

Ferdenzi C, Delplanque S, Barbosa P, Court K, Guinard J, Guo T, Roberts SC, Schirmer A, Porcherot C, Cayeux I, Sander D & Grandjean D (2013) Affective semantic space of scents. Towards a universal scale to measure self-reported odor-related feelings, *Food Quality and Preference*, 30 (2), pp. 128-138.

**This is the peer reviewed version of this article**

*NOTICE: this is the author's version of a work that was accepted for publication in Food Quality and Preference. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in Food Quality and Preference, [VOL 30, ISS 2 (2013)] DOI: <http://dx.doi.org/10.1016/j.foodqual.2013.04.010>*

# **Affective semantic space of scents.**

## **Towards a universal scale to measure self-reported odor-related feelings.**

Camille Ferdenzi<sup>1,2</sup>, Sylvain Delplanque<sup>1,2</sup>, Plinio Barbosa<sup>3</sup>, Kimberly Court<sup>4</sup>, Jean-Xavier Guinard<sup>4</sup>, Taomei Guo<sup>5</sup>, S. Craig Roberts<sup>6</sup>, Annett Schirmer<sup>7</sup>, Christelle Porcherot<sup>8</sup>, Isabelle Cayeux<sup>8</sup>, David Sander<sup>1,2</sup>,  
Didier Grandjean<sup>1,9</sup>

<sup>1</sup> Swiss Center for Affective Sciences, University of Geneva, 7 rue des Batoirs, 1205 Geneva, Switzerland.

<sup>2</sup> Laboratory for the Study of Emotion Elicitation and Expression (E3 Lab), Department of Psychology, FPSE, University of Geneva, 40 Bld du Pont d'Arve, 1205 Geneva, Switzerland.

<sup>3</sup> Department of Linguistics, State University of Campinas, Cidade Univeritária « Zeferino Vaz », Barão Geraldo, Campinas, São Paulo, Brazil.

<sup>4</sup> Department of Food Science and Technology, University of California, Davis, 1 Shields Avenue, Davis, CA 95616, United States of America.

<sup>5</sup> Key State Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China.

<sup>6</sup> Department of Psychology, University of Stirling, Stirling FK9 4LA, United Kingdom.

<sup>7</sup> Department of Psychology, Faculty of Arts and Social Sciences, National University of Singapore, Lower Kent Ridge Road, Singapore, 119099.

<sup>8</sup> Firmenich SA, route des Jeunes 1, P.O. Box 239, 1211 Geneva, Switzerland.

<sup>9</sup> Neuroscience of Emotion and Affective Dynamics Laboratory (NEAD Lab), Department of Psychology, FPSE, University of Geneva, 40 Bld du Pont d'Arve, 1205 Geneva, Switzerland.

*Correspondence to be sent to: Camille Ferdenzi, Swiss Center for Affective Sciences,*

*University of Geneva, 7 rue des Batoirs, 1205 Geneva, Switzerland. Email:*

*Camille.Ferdenzi@unige.ch or cferdenzi@hotmail.com. Tel: 00 41 22 379 98 10. Fax: 00 41*

*22 379 98 44*

## Abstract

Measuring self-reported affective feelings to odors and odorous products is a recent challenge for the food and cosmetic field, requiring the development of suited instruments. This paper finalizes a line of studies aimed at developing Emotion and Odor Scales (EOSs) in several cultures. Previously available for Switzerland, the United Kingdom and Singapore, new EOSs are presented here for the United States, Brazil, and China. These scales, developed with 350 to 540 participants per country, have been conceived to allow the measurement of affective feelings (e.g., emotions, moods, attitudes) in response to a wide range of odors including pleasant and unpleasant, food and non-food ones. Several affective categories were recurrent in the countries examined here: Disgust/Irritation, Happiness/Well-being, Sensuality/Desire, Energy, but also Soothing/Peacefulness and Hunger/Thirst, indicating a potential link between emotion and adaptive universal functions of olfaction such as danger avoidance, ingestion and social communication. For these common categories, similarity in affective responses generally reflected geographic proximity indicating also a strong influence of cultural aspects. Exceptions to this pattern were Singapore and China, with affective responses of Singaporeans being closer to those of Europeans. This series of studies allows us to propose a universal scale (UniGEOS) that might be used in the future for examination of other cultures. This scale comprises affective categories that we found to be culturally shared, enclosing the most frequently shared affective terms, and several culture-specific aspects that may be relevant in other cultures. This tool can be used in its complete form (25 affective terms) or as a short version with 9 categories entitled Unpleasant Feelings, Happiness/Delight, Sensuality/Desire, Energy, Soothing/Peacefulness, Hunger/Thirst, Interest, Nostalgia and Spirituality.

## Key-words

Olfaction, Emotion, Affective feelings, Self-report, Culture.

## Introduction

The impact of olfaction on emotional processing is well known and can be conceptualized as the result of low level of processing, shared with non-human animals, with high adaptive functions such as the avoidance of spoiled food through the induction of disgust feelings, and/or higher level of processing, involving complex cognitive mechanisms influenced by inter-individual and cultural differences characterized by the sharing of values and/or experiences among groups of people; nostalgia feelings are likely to be more influenced by these latter aspects than disgust feelings, for example. In this study we would like to propose a general model of the relationships between affective and olfactory processing for the use of scientists and other people interested in the study of such phenomena. Indeed, both fundamental and applied scientists might benefit from a general model of self-reported odor-related affective feelings to start investigating the affective phenomena induced by the processing of odors in different human groups and/or different cultures.

Measuring affective responses to odors, and by extension to products for which odors are a major characteristic (such as foods and cosmetics), is a recent challenge for the flavor and fragrance industries. Initiated several decades ago (Kotler 1973), sensory -and thus olfactory- marketing has undergone a major development (Rieunier 2002). This development was sparked by an interest in favorably influencing consumer behaviors towards a product or in a point of sale by stimulating the senses. Marketing studies showed that ambient scents can positively impact product evaluations, time and (in some cases, not all: see Knasko 1989; Schifferstein & Blok 2002) money spent in consumption contexts such as stores, restaurants or casinos (e.g., Hirsch 1995; Spangenberg et al. 1996; Morrin & Ratneshwar 2000; Guéguen & Petr 2006). Possible mechanisms could be that pleasant ambient odors have a favorable impact on mood by activating positive associations stored in memory. This may then produce approach behaviors and thus generally facilitate product orientation.

Alternatively odors may draw attention specifically to products they are congruent with (Seo et al. 2010).

The human-product interactions are not only influenced by environmental odors, but also by the olfactory properties of the product itself (among numerous other sensory, functional or economic aspects). Odors associated with products may produce varied emotional responses – from the most obvious ones such as liking/disliking to the subtlest ones such as energizing (for a sport shower gel for instance). Numerous studies have shown that odors influence mood (Knasko 1992, 1995; Schiffman et al. 1995a,b; Lehrner et al. 2005), performance in cognitive tasks as well as person and object evaluation (Rotton 1983) congruently with their valence (see also Ehrlichman & Bastone 1992; Herz 2009). In addition, behavioral and physiological approaches revealed that odors can alter an individual's arousal by inducing relaxation or excitation (e.g., Torii et al. 1988; Bensafi et al. 2002a; Heuberger et al. 2004; Goel et al. 2005). Although sensory affect is increasingly included in sensory testing by the food and fragrance industry, and gains importance in product development, theoretical and methodological supports are only in the early stages of development.

