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Mapping the Semantic Space for the Subjective Experience of Emotional Responses to Odors

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Abstract

Two studies were conducted to examine the nature of the verbal labels that describe emotional effects elicited by odors. In Study 1, a list of terms selected for their relevance to describe affective feelings induced by odors was assessed while participants were exposed to a set of odorant samples. The data were submitted to a series of exploratory factor analyses to 1) reduce the set of variables to a smaller set of summary scales and 2) get a preliminary sense of the differentiation of affective feelings elicited by odors. The goal of Study 2 was to replicate the findings of Study 1 with a larger sample of odorant samples and participants and to validate the preliminary model obtained in Study 1 by using confirmatory factor analysis. Overall, the findings point to a structure of affective responses to odors that differs from the classical taxonomies of emotion such as posited by discrete or bidimensional emotion theories. These findings suggest that the subjective affective experiences or feelings induced by odors are structured around a small group of dimensions that reflect the role of olfaction in well-being, social interaction, danger prevention, arousal or relaxation sensations, and conscious recollection of emotional memories.

Key words: affective experience, olfaction, psychometric approach, theories of emotion

Introduction

In all cultures, odor has always been considered as a powerful elicitor of emotions, and this assertion is rarely debated. In the last few decades, a growing scientific literature has documented various emotional effects of odors (for reviews, see e.g., Ehrlichman and Bastone 1992 and more recently Herz 2002). By using a large variety of approaches, research investigating the relation between odor and affective phenomena showed, for example, that odor experience is inextricably linked to odor hedonic tone and, thus, is likely to influence mood such that pleasant odors tend to induce positive moods, whereas unpleasant odors tend to induce negative moods (Schiffman, Miller, et al. 1995; Schiffman, Sattely-Miller, et al. 1995; Rétiveau et al. 2004). Numerous experiments also showed that odors produce effects on cognition and behavior that are similar to those produced by emotional stimuli in other perceptual modalities (Ludvigson and Rottman 1989; Degel and Köster 1999; Epple and Herz 1999; Ilmberger et al. 2001; Millot and Brand 2001; Millot et al. 2002; Chebat and Michon 2003). In addition, odor experience has been shown to provoke changes in physiological parameters, such as heart rate or skin conductance, which are directly involved in the emotional response (Alaoui-Ismaïli et al. 1997; Robin et al. 1999; Heuberger et al. 2001; Bensafi et al. 2002a, 2002b, 2002c; Pössel et al. 2005). Finally, odors can evoke autobiographical memories that are emotionally intense and long forgotten (for a review, see Chu and Downes 2000). These effects are usually interpreted as an interdependence of olfaction and emotion on overlapping neural systems (Phillips and Heining 2002), which has been recently confirmed with neuroimaging evidence (Royet et al. 2003; Herz, Eliassen, et al. 2004).

Surprisingly, despite this burgeoning literature, psychological research has rarely been concerned with the nature of the affective states induced by odors. The few studies that have investigated the affective subjective experience or feeling induced by odors are usually conducted by presenting different odorant samples to participants who are asked to report their feelings for each odor. In these studies, a typical way

to report the subjective experience is to answer a forced-choice self-report questionnaire. This type of forced-choice measurement derives from 2 approaches: 1) the discrete emotion theory, postulating the existence of a small number of so-called basic emotions based on phylogenetically stable neuromotor programs (Ekman 1984) or 2) the bidimensional theory that reduces emotions to positions in a bidimensional valence by arousal space (Russell et al. 1989). The disadvantage of these 2 approaches is that they use fixed-response categories and therefore restrain the description of respondents' experiences in those categories. Thus, these approaches assume a priori that the induced emotional states induced by olfactory stimulation fit into these "prototypical" categories that have been developed in the context of a theoretical framework that did not explicitly include olfactory processing. Consequently, one wonders whether these classical theoretical models can inform us about the kinds of affective experiences that can be induced by odors.

If we first consider the discrete emotion approach, a small number of primary basic emotions seems ill adapted to describe the rich set of highly differentiated responses and feeling states produced by odors. In fact, the few studies that have used this approach provide empirical evidence that shows that, in most cases, odor-elicited emotional experience does not match basic emotions such as anger, fear, or sadness (Alaoui-Ismaïli et al. 1997; Robin et al. 1999; Bensafi et al. 2002c; Desmet 2005). Furthermore, empirical evidence suggests that it is unlikely that human emotional experiences elicited by odors are based on a limited number of neuromotor programs resulting in specific emotional facial expressions or physiological response patterns as postulated by the discrete emotion theory. For example, in their study, Alaoui-Ismaïli et al. (1997) did not find consistent correlates between physiological response patterns and feeling states evoked by odorants. Finally, as suggested by the work of Warrenburg (2005), odors may elicit responses that are of a special kind and more complex than prototypical emotions, such as sensuous or apathetic feelings.

The approach based on bidimensional models has been used broadly to address issues on odors and emotions (Heuberger et al. 2001; Bensafi et al. 2002a, 2002b, 2002c; Chebat and Michon 2003; Herz, Schankler, and Beland 2004; Schifferstein and Tanudjaja 2004; Jonsson et al. 2005; Pössel et al. 2005; Warrenburg 2005) because it is advantageous for experimental practical reasons to report an emotion on scales of pleasantness and arousal. However, one can argue that such a characterization does not inform explicitly about the nature of the verbal descriptions that are used to describe a feeling induced by odors and consequently loses most of the important qualitative differences between the affective effects of different types of odors. Furthermore, there is a considerable disagreement about the number and nature of the dimensions that provide an optimal framework for studying emotions. Fontaine et al. (2007) have recently shown that at least 4 dimensions are needed to satisfactorily represent emotions: evaluation or pleasantness, potency or control, activation or arousal, and unpredictability. Thus, as posited in other domains, the use of a simple valence by arousal representation may not be sufficient to answer relevant questions related to olfaction.

The discussion so far suggests that asking respondents to choose between basic emotion labels or rating feeling states on positive–negative or active–passive dimensions is not optimally suited to study the affective phenomena associated with odors.

In consequence, we address the following questions: Can we identify a taxonomy that could be specifically used to verbally measure the subjective affective experience induced by odors? A second, related question is, to what extent can the subjective experience be disentangled from the intrinsic quality of the odors, that is, can odors induce feelings that are not dependent on the hedonic valence of the odors?

