maya (an ethnic group of Guatemala) and American birders on rated typicality for American birds, despite the fact that the Itza' had never seen many of the American birds before.

To conclude, our findings strongly support the view that there are universal and cultural constraints on how people organise their knowledge about information from the world. Thus, even though experiential knowledge may be influential in how different fruit or flower odours are representative or not of their category, different people encountering many different exemplars of a fruit or a flower odour may nonetheless generate more or less the same concept of 'fruit odour' and 'flower odour'. The remaining question is then to find out how the graded structure is acquired in order to take into account these universal and cultural constraints. Among the factors that have been widely reported as playing a central role in determining graded structure is how similar an exemplar is to ideals associated with its category, where ideals are properties that exemplars should have if they are to best serve goals associated with their category (Barsalou 1985). Several authors found that exemplars are rated highly typical as they approximate ideals associated with their category and that graded structure of these goal-derived categories is sensitive to participants' expertise such as cultural knowledge (Bailenson et al 2002; Barsalou 1985, 1987; Burnett et al 2005; Lynch et al 2000). This more recent view on categories and concept formation may provide an interesting framework for further investigations with odours. As suggested by Dubois (1997) when referring to "pragmatic factors of human activities" (eg hunting, cooking, domestic life, corporal odours) as a possible factor that drives odour categorisation, one can easily consider odours as entities sharing the same goal or function (eg odours smelled in the kitchen, odours used in cleaning products). Therefore, it would be of great interest to investigate further whether the notion of ideals may play a role in the organisation of odour-category structure.

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