Methods used to measure self-reported affective feelings to odors have mostly been inspired from the broader emotion literature and based on the valence-arousal (Russell 1980) or the basic emotion theories (Ekman 1984). Although valence is a dominant dimension of odor perception (Engen 1982; Yeshurun & Sobel 2010), limiting the description of emotional response to positive vs. negative (valence) and activating vs. calming (arousal) feelings is perhaps oversimplified and not well suited for a comprehensive view of odor-related affects. Just as inappropriate are basic emotions, usually defined as six states (*fear*, *anger*, *sadness*, *surprise*, *joy* or *happiness*, and *disgust*) putatively characterized by specific neural, physiological, expressive, and feeling components (Matsumoto & Ekman 2009). Whereas *disgust* and *happiness* can clearly be elicited by odors, other basic emotions such as *fear*, *anger* and *sadness* are much less often verbally reported (Alaoui-Ismaili et al. 1997;

1 Bensafi et al. 2002b; Desmet 2006). This contrasts with verbal reports of emotions triggered  
2 by visual objects (Croy et al. 2011). Several recent studies have proposed more  
3 comprehensive questionnaires comprising either an extended set of basic emotions (22  
4 terms: Desmet & Schifferstein 2008) or mood terms mostly taken from pre-existing mood  
5 scales (Churchill & Behan 2010; King & Meiselman 2010). However, even when the  
6 relevance of the affective terms was carefully controlled (King & Meiselman 2010), it must be  
7 conceded that these tools are highly product-specific (foods, and especially snacks: Desmet  
8 & Schifferstein 2008; King & Meiselman 2010; fragrances used in body care products:  
9 Churchill & Behan 2010) and may thus not be easily extended to other products or specific  
10 odorants. With the aim to tap a broader range of stimuli and affective facets, researchers  
11 from the University of Geneva initiated the development of the Emotion and Odor Scales, the  
12 characteristics of which are presented hereafter.

23  
24  
25  
26  
27  
28  
29 First, the Emotion and Odor Scales were designed to measure affective feelings in their  
30 widest sense (see Frijda & Scherer 2009). Accordingly, affective feeling is any emotional  
31 feeling that can be categorized as an emotion (e.g., happiness), an attitude (e.g., love), a  
32 personality trait (e.g., anxious) or a mood (e.g., cheerful) (Scherer 2005). The choice of terms  
33 relevant to describe odor-elicited feelings was solely based on participants' judgments of  
34 several hundred terms taken from the literature on emotion and odor perception. Second, the  
35 Emotion and Odor Scales were designed to judge feelings elicited by odors in general. Thus,  
36 the scale development process was based on participants' affective responses to a wide  
37 range of odor samples: pleasant and unpleasant, mostly familiar and pertaining to the food  
38 domain (sweet, savory, fruits, spices, drinks, and vegetables) or not (cosmetic, household,  
39 woody, plants, animal, floral, and medicine). Third, the participants involved in the  
40 development of the Emotion and Odor Scales were not only students, but also (and mostly)  
41 from the general population, which confers validity of the tools outside the laboratory  
42 conditions and for a broader audience. Additionally, the scales were developed based on  
43 examinations in different countries (first in Switzerland: Chrea et al. 2009; later in the United  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

1 Kingdom and Singapore: Ferdenzi et al. 2011; see also Ferdenzi et al. 2013) allowing the  
2 identification of cultural invariants and making them suitable for examination in other  
3 unstudied cultures. Fourth, the Emotion and Odor Scales have proven to be practical tools  
4 during sensory testing either in their long (less than 40 items) or short version (6 items,  
5 ScentMove® questionnaire: Porcherot et al. 2010, 2012, 2013). Fifth, some evidence was  
6 brought that the Emotion and Odor Scales allowed a finer approach to affective feelings than  
7 a simple valence measure (two samples with equivalent valence can be discriminated on  
8 other affective aspects: Porcherot et al. 2010). Evidence of the superiority of this tool – in  
9 terms of relevance, inter-rater agreement and discriminating power – compared to the  
10 classical models of emotion (valence-arousal, and basic emotions) was also brought recently  
11 in a dedicated study (Delplanque et al. 2012).

26 The first main aim of this article is to introduce the Emotion and Odor Scales developed  
27 in four geographic areas that were not included in our previous studies: two in the United  
28 States (Fayetteville, Arkansas, and Davis, California), one in an Asian country (Beijing,  
29 China) and the latter in South America (Campinas, Brazil). Comparison of the scales  
30 obtained in the different cultures presented here and in the previous publications (European  
31 areas: Geneva, Switzerland, and Liverpool, United Kingdom; and another Asian country:  
32 Singapore) are then performed in reference to geographic and historical differences. The  
33 second main aim of this article is to propose, based on the different scales obtained in these  
34 7 geographic areas, a unique scale that can be used in the future [in other cultures](#). As the  
35 scale development procedure is demanding and thus cannot be repeated over and over, and  
36 as there are substantial similarities between the different scales, we believe it makes sense  
37 to propose such a global scale for future research in olfaction and emotion.

## Method

### *Participants*

Age, gender and smoking habits of the participants as well as sample sizes are provided in Table 1 for the seven geographic areas. The participants in Studies 1 and 2 were recruited among university students and the participants in Study 3 were recruited among the general public during public events (Geneva, Davis), in public places such as museums (Liverpool, Singapore, Beijing), libraries (Davis, Campinas), parks (Beijing) or among a database of people from the general population (Fayetteville). Only participants who had spent most of their life in the countries where the experiment took place were included in the study (or in one of the adjacent countries with the same language, e.g., France for the Swiss sample, Ireland for the British sample, etc.). Informed written consent was obtained prior to participation. Committees on Research Ethics of all the Universities collaborating on the project approved the studies.

### *Materials*

#### *Affective terms*

The final Emotion and Odor Scales are the result of affective term selection from an initial set of about 480 terms. These terms were taken from the literature with or without reference to the olfactory modality. They were chosen to refer to affective feelings experienced in everyday life and to cover a wide range of emotions, moods, personality traits and attitudes. The experiment was performed in French in Geneva, Chinese in Beijing, Portuguese in Campinas, and English in the other places. Therefore, independent French, Chinese and Portuguese native speakers followed a strict procedure to translate the initial set of English terms into the target language. Specifically, a first person translated the English terms into the target language, and two or three other independent individuals translated this target list back into English without knowledge of the initial English list. The coordinating experimenter (CF) then checked the correspondence between the initial list and the back-translated list,



and new attempts of translation were made when necessary (for 15% of the terms in Brazil and 18% in China) after clarifying the meaning of the initial term.