As a first step in answering these questions, this paper reports pioneer research on a domain-specific approach to odor-induced feelings using a method strongly based on empirical criteria and thus independent of any theoretical framework. This method has been adapted from Zentner et al. (2008), who aimed at developing a judgmental rating scale for emotional feeling states adapted to the needs of music research. With the similar aim of developing a scale specifically suited for odor research, we conducted 2 interrelated studies (Studies 1 and 2) that investigated the verbal labels people find most appropriate to describe an affective subjective experience induced by olfactory stimulation. In both studies, psychometric analyses were performed on several sets of feeling assessments produced while respondents were exposed to a set of odorants representing a large range of odor types. The assessments were made from a list of candidate terms selected for their relevance to describe an affective state induced by odors. The goal of Study 1 was to examine the structure of feelings induced by odors by using exploratory factor analytic procedures to reduce the number of eligible terms to obtain a representative set of terms that can be organized in a few dimensions. Study 2, conducted during a public science fair, replicated Study 1 with a larger and more representative sample of odorant samples and participants in order to validate the preliminary model obtained in Study 1 by using confirmatory factor analytic procedures.

Study 1

Materials and methods

Material

List of terms relevant to describe odor-induced feelings. Because there is as yet no validated lexicon of feeling words in French that also explicitly includes potential descriptors of odor-related feelings, we report in this section a preliminary study that identified candidate affective terms to be

used in Study 1. For this preliminary study, we assembled from various sources a list of 480 terms, including 147 terms representing affective feelings experienced in everyday life with no reference to the olfaction domain (extracted from Zentner et al. 2008) and 333 terms that were more specific to the domain of olfaction and reflected either the character of the odors or the subjective experience elicited by the odors (e.g., Dravnieks 1985; Jellinek 1991; Boisson 1997; Rey-Hulman and Boccara 1998; David 2002; Chrea et al. 2004; Desmet 2005; Warrenburg 2005). The rationale behind this list was that it was to be as exhaustive as possible and to allow the examination of any potential link between the intrinsic quality of odors, that is, what the odors express, and the change in affective states that are produced by odors. In the preliminary study, participants ($N = 210$) rated the 480 terms for their relevance to describe an affective state induced by odors by answering the following question: ''In your opinion, is this term relevant for describing an emotional state you have already experienced when smelling odors in the past?'' (ratings were on a visual analogic continuous scale ranging from ''not relevant at all'' to ''extremely relevant''). From this preliminary study, we compiled a reduced list of 124 terms, including 105 terms that were understood and considered as relevant by a large majority of the respondents (at least 66%) and 19 terms that have been included in previous research on odor-induced feelings (Alaoui-Ismaïli et al. 1997; Desmet 2005; Warrenburg 2005). The inspection of these 124 terms indicated that some of them clearly reflected the intrinsic quality of the odors rather than the affective feeling they may elicit (e.g., intense, feminine, erotic). But others could also be evaluated as either affective or qualitative (e.g., pleasant, clean, mysterious). Thus, from the judgments of 10 experts on emotion from the Swiss Center for Affective Sciences (Geneva, Switzerland), we split the initial list of 124 terms into a primary list of 73 affective terms and a secondary list of 60 quality terms, with 9 terms overlapping between the affective and qualitative lists. The 2 lists of terms are available from the corresponding author upon request.

These 2 lists of terms were assigned in 2 experimental conditions in Study 1: Participants were evaluated for the same set of odorants, the affective terms in one condition and the qualitative terms in another, thereby allowing us to relate the intrinsic quality of odors to the affective change produced by these odors.

Odorant stimuli. Twenty-four odorants were selected in part on the basis of a previous study (Delplanque et al. 2008) in which the relation between pleasantness and familiarity ratings was examined for 48 odorants and in part from a pilot study in which familiarity and pleasantness ratings were also examined. From the average scores for pleasantness and familiarity, we selected 24 odorants in order to have as many pleasant as unpleasant odors, with a higher proportion of familiar odors as we sought to maximize elicitation of feelings produced by associations from past memories. The selected odorants covered a large range of everyday odors that tend to reflect different odor-related contexts (2 sweet aroma, 4 savory aroma, 3 cosmetic–household odors, 3 woody–earthy odors, 2 fruity odors, 2 floral odors, 2 spicy odors, 5 animal odors, and 1 medicine odor). The odorants, provided by Firmenich SA, were diluted in odorless dipropylene glycol in order to obtain a subjective average intensity roughly similar for all odorants (cf. Appendix 1 for the list of odorants with their respective concentrations). The diluted solutions were presented in a pen-like odor-dispensing device (provided by Burghart, Germany), in which the pen's tampon was filled with 2 ml of the diluted solution. Each odorant was coded by a random 3-digit code. Because there were too many odorant samples to evaluate for a single participant, we had to split the set of 24 odorants into 2 subsets, A and B, of 14 odorants each (4 odorants were overlapping between the 2 subsets as a measure of reliability between the 2 subgroups of participants).

Participants

Thirty-eight undergraduate students (24 females and 14 males) from the Faculty of Psychology at the University of Geneva took part in this study as part of a course requirement. The average age was 24.7 years (standard deviation = 5). Nineteen participants evaluated the list of affective and qualitative terms for subset A of odorant pens, and the other 19 participants evaluated the terms for subset B.

Procedure

The rating task took place in a well-ventilated experiment room in the Department of Psychology at the University of Geneva, which allowed 6 participants at once. The experimental task was a computer-based questionnaire. Participants were asked to attend 2 sessions separated by at least 1 day. Each session lasted approximately 90 min. In the affective condition session, participants were instructed to smell each odorant sample and rate the intensity of their subjective emotional experience by using the list of 73 affective terms selected from the preliminary study. In the qualitative condition session, participants were instructed to smell the same set of odorants and to evaluate the quality of the odors by using the list of 60 qualitative terms selected from the preliminary study. In both sessions, answers were given on a continuous scale ranging from ''not intense at all'' (0) to ''extremely intense'' (200). In addition, participants were asked to cross out any term they did not understand. The order of the sessions was counterbalanced across participants.

Results

One participant completed only the affective condition. Consequently, data were analyzed on the ratings of 19 participants for the affective condition and 18 participants for the qualitative condition.

First, we eliminated the terms that had been misunderstood by more than 5% of the participants for each list of terms. This was the case for 5 affective terms and 6 qualitative terms. The 68 remaining terms in the affective condition and the 54 terms in the qualitative condition were used for the following analyses.

Second, we were interested in checking the reliability of the ratings for the 4 odorants that overlapped between subsets A and B. To do so, we used the Pearson correlation to evaluate the consistency among the 2 groups of raters for the common odorants (peppermint, civet, pineapple, and mushroom). The Pearson correlations between the 2 groups of assessors indicated a strong reliability ($r = 0.88, P < 0.001$). This result suggests that there was no major difference between the 2 groups of assessors on the evaluation of the overlapping odorants. Consequently, for the following analyses, we did not consider assessor group as a factor of variability in the structure of the affective and qualitative terms, and we performed the analyses on the collapsed data from the 2 groups of assessors.