### Scale construction

Three selection steps or studies were used to obtain the final scales from the initial list of affective terms. These three steps are presented in detail in Chrea et al. (2009) and Ferdenzi et al. (2011), and are summarized hereafter. In Study 1, participants evaluated each initial term on a continuous scale for its ability to describe affective states elicited by odors, referring to their own past experience. No odors were smelled during this initial step. Only the most relevant and well-understood terms were kept, i.e. about 70-80 terms. In Study 2 and 3, participants were provided with odor samples (14 odor samples from a total of 24 in Study 2, and 7-8 odor samples from a total of 56 to 59 in Study 3) and for each odor they were asked to rate the intensity of their affective feelings using the terms selected in the previous study. An Exploratory Factor Analysis with Varimax rotation was performed on the data of Study 2 (Statistica). It allowed us to identify dimensions having satisfactory internal consistency (Cronbach's  $\alpha > .70$ ; Kline 1993) and to subsequently retain terms that had both high loading on these dimensions and high inter-rater agreement, i.e., between 30 and 40 terms in total. The aim of Study 3 was to test the robustness of the scale structure with a wider set of odorants and a larger sample of participants from the general public. A Confirmatory Factor Analysis (MPlus; Muthén & Muthén 2010) allowed us to test several structures (obtained from Exploratory Factor Analysis performed on the data from Study 2 and 3, as such and sometimes modified according to structures previously obtained in other geographic areas). We finally retained as the final Emotion and Odor Scale the structure or model with the best fit in each geographic area, i.e., with the lowest Root Mean Square Error of Approximation and the highest Comparative Fit Index (RMSEA being  $< .06$  and CFI  $> .90$ , according to recommendations for the definition of a good model; Hu & Bentler, 1999).

## Odors

Most odorous stimuli used in Study 2 and 3 were identical in all geographic areas and represented a large range of everyday odors including: i) as many pleasant as unpleasant odors, ii) a high proportion of familiar odors to elicit affective reactions linked to autobiographical memories (including culture-specific odors, such as durian in Singapore), iii) odors related to various food and non-food contexts. The list of 24 odors of Study 2 and 56 odors of Study 3 can be found in Chrea et al. (2009). In Study 3, several culture-specific odors were added to the 56-odor set: coconut, passion fruit, and banana in Brazil; soybean, coconut, and pandan in Singapore; soybean, and tea in China. This was performed to keep the odor set at an overall satisfactory level of familiarity in these cultures, not to miss any important but culture-dependent odor-elicited responses, and thus to favor the elicitation of affective feelings as they occur in everyday contexts. The odorous substances, provided by Firmenich SA, Geneva, were diluted in odorless dipropylene glycol to obtain similar subjective intensities (see Delplanque et al. 2008; Chrea et al. 2009). Pen-like devices (Sniffin' Sticks, Burghart GmbH, Germany) were filled with 7 ml of each diluted solution and coded with a 3-digit number. To limit olfactory fatigue and test duration, each participant evaluated a sub-set of fourteen odors in Study 2, and seven or eight odors in Study 3. During data collection, the odors were presented in random order.

## Procedure

Sessions in Study 1, 2 and 3 took respectively 1 hour, 1.5 hours and 20 minutes. Participants were asked to rate the intensity of their feelings with the help of the proposed affective terms. They were presented with the affective terms on a computer interface and gave their answers using a visual analogue scale labeled from "not at all" to "extremely". Their ratings were subsequently translated into a 0 to 200 score. When odors were presented (Study 2 and 3), affective ratings were followed by familiarity, pleasantness and intensity ratings on similar scales. Free odor identification was collected as well, except in Geneva, the first culture that was investigated, where this measure was unfortunately omitted

because this question was not addressed at that time. More details about the procedure can be found in Chrea et al. (2009) and Ferdenzi et al. (2011). The studies were conducted by C. Chrea and collaborators in Geneva, by C. Ferdenzi (CF) and collaborators in Liverpool, and by on-site collaborators in the other geographic areas (coordinated by CF).

## Results

### *Presentation of the final scales*

Results from Study 3 are reported here. Table 2 presents the goodness of fit results of the best model obtained for each geographic area with the Confirmatory Factor Analysis. All models have a good fit ( $RMSEA < .06$  and  $CFI > .90$ ). Each model (or scale, with terms organized in several latent variables that we will call affective categories from now on) is detailed in Tables 3a,b. The label of the categories was the result of subjective interpretations of the overall affective meaning of the group of terms gathered in these categories. Internal consistency of each affective category and of each term has been computed with Matlab (Cronbach's alpha), and is mentioned in Tables 3a,b, together with the parameter estimates of the terms.

Examination of the structure of the scales reveals that there are numerous affective categories that can be interpreted/labeled similarly in all studied geographic areas, even if these categories are not constituted by strictly identical lists of terms. Indeed, there are groups of affective terms related to Disgust/Irritation, Happiness/Well-being, Sensuality/Desire and Energy in the seven geographic areas. Soothing/Peacefulness and Hunger/Thirst were revealed by the factor analyses in respectively five and four geographic areas, and Negative Feelings and Nostalgia in two geographic areas. Finally, several categories were culture-specific and they are found mostly in Asian countries (except Sensory Pleasure in Geneva): Arousal and Melancholy in Beijing, and Intellectual Stimulation and Spirituality in Singapore (see terms in Tables 3a,b). Inter-rater agreement was very good for most categories (Cronbach's alpha  $> .70$ ; only Arousal in China and Spirituality and

Negative Feelings in Singapore were between .60 and .70). At the term level, inter-rater agreement was very good on average (from .75 in Singapore to .94 in Fayetteville). Questionnaires, including instructions and terms of the EOS are available at the following Internet address: <http://www.affective-sciences.org/eos>.

### *Cultural differences in affective feelings*

To investigate and visualize the extent of cultural differences and similarities, we combined Cluster and Multi-Dimensional Scaling (MDS) analyses. First, cluster analyses (Ward's method on city-block –Manhattan– distances<sup>1</sup>) were performed for each affective category common to four or more geographic areas (i.e. Disgust/Irritation, Happiness/Well-being, Sensuality/Desire, Energy, Soothing/ Peacefulness and Hunger/Thirst), using the average scores per odor per geographic area (56x7 matrices). These analyses provided a matrix of the distances between the geographic areas for each affective category, and allowed us to constitute groups of areas as a function of their statistical proximity. Determination of the number of groups (i.e., clusters), generally two or three, was based on a visual determination of the inflexion point on the plot of linkage distances. For graphic representation purposes, we then conducted MDS on each distance matrix and found that two-dimensional spaces were the most suited (increasing the number of dimensions did not improve the part of explained variance, i.e., did not decrease the stress values). Figure 1 illustrates the MDS results on two-dimensional spaces and the groups obtained with the cluster analyses. The results suggest that, except for the Asian countries, geographic proximity is linked to a similarity in odor-related affective feelings and odor perception. Namely, the two regions of the United States, Arkansas and California, are always in the same cluster (EOS categories but also familiarity, liking and identification), and Brazil is rather close to them as it is in the same cluster for most olfactory variables. Similarly, the two

---

<sup>1</sup> City-block (Manhattan) distance is the average difference across dimensions. In most cases, this distance measure yields results similar to the simple Euclidean distance. However, in this measure, the effect of single large differences (outliers) is dampened since they are not squared. Ward's method uses an analysis of variance approach to evaluate the distances between clusters. It attempts to minimize the sum of squares of any two (hypothetical) clusters that can be formed at each step. In general, this method is regarded as very efficient (see Electronic Statistics Textbook for further details; StatSoft, Inc., 2013; <http://www.statsoft.com/textbook>).

European countries, United Kingdom and Switzerland, appear in the same cluster for all the EOS categories they are concerned with, and for liking. However, China seems to be quite different from the other geographic areas, since this area alone constitutes a separate cluster in three EOS categories out of five. Also, it is always fairly distant from the other Asian country, Singapore, which tends to be closer to the European countries (clustered with them for all the EOS categories).

Based on the same 56 odors x 7 countries matrices, we conducted repeated-measures ANOVAs to investigate cultural differences in scale use (only the six categories available for all the seven countries were taken into account: Disgust/Irritation, Happiness/Well-being, Sensuality/Desire, Energy, Familiarity, and Liking). There was a significant effect of country on the average ratings ( $F_{6,330} = 216.99, p < .001$ ), which can be described as: Singapore < United Kingdom < Switzerland < United States, China and Brazil (based on post-hoc Tukey HSD tests). There were also significant effects of category and a country by category interaction, but we decided not to present them here because they do not add valuable new elements to further qualify country differences.

### *Construction of the universal scale UniGEOS*

Emotion and Odor Scales have now been developed specifically for geographic areas with very distinct cultures on different continents (Europe, America and Asia). We previously proposed (Ferdenzi et al. 2011; Delplanque et al. 2012) that the affective categories common to the different scales we developed and confirmed by the new scales presented in this article might be related to major functions of olfaction in humans, such as ingestion, avoidance of environmental hazards, and social communication (Stevenson 2010). Affective responses such as disgust, desire, or well-being certainly play a major role in driving subsequent behaviors related to functions of olfaction that are common to all human beings. Therefore, we now would like to propose a new scale, mainly based on the culturally common affective categories we found, which would be likely to tackle affective feelings

triggered by smell in humans in general and thus potentially in most new cultures investigated with this scale.

To define this scale we used three criteria. First, term selection was based on the number of occurrences of the terms in the cultures we have already studied. The most frequently used terms were prioritized to increase the likelihood of the terms being relevant in additional cultures. Second, a maximum of three terms per category were chosen, to allow the use of the scale in its short or long version, the short version consisting of an evaluation of the three items in the category as a whole on a unique subscale (see Porcherot et al. 2010), and the long version evaluating each term. Third, the retained categories were prioritized as those that were common to four or more of the seven studied geographic areas. This approach yielded six categories that are detailed below. We decided to add three categories derived from culture-specific aspects, with the aim to cover the largest possible spectrum of odor-related affective feelings while respecting the overarching goal of creating a compact scale.

Consequently, six categories common to four or more geographic areas were first retained: Disgust/Irritation, Happiness/Well-being, Sensuality/Desire, Energy, Soothing/Peacefulness, and Hunger/Thirst. Their labels were in some cases slightly modified to avoid redundancy between the category title and its constituting terms (e.g., the category Disgust/Irritation and the term disgust), as shown in Table 4. The number of occurrences of each term (i.e., number of scales among the seven available in which the term appears) is mentioned in Table 4. The three additional categories cover aspects related to interest, nostalgia and spiritual feeling. For the Interest category we gathered three terms, taken from the Sensory Pleasure (CH), Arousal (CN) and Intellectual Stimulation (SG) culture-specific categories (Tables 3a,b), that are related to the holding or the attraction of one's attention in a very pleasant (amusement) or rather positive way (interesting, impressed). For the Nostalgia category, we gathered the term nostalgic from the Nostalgia category (UK & BR) and the terms melancholic and sad present in the Melancholy (CN) and the Negative Feeling category (SG). It must be kept in mind, however, that nostalgia, although being close to the

1 feelings of sorrow or regret, is likely to be slightly more positive than sad and melancholic  
2 states because it refers to the yearning for the return of past pleasant circumstances. Finally  
3 we added Spiritual Feelings (SG) because we thought that despite its cultural specificity it  
4 might be meaningful in other cultures with strong odor-related rituals such as religious or  
5 other ones.  
6  
7  
8  
9

## 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65

The present research allowed to complete the set of affective scales that was initiated a few years ago (EOS, Emotion and Odor Scales: Chrea et al. 2009; Ferdenzi et al. 2011) by adding new Asian and American cultures, and by then proposing a single universal scale (UniGEOS) for the future study of odor-related affective feelings in other cultures. The preliminary result that some categories of feelings are recurrent in different cultures was confirmed. Namely, the categories Disgust/Irritation, Happiness/Well-being, Sensuality/Desire and Energy were found in the seven studied geographic areas, and Soothing/Peacefulness and Hunger/Thirst in almost all of them – which also justifies the fact that they were kept in the UniGEOS.

The main theoretical implication of this line of studies is that self-reported feelings in response to odors are more accurately depicted using an olfactory-specific set of emotional terms (Chrea et al., 2009; Ferdenzi et al. 2011; Delplanque et al. 2012). Indeed, the emotional categories introduced in our studies and observed in many different cultures extend traditional basic emotions or valence-arousal-dominance approaches applied to olfaction. We have proposed that, on the one hand, by focusing on a small number of evolutionarily based basic emotions, one downplays the more complex forms of emotional processes involved in response to odors. On the other hand, with a description limited to two or three dimensions as for the valence-arousal-dominance approach, one misses most of the important qualitative differences between the affective effects of different types of odorous substances (Delplanque et al. 2012). This result does not constitute an epiphenomenon

1 associated with a specific culture since common emotional categories were found across the  
2 cultures we studied.  
3

4         The present results also reinforce the idea, proposed previously, that the identified  
5 categories of affective responses to odors are common to different cultures because they  
6 contribute to the major functions of olfaction in humans. Emotional, and more generally  
7 affective processes are viewed as adaptive mechanisms that allow the individual to adjust to  
8 environmental conditions or events by displaying adapted, suited behaviors (Scherer 1994;  
9 Keltner & Gross 1999). In this frame, the feeling component of an emotion integrates and  
10 might regulate its other components (cognitive, behavioral, expressive, and physiological) to  
11 motivate a response that fits the demands of the physical and social environment (Grandjean  
12 et al. 2008; Scherer 2009). Specifically, subjective affective experiences of odors may serve  
13 universal and phylogenetically grounded functions of olfaction in humans, which have been  
14 classified into three major categories by Stevenson (2010). First, some odor-related affective  
15 feelings, such as disgust for stimuli representing a source of disease or fear of stimuli  
16 announcing a danger, (e.g., a fire or a gas leak), serve the first function: avoidance of  
17 environmental hazards. The second function of olfaction is ingestion including the “detection  
18 and identification of food suitable for eating, rejection of foods that have an unexpected  
19 flavor, modulation of appetite, and promoting breast feeding in neonates”. Several odor-  
20 related affective feelings can serve this function. The feelings of hunger and thirst prompted  
21 by food odors (Hunger/Thirst category) are directly involved in appetite stimulation,  
22 promotion of food/beverage intake and result from the identified suitability of the  
23 corresponding product for eating. In addition, feelings of Disgust/Irritation may promote  
24 withdrawal behavior when expectations are broken by foods with an unexpected flavor (e.g.,  
25 spoiled). Feelings of Happiness/Well-being could reflect some feelings associated with the  
26 satisfaction produced by food intake. The third function of olfaction described by Stevenson  
27 (2010) is social communication, namely “human mate selection in respect of inbreeding  
28 avoidance and fitness detection, and emotional contagion”. In this perspective, affective  
29 feelings related to Sensuality/Desire are a preliminary step to potential approach of other  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65