Factorial structure of the affective and qualitative terms

The purpose of the subsequent analyses was 2-fold: First, to reduce the set of terms to a smaller set of summary scales, and second, to gain preliminary insight into the structure of feelings elicited by odors derived from affective and qualitative assessments. The 68 affective terms in the affective condition and the 54 terms in the qualitative condition were submitted as variables to a series of exploratory factor analyses (EFAs), followed by VARIMAX rotation. The factor analysis on the affective terms yielded 7 factors that together explained 68.3% of the total variance. However, we considered only the most reliable factors, that is, with a Cronbach's α over 0.80. Concerning the terms, only the most discriminative of each factor were retained, that is, terms with high loadings on one factor and relatively low loadings on other factors. Table 1 presents an overview of the 5 affective factors, including their most discriminative terms and their respective alpha coefficients. The 5 factors were interpreted as happiness–well-being, awe–sensuality, disgust–irritation, soothing–peacefulness, and energizing–refreshing.

The factor analysis on the quality terms yielded 9 factors that explained 68% of the total variance. However, the alpha coefficients dropped dramatically above the first 4 factors. Because we were interested in extracting the factors that give rise to the highest internal reliability, we considered only the first 4 factors, associated with the delicacy, heaviness, sweetness, and healthiness features of the odors, respectively. Table 2 presents an overview of the 4 quality factors, including their most discriminative terms and their respective alpha coefficients.

Relationship between affective and qualitative factorial structure

In order to evaluate to what extent the intrinsic qualities of odors may predict the odor-induced subjective affective experience, we used canonical correlation, a statistical technique used to assess the relationships between 2 sets of variables. Canonical correlation computes a linear combination within each set of variables so as to maximize the correlation between 2 linear combinations of variables (e.g., Tabachnick and Fidell 1989). The first set of variables consisted of the factor scores on the 5 factors of the VARIMAX-rotated EFA computed on the affective terms. The second set of variables consisted of the factor scores on the 4 factors of the VARIMAX-rotated EFA computed on the qualitative terms. The results of this analysis showed a reliable correlation between the 2 sets of variables (canonical correlation = 0.83, maximum likelihood ratio test, $P < 0.001$). Four canonical correlations were significant (about 20% of variance explained by each canonical correlation). Standardized canonical coefficients and structure correlation coefficients for each of these significant canonical variables are presented

Table 1 Extracted factors, their most discriminating terms, and Cronbach's α in the affective condition of Study 1

Factor	Discriminative terms	Cronbach's α
1. Happiness–well-being	Pleasant–pleasant surprise–amusement–attracted–well-being–happiness–nostalgic–salivating	0.97
2. Awe–sensuality	Admiration–in love–desire–feeling awe–excited–romantic–sensual–sexy	0.96
3. Disgust–irritation	Disgusted–unpleasant–unpleasant surprise–angry–dissatisfaction–irritated–sickening–dirty	0.95
4. Soothing–peacefulness	Soothed–light–clean–relaxed–serene–reassured	0.94
5. Energizing–refreshing	Energetic–refreshed–revitalized–stimulated–invigorating–shivering	0.92

Table 2 Extracted factors, their most discriminating terms, and Cronbach's α in the qualitative condition of Study 1

Factor	Discriminative terms	Cronbach's α
1. Delicacy feature	Pleasant–attractive–benificial–carnal–delicate–discrete–distinguished–soft–elegant–erotic–feminine–harmonious light–clean–refined–reassuring–romantic–seducing–sensual–sophisticated–subtle–voluptuous	0.96
2. Heaviness feature	Animal–unpleasant–foul–heavy–nauseous–penetrating–stinky–dirty–persistent	0.94
3. Healthiness feature	Dynamic–fresh–spring-like–clean–pure–invigorating–healthy–tonic	0.92
4. Sweetness feature	Mouth watering–childish–sweet	0.82

Table 3 Standardized canonical coefficients (STDs), structure correlation coefficients (STRs), and canonical correlation for each of the significant canonical variates (CVs)[a]

	CV1		CV2		CV3		CV4	
	STD	STR	STD	STR	STD	STR	STD	STR
Affective variables								
Happiness–well-being	0.47	0.46	–0.18	–0.15	0.42	0.41	–0.75	–0.77
Disgust–irritation	0.68	0.69	0.68	0.68	0.01	0.02	0.27	0.27
Awe–sensuality	0.29	0.29	–0.54	–0.53	0.46	0.44	0.50	0.53
Soothing–peacefulness	0.31	0.33	–0.35	–0.35	–0.15	–0.15	0.23	0.24
Energizing–refreshing	0.36	0.37	–0.32	–0.32	–0.77	–0.78	–0.15	–0.15
Qualitative variables								
Delicacy feature	0.55	0.54	–0.66	–0.66	0.23	0.23	0.47	0.47
Heaviness feature	0.67	0.65	0.71	0.72	0.05	0.05	0.21	0.22
Healthiness feature	0.45	0.44	–0.21	–0.22	–0.73	–0.73	–0.46	–0.47
Sweetness feature	0.26	0.26	–0.06	0.07	0.65	0.64	–0.72	–0.72
Canonical correlation % of explained variance	20		20		20		21	

[a]Coefficients that are predominant are highlighted in gray.

in Table 3. Only canonical variables explaining 60% of variance or more were interpreted.

The first canonical variable pair revealed the relationship between the heaviness feature of odors and negative feelings. The second canonical variable pair again revealed the relationship between the heaviness feature of odors and negative feelings and to a lesser extent the relationship between the delicacy feature of odors and awe–sensuality feelings. The third canonical variable pair revealed the relationship between the healthiness feature of odors and energizing-refreshing feelings. Finally, the last canonical variable revealed the relationship between the sweetness feature associated with certain odors and happiness–well-being feelings.

Discussion

Study 1 provided a first glimpse of the semantic space describing affective feelings elicited by odors. First, Study 1 highlighted a relationship between the intrinsic quality of the odors and the subjective affective experience induced by them. Indeed, we found that the emotional experience could be finely differentiated across odor types, not only in the sense that unpleasant odors are more likely to produce unpleasant feeling and pleasant odors pleasant feelings but also in the sense that some specific qualitative features of the odors, such as perceived delicacy or healthiness, may be associated with particular subjective experience, such as sensuality or energizing feelings. This finding complements the conclusions drawn by Rétiveau et al. (2004) in a study on fine fragrances. Indeed, the latter authors found that 3 fragrances with similar hedonic values but different qualitative notes produced 3 differentiated affective responses among the respondents.