1 individuals, partly guided by the blend of natural body odor and extraneous (e.g., cosmetic)  
2 fragrances emitted by these individuals: body odors are indeed known to help guiding bias  
3 against inbreeding (Weisfeld et al. 2003, but see also Ferdenzi et al. 2010) and to promote  
4 genetic diversity (e.g., Wedekind et al. 1995), cosmetic odors being potentially consistent  
5 with the latter signal (Milinski & Wedekind 2001; Lenochová et al. 2012). Extraneous odors  
6 may have their importance in the EOS category, since those contributing the most to form  
7 this category are related to cosmetics (namely flowery and fruity odors). Finally, Energy and  
8 Soothing/Peacefulness could depict feelings that motivate responses in relation to many  
9 functions of olfaction and could be, for instance encountered in food or social contexts  
10 (stimulation by a food odor initiating eating behavior, or by the exciting smell of a potential  
11 partner, comfort provided by food ingestion or by smelling the partner's odor). Less vital  
12 along phylogeny, and maybe becoming relevant specifically in humans, they could be  
13 associated with a 'comfort' function: wellness, a state related to physical integrity (health) and  
14 psychological fulfillment of expectancies. An example of this is ancient as well as  
15 contemporary aromatherapy (see Herz 2009), which uses plant-based aromas to promote  
16 well-being, and stimulation or relaxation depending on the needs.

17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
There are cultural differences though in the way these common affective categories are  
used in response to the different odors we specifically used in our study (beyond the  
differences in the way to use scales in general, as described in the Results section). Before  
discussing these differences, we would like to emphasize the particular care we took to limit  
as much as possible variations that could be attributed to pure experimental differences  
across cultures. This was achieved by a rigorous coordination work consisting in providing  
each experimenter with the same stimuli, the same test interfaces and the same detailed  
instructions on how to conduct the study and recruit participants. Although such undesired  
variations cannot totally be ruled out, we believe that the observed variations are most likely  
due to cultural differences than to experimental biases, and they will be discussed as such.  
Looking at the results, we found that there were more similarities between areas with higher

geographic proximity, a result similar to the conclusions of the study on aroma preferences conducted by Pangborn et al. (1988) on the five continents. The two regions of the United States, Arkansas and California, have extremely similar affective answers to the presented odors, and Brazil, another American culture, is often classified in the same group. Although being culturally very different, it is thus likely that there are more similarities between Brazil and the United States than between the United States and Europe, both in terms of quality of the olfactory environment, contexts in which given odors are encountered and food/cosmetic habits associated with given odors. A similar conclusion can be made for the European countries, United Kingdom and Switzerland, that were found to have similar affective responses and that differentiated quite well from the American countries. The results concerning the two Asian countries Singapore and China have to be interpreted differently. China appears to behave, in terms of odor-related affective feelings, in a rather unique way compared to all other countries, including Singapore, especially for Happiness/Well-Being, Sensuality/Desire and Soothing/Peacefulness. As it does not seem to be driven by major odor familiarity or pleasantness differences (see Fig. 1), it is likely to be due to differences in emotional functioning between Eastern versus Western countries (e.g., related to interpersonal styles, independent or individualistic in Western cultures versus interdependent or collectivist in Eastern cultures, Markus & Kitayama 1991; higher sensitivity to social desirability in Eastern cultures; Middleton & Jones 2000; stronger self-regulation of negative emotions in Eastern cultures: Markus & Kitayama 1991). Singapore's affective responses to odors were found to be close to European responses – in spite of significant differences in familiarity, pleasantness and identification. This is surprising on the one hand, since many Singaporeans originate from China (79% of our participants were of Chinese ethnicity, see Ferdenzi et al. 2011). But on the other hand, the almost two centuries of British colonization (19<sup>th</sup> and part of 20<sup>th</sup> centuries, during which Chinese population increased in Singapore) and the massive industrialization of the country at the end of the 20<sup>th</sup> century are likely to have strongly influenced thinking and behaviors in a Western-like way.

1 The cultures we investigated also differed on several culture-specific feeling categories.  
2 Some of them are clearly or slightly negatively connoted (Negative Feelings in California and  
3 Singapore, Melancholy in China), while some are related to nostalgia (in the UK, Brazil and  
4 Switzerland), interest elicitation (Arousal in China, Intellectual Stimulation in Singapore, and  
5 partly in the Sensory Pleasure category in Switzerland) and spirituality (in Singapore).  
6 Although it remains difficult to explain why some categories are present in some cultures and  
7 not in others, we can formulate some speculations. For instance, odors (incense) are very  
8 frequently associated with religious rituals in the Singaporean Chinese community (Friborg et  
9 al. 2008; Ferdenzi et al. 2011) explaining the importance of the affective feelings related to  
10 Spirituality in this culture. In Brazil specifically, the term “saudoso” was added to the list of  
11 initial terms: in every country we studied, on-site collaborators were given the possibility to  
12 suggest some additions to the list of initial terms if they felt that an affective feeling important  
13 to their culture was missing (it was effectively the case only in Brazil). “Saudoso” was added  
14 because it is considered a very important feeling in this culture (so much that it is celebrated  
15 on a dedicated day of the year), although very difficult to translate in other languages (sort of  
16 nostalgia imbued with melancholy). It explains why Nostalgia is a significant category kept  
17 along the Brazilian scale construction.  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39

40 The above-discussed cultural similarities, as well as some cultural specificities, have  
41 been summarized in the universal scale UniGEOS proposed in this study, and for which we  
42 can now provide several recommendations of use. First, we would like to emphasize that it is  
43 always better to use the culture-specific model if available instead of the universal version,  
44 because it more closely fits the feelings experienced in that culture (Ferdenzi et al. 2011).  
45 Second, UniGEOS can be used in different ways according to the testing constraints.  
46 According to time constraints it can be used either in its long or short form. The 25 affective  
47 terms of UniGEOS can be rated individually, possibly in a random order (but we recommend  
48 similar order for the different odors judged by a given rater, to limit cognitive load), or only 9  
49 series of 3 (or 1) terms corresponding to the 9 categories of UniGEOS, similarly to Porcherot  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

et al. (2010) with the Swiss version. We can presume that, as in Porcherot et al. (2010), responses to both versions should be highly correlated. In addition, although we always used continuous rating scales with labels on each end for a finer discrimination between odors during the processes of scale development, other methods might be preferred such as a discrete rating scale (1-to-9 for instance, same labels) or even the check-all-that-apply method (CATA) for which respondents only indicate whether each feeling is experienced or not. Finally, it must be kept in mind that categories 1 to 6 (see Table 4) are very likely to be relevant for most studied cultures, whereas categories 7 to 9 may or may not be relevant since they were derived from several culture-specific categories. If ever a category is not relevant, i.e., if an affective feeling is never experienced, it has no further consequences than getting scores close to zero. Moreover, users must be warned that the terms we artificially put together in categories 7 to 9 are likely to be less correlated within a category than the terms in categories 1 to 6. Indeed, in categories 1 to 6, factor analyses objectively revealed their relationship, whereas in categories 7 to 9, terms were gathered based on a more subjective similarity (see procedure in Construction of the universal scale UniGEOS).

Despite the significant theoretical and practical advantages of the Emotion and Odor Scales detailed in the introduction, some limits of these tools should be acknowledged. First, when using the EOSs, one should keep in mind that the terms only capture one of the emotional components, namely feelings, not the full emotional phenomenon. Although the feeling component of an emotion is supposed to integrate and regulate the other components (i.e., action tendencies, physiological arousal, cognitive processes, and expressive motor behavior, e.g. Frijda & Scherer 2009), we can only assert that the EOSs capture “potential emotions”. The current differentiation on the feeling level needs to be confirmed by differentiation on a cognitive, behavioral, or physiological level to be fully considered as true emotions (Zentner et al. 2008).

Second, whereas other similar scales were developed recently with specific categories of products (snacks: Desmet & Schifferstein 2008; King & Meiselman 2010; body care

products: Churchill & Behan 2010), our scales have been conceived to measure affective responses to a wide range of odors, not only pleasant ones, and not from only one category. Of course this is an advantage because we presume it can be used for varied odor-emitting products (foods, cosmetics but also other consumer goods such a car interiors, or places such as stores or underground parking). But it must be acknowledged that using the EOSs for a given category of odorous products (e.g., shampoos, air care or food products) would reduce its power to discriminate between different feelings. Indeed, as developed above, each affective category could be more or less associated with a function of olfaction. When using a specific range of products, it is very likely that only one type of function would be targeted, thus automatically weakening the discriminative power of the EOSs, which may also miss affective aspects related to that specific category of products. Indeed, EOSs do not allow measuring the affective response to the whole product (which involves many other aspects such as sensory and esthetic, practical and economic aspects). Future research should test the adequacy of the EOSs to do so, or investigate to what extent modified versions of the EOSs with additional specific subscales might be useful.

Third, it must also be acknowledged that, even if the EOSs are specifically targeted at odors, an odor is hardly dissociable from its source, as is clearly shown by the participants' identification responses. A good example of this is the wintergreen odor and its cultural association with sweets and sodas in the North American cultures, and with medicine (muscle balms, mostly) in the European cultures. Spontaneous reactivation of this information triggers well-differentiated affective responses to the smell itself (more positive in the American populations). The link between the content of semantic information participants attach to the odor and the EOSs responses to it has been studied and described elsewhere (Ferdenzi et al. 2013). Therefore, another limit of our tool is that there is some uncontrolled variation in the affective response to odors due to associated products and contexts in memory (e.g., food vs. nonfood contexts). However, the extent of this noise remains restricted since high levels of inter-rater agreement were obtained (see Cronbach's alphas in Table 3) for all categories in all cultures.

Fourth, it must be acknowledged that an extension of this line of studies to very important population groups like Spanish-speaking or African cultures is lacking and would deserve to be conducted in the future. Although it can be predicted that affective categories similar to the ones common to all the cultures we studied would result from such investigations (Disgust, Happiness, Desire and Energy), examination of the culture-specific categories would be have been of interest and it cannot be excluded that it could have led to a slightly different universal (UniGEOS) scale.

To conclude, given the past studies and the results of the present study, we think that the new general model UniGEOS measuring self-reported odor-related affective feelings might not only be useful to carry on fundamental research in this field but might also be especially relevant for applied science investigating the complex relationships between odors and elicited affective states.

### **Acknowledgments**

The authors wish to thank all the people who ensured an efficient data collection in the new cultures presented in this paper, namely Jean-François Meullenet, Joshua Tubbs, and Lydia Rice in Fayetteville, Peiyao Chen and Bingle Chen in Beijing, and Wellington da Silva, André Xavier, Ellen Osbourn and Bob Wyatt in Campinas. Britta Komaromi is also thanked for her help with the Chinese translation. Nadine Gaudreau and Jeannine Delwiche from Firmenich are very much thanked for technical, logistic help and introduction to collaborators. Furthermore, we extend our grateful appreciation to Olivier Rosset and Dajana Kapusova from the Swiss Center for Affective Science, for their precious help in dealing with the testing web interface. This research was supported by a grant from Firmenich to CF and SD, and by the National Center of Competence in Research (NCCR) Affective Sciences financed by the Swiss National Science Foundation.

## References

- Alaoui-Ismaïli O, Robin O, Rada H, Dittmar A, Vernet-Maury E. 1997. Basic emotions evoked by odorants: comparison between autonomic responses and self-evaluation. *Physiol Behav.* 62:713–720.
- Bensafi M, Rouby C, Farget V, Bertrand B, Vigouroux M, Holley A. 2002a. Autonomic nervous system responses to odours: the role of pleasantness and arousal. *Chem Senses.* 27:703–709.
- Bensafi M, Rouby C, Farget V, Bertrand B, Vigouroux M, Holley A. 2002b. Psychophysiological correlates of affects in human olfaction. *Neurophysiol Clin.* 32:326–332.
- Chrea C, Grandjean D, Delplanque S, Cayeux I, Le Calvé B, Aymard L, Velazco MI, Sander D, Scherer KR. 2009. Mapping the semantic space for the subjective experience of emotional responses to odors. *Chem Senses.* 34:49–62.
- Churchill A, Behan J. 2010. Comparison of methods used to study consumer emotions associated with fragrance. *Food Qual Prefer.* 21:1108–1113.
- Croy I, Olgun S, Joraschky P. 2011. Basic emotions elicited by odors and pictures. *Emotion.* 11:1331–1335.
- Delplanque S, Chrea C, Grandjean D, Ferdenzi C, Cayeux I, Porcherot C, Le Calvé B, Sander D, Scherer KR. 2012. How to map the affective semantic space of scents. *Cogn Emot.* 26:885–898.
- Delplanque S, Grandjean D, Chrea C, Aymard L, Cayeux I, Le Calvé B, Velazco MI, Scherer KR, Sander D. 2008. Emotional processing of odors: evidence for a nonlinear relation between pleasantness and familiarity evaluations. *Chem Senses.* 33:469–479.
- Desmet PM, Schifferstein HN. 2008. Sources of positive and negative emotions in food experience. *Appetite.* 50:290–301.
- Desmet PMA. 2006. Typology of fragrance emotions. In: Fellows DS, editor. *Excellence 2006; Esomar world research papers.* Amsterdam: Esomar. pp. 309–320.
- Ehrlichman H, Bastone L. 1992. Olfaction and emotion. In: Serby MJ, Chobor KL, editors. *Science of Olfaction.* New York: Springer-Verlag. pp. 410–438.
- Ekman P. 1984. Expression and the nature of emotion. In: Scherer KR, Ekman P, editors. *Approaches to emotion.* Hillsdale, NJ: Erlbaum. pp. 319–344.
- Engen T. 1982. *The perception of odors.* New York: Academic Press.
- Ferdenzi C, Roberts SC, Schirmer A, Delplanque S, Cekic S, Porcherot C, Cayeux I, Sander D, Grandjean D. 2013. Variability of affective responses to odors: Culture, gender, and olfactory knowledge. *Chem Senses.* 38:175–186.
- Ferdenzi C, Schaal B, Roberts SC. 2010. Family scents: developmental changes in the perception of kin body odor? *J Chem Ecol.* 36:847–854.
- Ferdenzi C, Schirmer A, Roberts SC, Delplanque S, Porcherot C, Cayeux I, Velazco M-I, Sander D, Scherer KR, Grandjean D. 2011. Affective dimensions of odor perception: a comparison between Swiss, British, and Singaporean populations. *Emotion.* 11:1168–1181.
- Friborg JT, Yuan JM, Wang R, Koh WP, Lee HP, Yu MC. 2008. Incense use and respiratory tract carcinomas: a prospective cohort study. *Cancer.* 113:1676–1684.
- Frijda NH, Scherer KR. 2009. Affect (psychological perspectives). In: Sander D, Scherer KR, editors. *The Oxford companion to emotion and the affective sciences.* Oxford: Oxford University Press. p. 10.
- Goel N, Kim H, Lao RP. 2005. An olfactory stimulus modifies nighttime sleep in young men and women. *Chronobiol Int.* 22:889–904.
- Grandjean D, Sander D, Scherer KR. 2008. Conscious emotional experience emerges as a function of multilevel, appraisal-driven response synchronization. *Conscious Cogn.* 17:484–495.
- Guéguen N, Petr C. 2006. Odors and consumer behavior in a restaurant. *Int J Hosp Manag.* 25:335–339.
- Herz RS. 2009. Aromatherapy facts and fictions: a scientific analysis of olfactory effects on mood, physiology and behavior. *Int J Neurosci.* 119:263–290.
- Heuberger E, Redhammer S, Buchbauer G. 2004. Transdermal absorption of (-)-linalool induces autonomic deactivation but has no impact on ratings of well-being in humans. *Neuropsychopharmacology.* 29:1925–1932.
- Hirsch AR. 1995. Effects of ambient odors on slot machine usage in a Las Vegas casino. *Psychol Market.* 12:585–594.
- Hu L, Bentler PM. 1999. Cutoff criteria for fit indices in covariance structure analysis: conventional criteria