From these first findings, we can thus expect that the verbal scale we are developing to measure odor-induced feelings accounts for fine-grained differentiated affective states due to intrinsic quality differences across odors.

Second, our findings suggest that the structure underlying affective feelings of odors is rich and differs from the taxonomy used to refer to habitually experienced emotions in everyday life. For example, guilt, shame, anger, and sadness, which are found to be frequent emotions in everyday life (Scherer et al. 2004), did not appear to be relevant to describe affective states elicited by odors. Even though these terms were presented to the assessors in the affective conditions, the terms did not emerge in the semantic structure resulting from the EFA. Indeed, among the factors emerging from the EFA, only disgust was strictly common to the factorial structure from our study and the discrete emotion model. This is not surprising as disgust was originally defined in terms of a food-related emotion (Darwin 1872 in Rozin and Fallon 1987; Phillips and Heining 2002), with a particular focus on waste products from the human or animal body. This conception of disgust is thus appropriate to describe the feeling elicited by odorous substances emanating from rotten food or biological material in decomposition. Overall, these first findings suggest that the vocabulary used to describe odor-induced feelings is much richer when considering pleasant experiences than unpleasant experiences. This outcome leads to a different pattern compared with classical models of emotions, which tend to account more for negative feelings in the case of the discrete emotion model and for positive and negative feelings equally in the dimensional model.

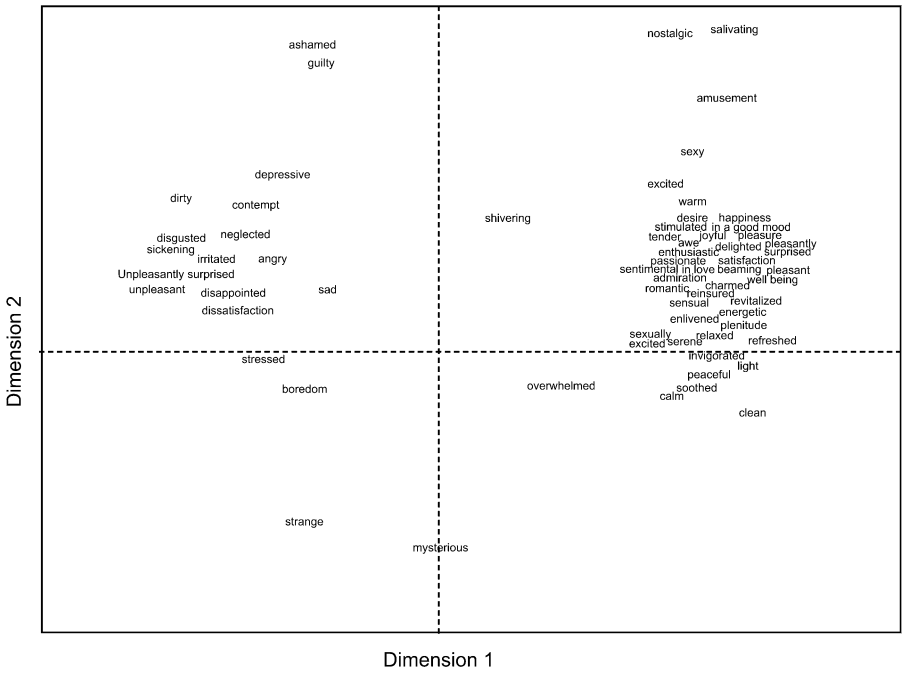
Moreover, when comparing our findings to predictions of the bidimensional model of emotions, the match between the 2 structures seemed obvious. Indeed, we found a soothing–peacefulness factor and an energizing–refreshing one that could correspond to an activation dimension. In the same way, we found a happiness–well-being factor and a disgust–irritation factor that could be interpreted as valence dimension. In order to verify this interpretation of our data, we computed the Pearson correlation between all pairs of individual ratings among all affective terms. We submitted the resulting correlation matrix to multidimensional scaling (MDS). The MDS allows us to represent the affective terms in *n*-dimension space, where the dimensions characterize the attributes of properties of the terms. A 2-dimensional MDS solution was selected as most appropriate (cf. Figure 1). Contrary to what is postulated by the bidimensional theory of emotions, the MDS solution presented in Figure 1 did not yield a valence by arousal bidimensional space. Even though the first dimension seemed to separate clearly positive affective terms from negative terms, the second dimension could not be interpreted as an activation dimension.

In sum, Study 1 suggests that a model with 5 factors, different from and not reducible to classical models, seems to represent the semantic space describing affective feelings elicited by odors. These first findings give strong support to the argument that a specific verbal scale is needed to measure the subjective affective experience related to odors. However, one of the main limitations of Study 1 was the representativeness of both the odorant samples and the population sample. Thus, in Study 2, we intended to test the strength of this preliminary model with a set of new judgments collected on a more representative sample of odors and participants.

Study 2

The goal of Study 2 was 2-fold: First, to extend findings from Study 1 with a more representative sample of odors and participants, and second, to examine the structure of odor affective ratings based on confirmatory factor analytic procedures to test how well the current ratings conformed to the original 5 factors emerging in Study 1. Confirmatory factor analysis (CFA) provides a more stringent test of the model's validity because, unlike EFA, the terms defining each factor and the relationships among factors are specified a priori rather than through the factor analytic methods (Maruyama 1997).

The research was carried out during a public scientific fair aimed at promoting research for the general public. This fair takes place in Geneva every 2 years (''Nuit de la Science'') and attracts a profusion of visitors. This fair offered the advantage of recruiting a large sample of participants from different age groups and socioeconomic strata



[a] For readability, the 73 terms on the figure are presented in English but they were evaluated in French by the participants.

Figure 1 Two-dimensional solutions resulting from the MDS performed on the correlation matrix between the 73 affective terms in Study 1. For readability, the 73 terms on the figure are presented in English but they were evaluated in French by the participants.

while maintaining excellent conditions for an experimental setting.

Materials and methods

Participants

Participants were volunteers among the visitors at the science fair. Three hundred and seventeen visitors took part in this experiment. Because the experimental setting allowed any visitor to log in to access the questionnaire, we decided, for the data analyses, to consider only the participants who completed at least one-third of the questionnaire as a criterion of participants' understanding and motivation for the task. Thus, a total of 282 participants (189 females and 93 males) were considered in our data analyses. The mean age was 33.4 years (range 7–81; standard deviation = 16.3).