- versus alternatives. *Struct Equ Modeling*. 6:1–55.
- Keltner D, Gross JJ. 1999. Functional accounts of emotions. *Cogn Emot*. 13:467–480.
- King SC, Meiselman HL. 2010. Development of a method to measure consumer emotions associated with foods. *Food Qual Prefer*. 21:168–177.
- Kline P. 1993. *Handbook of psychological testing*. London: Routledge.
- Knasko SC. 1989. Ambient odor and shopping behavior. *Chem Senses*. 14:718.
- Knasko SC. 1992. Ambient odor's effect on creativity, mood, and perceived health. *Chem Senses*. 17:27–35.
- Knasko SC. 1995. Pleasant odors and congruency: effects on approach behavior. *Chem Senses*. 20:479–487.
- Kotler P. 1973. Atmospherics as a marketing tool. *J Retail*. 49:48–64.
- Lehrner J, Marwinski G, Lehr S, Jöhren P, Deecke L. 2005. Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office. *Physiol Behav*. 86:92–95.
- Lenochová P, Vohnoutová P, Roberts SC, Oberzaucher E, Grammer K, Havlíček J. 2012. Psychology of fragrance use: perception of individual odor and perfume blends reveals a mechanism for idiosyncratic effects on fragrance choice. *PLoS ONE*. 7:e33810.
- Markus H, Kitayama S. 1991. Culture and the self - Implications for cognition, emotion, and motivation. *Psychol Rev*. 98:224–253.
- Matsumoto D, Ekman P. 2009. Basic emotions. In: Sander D, Scherer KR, editors. *The Oxford companion to emotion and the affective sciences*. Oxford: Oxford University Press. pp. 69–72.
- Middleton KL, Jones JL. 2000. Socially desirable response sets: The impact of country culture. *Psychol Mark*. 17:149–163.
- Milinski M, Wedekind C. 2001. Evidence for MHC-correlated perfume preferences in humans. *Behav Ecol*. 12:140–149.
- Morrin M, Ratneshwar S. 2000. The impact of ambient scent on evaluation, attention, and memory for familiar and unfamiliar brands. *J Bus Res*. 49:157–165.
- Muthén LK, Muthén BO. 2010. *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.
- Pangborn RM, Guinard J-X, Davis RG. 1988. Regional aroma preferences. *Food Qual Prefer*. 1:11–19.
- Porcherot C, Delplanque S, Gaudreau N, Cayeux I. 2013. Seeing, smelling, feeling! Is there an influence of color on subjective affective responses to perfumed fabric softeners? *Food Qual Prefer*. 27:161–169.
- Porcherot C, Delplanque S, Planchais A, Gaudreau N, Accolla R, Cayeux I. 2012. Influence of food odorant names on the verbal measurement of emotions. *Food Qual Prefer*. 23:125–133.
- Porcherot C, Delplanque S, Raviot-Derrien S, Le Calvé B, Chrea C, Gaudreau N, Cayeux I. 2010. How do you feel when you smell this? Optimization of a verbal measurement of odor-elicited emotions. *Food Qual Prefer*. 21:938–947.
- Rieunier S. 2002. *Le Marketing sensoriel du point de vente* : Créer et gérer l'ambiance des lieux commerciaux. Paris (France): Dunod.
- Rotton J. 1983. Affective and cognitive consequences of malodorous pollution. *Basic Appl Soc. Psychol*. 4:171–191.
- Russell JA. 1980. A circumplex model of affect. *J Pers Soc Psychol*. 39:1161–1178.
- Scherer KR. 1994. Emotion serves to decouple stimulus and response. In: Ekman P, Davidson R, editors. *The nature of emotion: Fundamental questions*. New York: Oxford University Press. pp. 127–130.
- Scherer KR. 2009. Feelings (psychological perspectives). In: Sander D, Scherer KR, editors. *Oxford companion to emotion and the affective sciences*. Oxford: Oxford University Press. pp. 183–184.
- Schiffstein HN, Blok ST. 2002. The signal function of thematically (In)congruent ambient scents in a retail environment. *Chem Senses*. 27:539–549.
- Schiffman SS, Miller EA, Suggs MS, Graham BG. 1995a. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Res Bull*. 37:369–375.
- Schiffman SS, Sattely-Miller EA, Suggs MS, Graham BG. 1995b. The effect of pleasant odors and hormone status on mood of women at midlife. *Brain Res Bull*. 36:19–29.
- Seo H-S, Roidl E, Müller F, Negoias S. 2010. Odors enhance visual attention to congruent objects. *Appetite*. 54:544–549.