Material

Affective terms. Seventy-three affective terms were used in Study 1. However, for the particular context of Study 3, we had to limit the number of terms to maximize participant's attention and motivation for the test. To reduce the number of terms, we selected them on the basis of 3 criteria: 1) the interrater agreement to characterize the odorant samples for each term (measured by intraclass correlation [ICC]) so that only the terms with the highest ICC were selected; 2) the ability of the terms to discriminate different odorant samples (measured by the loadings of the terms on the different factors) so that only terms with high loading on a specific factor without high cross-loadings on the other factors were selected; and 3) the homogeneity in the number of representative terms among the 5 factors so that all 5 factors would be represented by a roughly equal number of terms—this latter criterion constituting a major concern for the implementation of the model when using the confirmatory factor analytic procedure. On the basis of these 3 criteria, 36 terms were selected (cf. Figure 2).

Odorants. Fifty-six odorants were selected for Study 2 to reflect a large range of everyday odors (cf. Appendix 1 for the list of odorants with their respective concentrations). The odorants were presented via the same device as in Study 1 and coded with a 3-digit number. In order to limit olfactory fatigue and to optimize the test duration, we split the set of 56 odorants into 8 subsets and each participant evaluated only 7 odorants among the 56. Each subset was rated by approximately the same number of participants (≈35).

Procedure

The experiment was conducted in a 4 × 4 m tent erected in a Geneva park specifically for Nuit de la Science. Eight computers (one computer dedicated to each odorant subset) were set up to run the same computer-based questionnaire. Two experimenters were always present at the test location and approached the visitors to explain the goal of the study. Visitors who agreed to participate sat in front of a computer and were told how to complete the questionnaire. The instructions and rating procedure were the same as in Study 1. The presentation order of the odorants and the affective terms was randomly assigned for each participant.

Results

Of the 282 participants who completed at least one-third of the experiment, 260 completed the task for 7 odorants, 4 participants rated only 6 odorants, 11 rated 4 odorants, and 7 rated 3 odorants. The main goal of this study was to use CFAs to test how well the current affective ratings conformed to the original 5 factors emerging in Study 1. We first tested the original model that consisted of 5 factors as reported in Table 1. Then we tested this original model against alternative models. A first alternative model was derived from the results of an EFA computed on the data from Study 2. The EFA yielded 5 factors that together explained about 70% of the total variance.

Table 4 presents an overview of the 5 factors, including their most discriminative terms and their respective alpha coefficients. The comparison of the EFA between Study 1 and Study 2 suggested that the happy–well-being factor was the most unstable from Study 1 to Study 2. Specifically, the results suggested that, on the one hand, the factor soothing–peacefulness could be merged with the factor happiness–well-being and, on the other hand, the latter factor could be split into 2 separate factors, namely, happiness–well-being and one that we labeled sensory pleasure. Results from the EFA also revealed the instability of some terms on different factors. For example, the term "awe" loaded on the happiness–well-being factor rather than on the sensuality factor, as in Study 1. In the same way, the term "clean" loaded better on the refreshing–energizing factor than on the soothing–peacefulness factor. In the formulation of the alternative model, all these observations were taken into account and the modifications yielded a 6-factorial model (see Figure 2).

MPlus 3.0 software (Muthen L and Muthen B 1998–2004) was used to examine the alternative models. For this analysis, 3 fit indexes were considered: the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), and the comparative fit index (CFI). According to Hu and Bentler (1999), a combination of an SRMR <0.8 with an RMSEA <0.6 corresponds to a good fit. Similarly, CFI values of 0.90 or greater indicate an acceptable fit.

The 3 fit indexes for the different tested models, as well as the chi-square statistic, are reported in Table 5. The original model with 5 factors gave a good fit. However, the alternative model with 6 factors gave a better fit (the difference in fit between both models was significant, $\Delta\ \chi^2\ (5) = 129.41$, $P < 0.0001$). We also tested 2 simpler models with fewer latent factors (for the fit indexes, see Table 5). The first model separated happiness–well-being, awe–sensuality, energizing–refreshing, and soothing–peacefulness from disgust–irritation (positive vs. negative feelings model in Table 5). The second model differentiated the

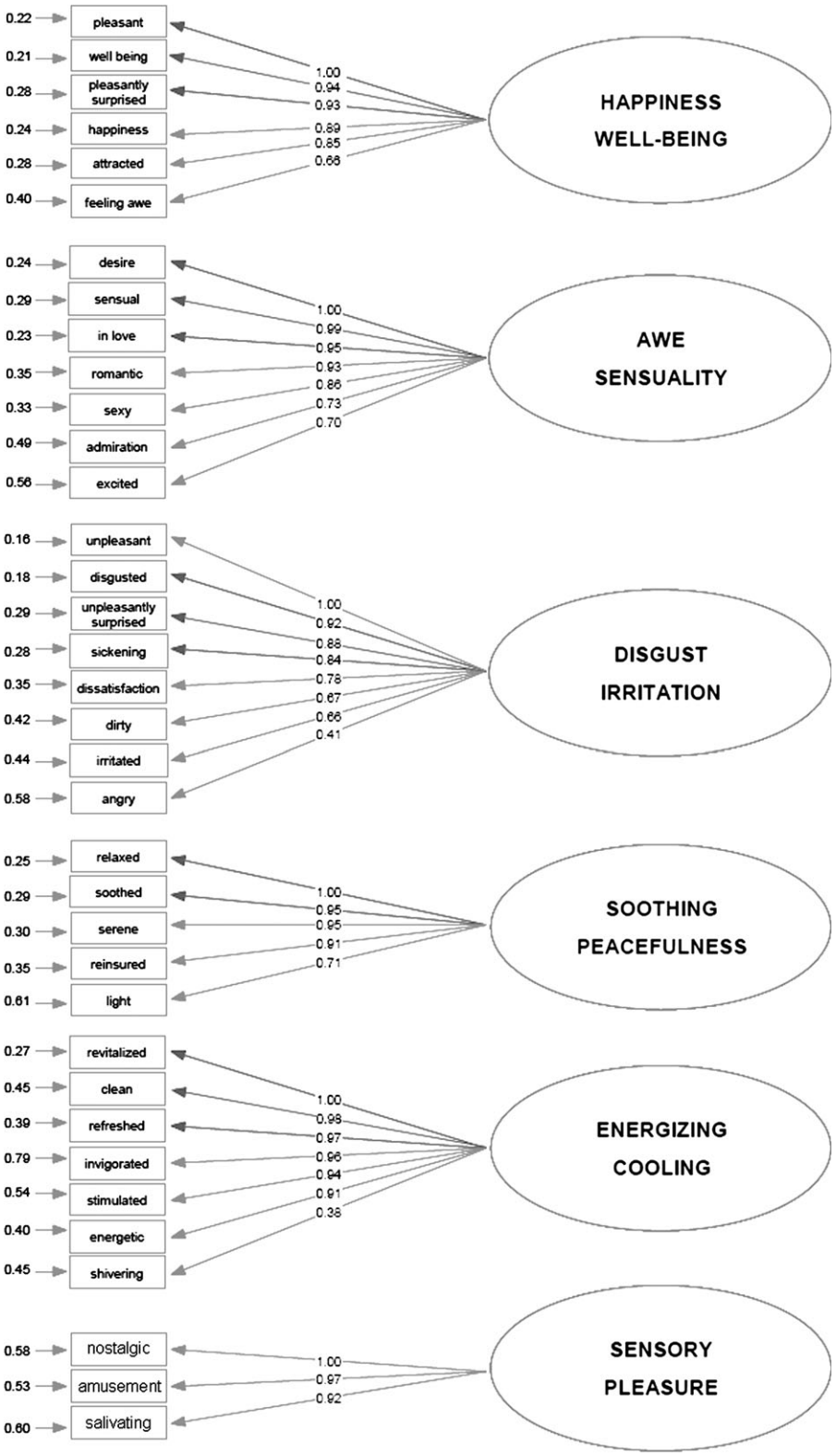


Figure 2 CFA on emotional responses to odors. The boxes are items, with the error terms on the left. On the right are the latent factors. Values on arrows are the standardized parameter estimates. For readability, the 36 terms in the boxes are presented in English but they were evaluated in French by the participants.

emotions according to a bidimensional valence by arousal space resulting in 4 latent factors, namely, happiness–well-being–awe–sensuality, disgust–irritation, soothing–peacefulness, and energizing–refreshing (bidimensional model in Table 5). Both models showed a significant inferior fit compared with the 6-factorial model ($\Delta\chi^2(14) = 364.64$, $P < 0.001$ for the positive vs. negative feelings model and $\Delta\chi^2(9) = 244.05$, $P < 0.001$ for the bidimensional model).

The architecture of the final 6-factorial model is illustrated on Figure 2. This model is composed of 36 affective terms loading on 6 latent factors that have been named as follows:

Pleasant feeling. This dimension is mainly related to happiness and well-being, with a noteworthy association to ecstatic feeling as reflected by the terms "attracted" and "feeling awe."

Unpleasant feeling. This dimension is mainly related to disgust and irritation, but it also emphasizes other irritating feelings, such as anger and dissatisfaction.

Sensuality. This dimension reflects the role of olfaction in social interaction and, in particular, in sociosexual behaviors, as expressed by the terms "sensual," "desire," or "in love."

Relaxation. This dimension is strongly associated with soothing effects, to the point that certain odors may produce meditative feelings, as suggested by the terms "light" and "serene."

Refreshment. This dimension is mainly associated with effects of stimulation and purification and also includes physiological responses, as expressed by the term "shivering."

Sensory pleasure. This dimension is represented by 3 terms that have well-differentiated meanings (amusement, nostalgia, and salivating) but together could be related to evoked-event pleasure, especially in relation to food. Indeed, when examining the odorants for which these specific terms were highly rated, we found that this sensory pleasure factor was particularly relevant for odors such as caramel, beef stew, or strawberry that are nostalgic reminders from the past.

The intercorrelations between the 6 factors are presented in Table 6. Although some of these intercorrelations seem particularly high from the point of view of statistical parsimony, they suggest that rather than occurring separately, these affective feelings are most typically experienced in blended or coupled form.

The 36 items and their respective groupings provide a measurement tool to investigate odor-induced affective feelings—a tool we called the Geneva Emotion and Odor Scale (GEOS). Questionnaires, instruction, and terms of the GEOS are available at the following Internet address: http://www.affective-sciences.org/geos.

Table 4 Extracted factors, their most discriminating terms, and Cronbach's α in Study 2

Factor	Discriminative terms	Cronbach's α
1. Well-being–peacefulness	Relaxed–serene–soothed–well-being–pleasant–pleasantly surprised–feeling awe–light–clean–attracted–well-being–happiness–admiration–feeling awe	.96
2. Disgust–irritation	Disgusted–unpleasant–unpleasant surprise–angry–dissatisfaction–irritated–sickening–dirty	.94
3. Sensuality	In love–desire–excited–romantic–sexy–sensual	.90
4. Energizing–refreshing	Energetic–refresh–revitalized–stimulated–invigorating	.91
5. Sensory pleasure	Nostalgic–amusement–salivating	.69

Table 5 Summary of goodness of fit indices for the different models tested in Study 2[a]

Model (number of factors)	χ^2	df	RMSEA	CFI
5-Emotions model (Study 2)	2486.62	584	0.048	0.914
6-Emotions model (Study 3)	2262.37	630	0.046	0.924
Positive versus negative feelings model	4391.88	593	0.068	0.829
Bidimensional model	3039.44	588	0.055	0.890

[a]$N = 2256$ and df = degrees of freedom. All models are nested (with 36 observed variables). The model that gave the best fit is highlighted in gray.

Discussion

A first goal of Study 2 was to test the preliminary model found in Study 1 with a different and larger sample of participants and odorants. Altogether, findings from Studies 1 and 2 converged to a similar structure. These findings suggest that, on the basis of empirical data obtained with various types of odorant stimuli and populations, we can propose a new set of scales that represents the semantic space describing subjective affective responses induced by odorant substances. Although we found that the 5-factorial model obtained using exploratory analysis from Study 1 provided

Table 6 Intercorrelations between the 6 odor-elicited emotional factors in Study 2

	Pleasant feeling	Sensuality	Unpleasant feeling	Relaxation	Refreshing
Sensually	0.88				
Unpleasant feeling	−0.51	−0.34			
Relaxation	0.91	0.80	−0.41		
Refreshing	0.86	0.74	−0.44	0.83	
Sensory pleasure	0.85	0.75	−0.42	0.71	0.68

a satisfactory fit to the data, a few modifications improved the fit, leading to a model with 6 factors that we called the GEOS. An examination of this domain-specific model highlights some of the specific features of the sense of olfaction.

First, the emergence of the sensuality factor highlights the central role of olfaction in social interactions, more specifically in sociosexual behaviors, as suggested by the affective terms loading on this factor. This finding is consistent with previous work on the affective effects induced by odors (Warrenburg 2005). This finding can be compared with arguments claiming that olfaction has an important role in reproductive behaviors (for a recent review, see Grammer et al. 2005). For example, in a study on immune-related mating preference (Milinski and Wedekind 2001), the authors found that perfumes, known for their role in boosting sexual attractiveness, have biological significance in the choice of potential sexual partners. Even though there is still not enough evidence on the process underlying the role of olfaction in interpersonal communication, our results tend to suggest that in terms of representations, laypeople attribute a specific power to odors.

Second, the GEOS emphasizes the importance of relaxing or stimulating effects produced by odors, as pointed out by terms such as "soothed," "serene," "reinsured," or "light" on one hand and "revitalized," "energetic," "clean," and "fresh" on the other. This finding is consistent with the broad literature on the effects of odors on mood and cognition (for a review, see Herz 2002). For example, it has been claimed that lavender and vanilla have a relaxing effect (Moss et al. 2003; Marlier et al. 2005). In contrast, mint and citrus are supposed to have a stimulating effect (Ilmberger et al. 2001). Even though scientific confirmation of these facts is still needed, good empirical evidence shows that at a subjective and physiological level, people feel more relaxed in the presence of certain odors and more stimulated in the presence of others (Herz 2002). Nonetheless, as we showed in Study 1, these factors cannot be projected onto an activation dimension, as classically reported in bidimensional models of emotion (Russell et al. 1989). The CFA performed on the new set of data collected in Study 2 confirmed that these 2 factors (relaxing and stimulating) were strongly positively correlated ($r = 0.83$), not negatively correlated, as we should expect if they were projected onto an activation dimension. Thus, the verbal scale that emerges from Studies 1 and 2 fits with a domain-specific model in which feelings are neither sharply distinct nor projected on a bidimensional space.

Finally, the confirmatory analysis in Study 2 allowed us to discriminate 2 related but separable factors that were not discriminated by the exploratory analysis performed in Study 1, namely, a pleasant feeling factor defined by terms such as "happiness," "well-being," "pleasant," and "feeling awe" versus a sensory pleasure factor defined by the terms "nostalgia," "amusement," and "salivation." These findings are again in accord with the existing literature on odors. The robustness of the pleasant feeling factor gives support to the claim that odors can improve our mood and well-being (Herz 2002; Warrenburg 2005). In fact, in addition to the commercial use of odors to influence the behavior and the evaluation of the retail store environment (Spangenberg et al. 1996), recent studies have demonstrated the positive influence of odors in therapeutic contexts, as in urge reduction in smokers (Sayette and Parrott 1999), in pain tolerance (Villemure et al. 2003), and in preventing apnea in premature newborns (Marlier et al. 2005). Along the same lines, a more recent study suggests that ambient odor can become associated with emotionally significant events and can be used to influence conscious behavior in a positive manner (Chu 2008).

The emergence of a sensory pleasure factor constitutes a more striking finding. From our point of view, this finding provides empirical evidence for a strong link between memory and olfaction as this sensory pleasure factor reflects specifically the power of some food-related odors to bring us back to our childhood. This link could be related to the Proustian phenomenon concerning the impressive ability of odors to bring to awareness long-forgotten autobiographical memories (for a review, see Chu and Downes 2000). In particular circumstances, an odor seems to be linked with the past in a way that could be described as "flashbulb memory," a term that describes a memory that retains exact and detailed circumstances of a highly emotional situation (Brown and Kulik 1977). This possibility fits well with the experience that a specific smell can vividly revive a past situation that is particularly emotional. The process underlying this phenomenon is still unclear (Chu and Downes 2000), but the important connections between the olfactory system and the limbic system, involved both in emotion and memory processes, could play a major role.

General discussion

Olfaction has often been regarded as not only the most emotional sense among the 5 senses but also the most difficult to study because of the high variability in the affective responses produced by odors (Hudson and Distel 2002). Therefore, mechanisms underlying the emotional effects of odors are still poorly explored. It was the aim of the present study to consider a domain-specific approach in order to get a better understanding of the nature and organization of feelings elicited by odors. By using an approach based on strictly empirical criteria, we carried out a series of interrelated studies in order to investigate which labels in everyday life people find most appropriate to describe subjective affective experiences or feelings elicited by odors. Our findings lend support to the view that an accurate description of odor-elicited affective feelings seems to require a specific affect vocabulary and taxonomy, which differ from those provided by classical models of emotion theories.

A first point of interest in this domain-specific taxonomy that emerges from our research concerns the poor representation of negative feelings compared with positive feelings. At first glance, this finding suggests, in agreement with the existing literature, that odors not only reduce negative

emotions but also enhance positive emotions (e.g., Rétiveau et al. 2004; Warrenburg 2005). Moreover, this finding confirms the strong belief observed in laypeople about the beneficial effects of odorous compounds and the general positive attitude toward odors (Martin et al. 2005; Bulsing et al. 2007). However, we cannot rule out the possibility that a greater variety of negative feelings than that emerging from our research can be induced by olfactory stimulation. Participants were not given specific situations or contexts to consider for their judgments in order to sample a wide range of experiences. What remains to be tested is the possibility that negative feelings require an appropriate—possibly social—context in order to be elicited via odors. Indeed, unpleasant terms associated with basic emotions, such as anger, shame, or sadness, may not have been rated as pertinent because the odors were not delivered in a context that facilitates the emergence of such an affective subjective experience.

One can wonder to what extent this ratio is dependent on the methodology, we used to extract the relevant dimensions to describe odor-induced feelings. In fact, because no context was set while respondents were assessing the odors, we may have neglected rare phenomena that are important for understanding the underlying process as a whole. A hypothesis that remains to be tested is whether the context has an impact on the semantic affective space describing affective feelings elicited by odorous substances, in particular for the representativeness of negative feelings. Although the effect of context on the emotional evaluation of odors has been rarely addressed to date, the GEOS provides a tool to investigate in a more systematic fashion how the context can modulate the way we affectively respond to odors.

As suggested by Desmet (2005), recent cognitive emotion theories such as appraisal theories may facilitate the interpretation of findings on the nature of emotional effects of odors. Appraisal theories claim that emotions tend to be elicited by appraisal processes and that each type of emotion experienced by an individual can be predicted on the basis of the results of the appraisal process (see Scherer 2001). In other words, as an event occurs, the individual concerned evaluates its significance on a number of criteria such as pertinence of the consequences to one's well-being, conduciveness or obstructiveness for one's plans and goals, the ability to cope with such consequences, and the compatibility of the action consecutive to the evaluation with personal values and cultural norms. In this theoretical framework, some authors postulate, for example, that anger, fear, or sadness are emotions experienced in response to an appraisal of a high goal hindrance (Scherer 1997). We can easily conceive that none of these emotions were likely to be experienced in the experimental context of Studies 1 and 2 because no context was set in these experiments, and so respondents would not have a goal that could be directly hindered by the odorant samples presented to them. However, in everyday life, one can assume that these emotions could be experienced, even rarely. For example, in approaching an office, the lingering smell of the typical perfume of a female collaborator whom one finds overbearing and tends to avoid may be evaluated as goal obstructive and may induce negative emotion such as anger. Thus, it is possible that, because of our experimental setting, which differed from a daily life context, some negative emotions were unlikely to be experienced because of the absence of certain appraisal dimensions such as goal or need conduciveness or coping potential. However, if the interpretation of our findings within the framework of an appraisal approach is grounded for the negative emotions, it is also the case for the interpretation of the rich differentiated positive affective feelings emerging from our studies. For example, the subjective affective experience related to the sensuality or the sensory pleasure factors should be predicted by the results of specific appraisals. Our current research was still exploratory and was not designed to investigate in a systematic fashion, the nature of the appraisals that may predict odor-related emotions. Thus, it would be purely speculative to infer specific appraisals of the emotions emerging from our studies. However, the nature of the appraisals may constitute a crucial issue for future work in order to develop the most appropriate emotion scales specific to the olfactory domain.

A secondary point of interest concerns the new perspectives that are brought by this research. In fact, this research constitutes a first step in the construction of a new scale that verbally measures the specific subjective affective feelings elicited via olfactory stimulation. Although further studies could be conducted to refine the psychometric properties of this scale, we hope that the GEOS will be adopted by the academic and applied research community. From an applied point of view, this new scale could be used by professionals from diverse domains who are interested in assessing the subjective emotional experience elicited by odorant substances. For example, it is crucial for food and cosmetic industries to better understand the emotional effects of odors in order to design products with a specific emotional impact on users. This new set of scales could thus be useful to assess the fine-grained differences in the emotional effects of scented products. From a theoretical point of view, the emergence of a domain-specific scale that differs from the current emotion scales could help us to get a better understanding of the process underlying the relation between odors and emotion, not only at the subjective level but also at all the integrated levels (cognitive, physiological, motivational, and expressive effects). Earlier, we discussed in particular the relevance of more recent theories such as the appraisal theory of emotions, which may be more appropriate for explaining and predicting the processes underlying emotion elicitation through olfactory stimulation, as it allows for a more comprehensive conceptualization of the major determinants and their interaction. We can wonder to what extent the GEOS can inform us about the underlying mechanisms. Even though we are not sufficiently advanced in the development of the new instrument, some preliminary observations from the present paper are noteworthy. The restricted set of

affective terms obtained from our approach includes many different types of affective states that reflect the fact that, as theoretically argued earlier, feeling states can be considered as a reflection of the changes in all components of an emotion because they refer to a cognitive (nostalgic, romantic), physiological (shivering, salivating), or motivational action-related component (attracted). In consequence, using the criterion of what people find most appropriate as labels to describe affective feelings induced by odors seems to provide promising leads for the inquiry into the underlying mechanisms, in contrast to basic emotion lists or valence–activation dimensions.

Conclusion

We have presented evidence of a 6-scale model (GEOS) to describe the subjective affective feelings induced by odors. We do not suggest that this model provides a complete picture of the nature and organization of odor-elicited feelings. Further investigation is needed to know if this scale is more appropriate for the olfactory domain than the current prominent scales. More generally, in light of our current findings, the question of the appraised antecedents of odor-elicited emotions needs to be further investigated, rather than choosing the convenience of classical models of emotion. An important recommendation for further investigation in this direction would be to put a greater emphasis on the context on the affective response to odors in order to avoid the possibility of neglecting rare phenomena. Finally, expanding this research to a larger range of odorant substances (e.g., fine fragrances and functional fragrances such as detergent or bath foam) would allow us to examine, in a more comprehensive fashion, the validity of the current affective terms and the appropriateness of such a new scale.

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Appendix 1 Odorants used in Studies 1 and 2

Odorant name	Descriptor	% V/V	Study 1	Study 2	Odorant name	Descriptor	% V/V	Study 1	Study 2
Agarwood smoke	Wood	20		×	Lavender	Lavender	10	×	×
Anethol	Anise	20		×	Leather	Leather	5	×	×
Basil	Basil	5	×		Lilac	Lilac	10		×
Beef	Beef stew	10		×	Lily of the valley	Lily of the valley	10		×
Beer	Beer	20	×	×	Lime	Lime	20	×	
Butter popcorn	Rancid butter	20	×	×	Magnolia	Magnolia	20		×
Cake	Cake	20	×		Methyl salicylate	Methyl salicylate	10		×
Caramel	Caramel	20		×	Neroli	Orange blossom	5	×	
Carbinol	Mushroom	5	×	×	Oil of cade	Fire smoke-smoked ham	20		×
Chinese incense	Chinese incense	20		×	Olive oil	Olive oil	20		×
Cigarette smoke	Cigarette smoke	Pure		×	Paradisone	Paradisone	Pure		×
Cinnamon	Cinnamon	20		×	Patchouli	Patchouli	10		×
Civet	Feces	10	×	×	Pepper	Pepper	Pure		×
Classical face cream fragrance	Face cream	1	×	×	Peppermint	Peppermint	20	×	×
Classical shampoo fragrance	Shampoo	10	×	×	Pineapple	Pineapple	10	×	
Classical soap fragrance	Soap	10	×		Pipol	Grass	20		×
Coffee	Coffee	20		×	PK EXTRA	Manure	1	×	
Cream strawberry	Cream strawberry	5		×	Resinoide incense	Incense	50		×
Cucumber	Cucumber	20		×	Rum	Rum	20		×
Curry	Curry	10	×		Sclarymol	Sulfury and onion	1		×
Durian	Durian	20		×	Stone pine	Pine	Pure	×	×
Dynascone	Dynascone	20		×	Strawberry	Strawberry	10		×

Appendix 1 Continued

Odorant name	Descriptor	% V/V	Study 1	Study 2	Odorant name	Descriptor	% V/V	Study 1	Study 2
Eucalyptus	Eucalyptus	20		×	Sulfox	Rotten egg	0.05		×
Eugenol	Clove	20		×	Synthetic body odor	Sweat	Pure	×	×
Fig	Fig	10		×	Tangerine	Tangerine	20		×
Firsantol	Wood	20		×	Thyme	Thyme	20		×
Floral strawberry	Floral strawberry	5		×	Tiare	Tiare	Pure		×
Fried shallot	Onion	20	×	×	Tutti fruiti	Tutti fruiti	10	×	
Ghee	Cheese	5	×	×	Vetyver	Vetyver	20		×
Grape fruit	Grape fruit	20		×	Violet	Violet	10		×
Honey	Honey	10		×	Wolfwood	Wood	Pure		×
Isovaleric acid	Dirty socks	1	×	×	Yogurt	Yogurt	10		×
Landes wood	Wood	5	×	×					

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