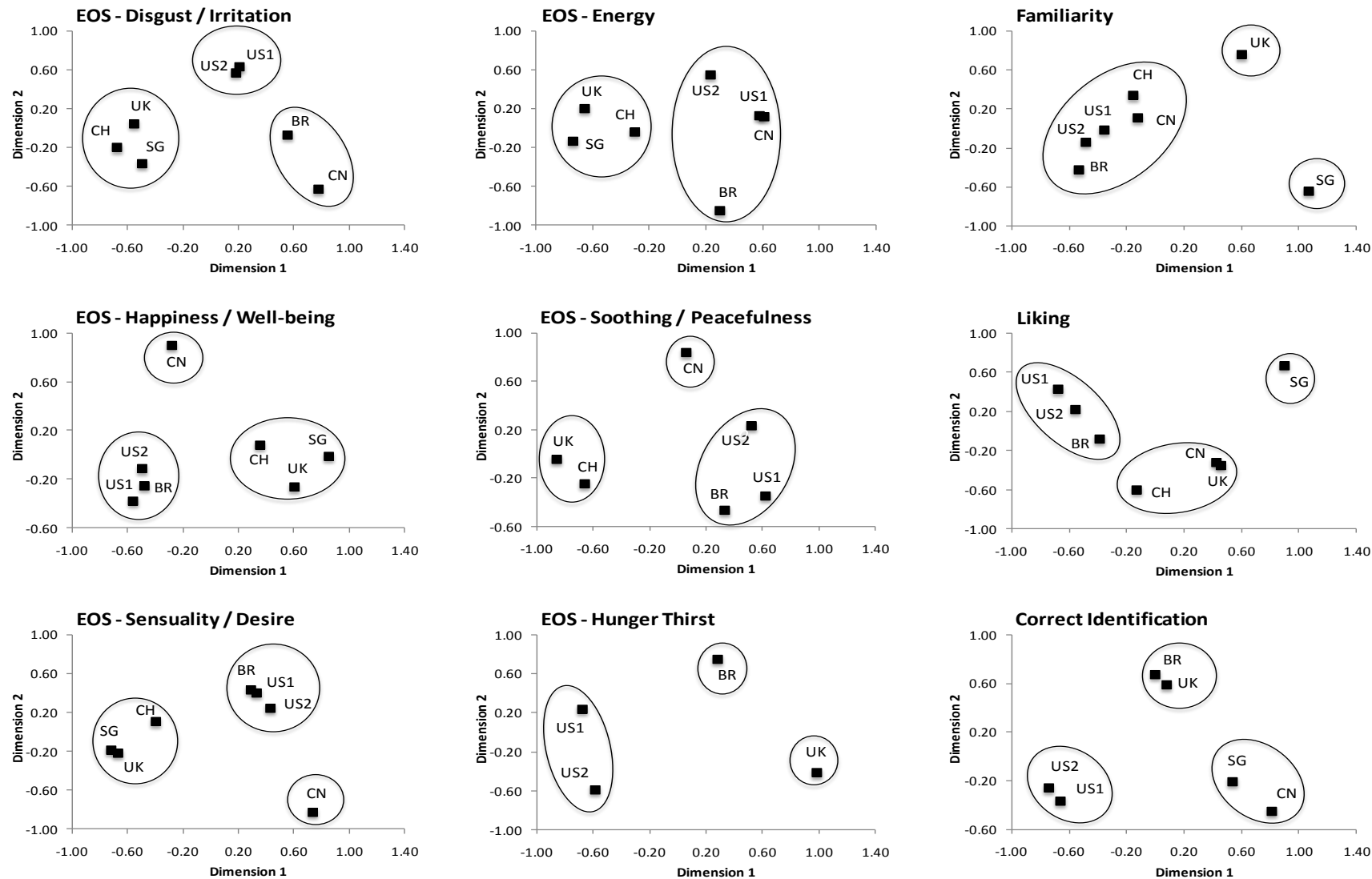
- 1 Spangenberg ER, Crowley AE, Henderson PW. 1996. Improving the store environment: do olfactory cues  
2 affect evaluations and behaviors? *J Marketing*. 60:67–80.
- 3 Stevenson RJ. 2010. An initial evaluation of the functions of human olfaction. *Chem Senses*. 35:3–20.
- 4 Torii S, Fukado H, Kanemoto H, Miyachi R, Hamazu Y, Kawasaki M. 1988. Contingent negative variation  
5 (CNV) and the psychological effects of odour. In: Van Toller S, Dodd GH, editors. *Perfumery - The*  
6 *Psychology and Biology of Fragrance*. London: Chapman & Hall. pp. 107–120.
- 7 Wedekind C, Seebeck T, Bettens F, Paepke AJ. 1995. MHC-dependent mate preferences in humans. *Proc R*  
8 *Soc B*. 260:245–249.
- 9 Weisfeld GE, Czilli T, Phillips KA, Gall JA, Lichtman CM. 2003. Possible olfaction-based mechanisms in  
10 human kin recognition and inbreeding avoidance. *J Exp Child Psychol*. 85:279–295.
- 11 Yeshurun Y, Sobel N. 2010. An odor is not worth a thousand words: from multidimensional odors to  
12 unidimensional odor objects. *Annu Rev Psychol*. 61:219–241, C1–5.
- 13 Zentner M, Grandjean D, Scherer KR. 2008. Emotions evoked by the sound of music: characterization,  
14 classification, and measurement. *Emotion*. 8:494–521.
- 15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

## Figure legend

**Figure 1.** Representation of the seven geographic areas on the two first dimensions of the Multi-Dimensional Scaling MDS analyses for the EOS (Emotion and Odor Scales) categories, familiarity, liking, and correct identification. Black circles represent the groups obtained with the cluster analyses (Ward's method on city-block Manhattan distances). BR=Brazil, CH=Switzerland, CN=China, SG=Singapore, UK=United Kingdom, US1=United States Arkansas, US2=United States California.

Figure 1

Figure 1



**Table 1** Sample size, gender (% men), age (mean  $\pm$  standard deviation, range in years) and % smokers in the groups of participants in Study 1, 2 and 3, in each of the seven geographic areas investigated.

	N	(% men)	Age (M±SD, range)			% Smokers
EUROPE						
Geneva, CH <sup>a</sup>						
Study 1	220	(29%)	31.7	± 11.5	(19-60)	21%
Study 2	37	(32%)	24.6	± 5.1	(16-37)	19%
Study 3	210	(28%)	37.8	± 12.1	(16-65)	21%
Liverpool, UK <sup>b</sup>						
Study 1	148	(35%)	21.7	± 3.4	(18-35)	11%
Study 2	41	(46%)	23.6	± 5.1	(18-40)	12%
Study 3	351	(41%)	32.3	± 13.8	(16-78)	18%
AMERICA						
Fayetteville, AR, USA						
Study 1	199	(42%)	25.8	± 6.6	(16-49)	6%
Study 2	40	(50%)	23.5	± 6.9	(18-55)	8%
Study 3	301	(49%)	41.2	± 14.8	(18-74)	9%
Davis, CA, USA						
Study 1	170	(42%)	22.5	± 4.4	(18-42)	5%
Study 2	40	(50%)	21.2	± 3.2	(18-29)	8%
Study 3	301	(33%)	39.3	± 15.2	(18-78)	10%
Campinas, BR						
Study 1	151	(42%)	27.3	± 9.8	(18-61)	58%
Study 2	40	(40%)	21.3	± 3.8	(17-32)	5%
Study 3	234	(45%)	30.1	± 11.9	(16-65)	10%
ASIA						
Singapore, SG <sup>b</sup>						
Study 1	105	(27%)	20.7	± 1.4	(18-24)	4%
Study 2	38	(29%)	21.1	± 1.9	(19-30)	3%
Study 3	211	(41%)	30.0	± 9.0	(16-58)	8%
Beijing, CN						
Study 1	100	(27%)	21.8	± 2.6	(18-32)	3%
Study 2	38	(42%)	21.9	± 2.1	(18-26)	0%
Study 3	293	(37%)	33.3	± 12.6	(16-73)	14%

<sup>a</sup> Chrea et al. (2009)

<sup>b</sup> Ferdenzi et al. (2011)

**Table 2** Goodness of fit indices for the best model found in each geographic area following Confirmatory Factor Analysis.

Model	Number of observations	Number of dependent variables	Number of latent variables	$\chi^2$	df <sup>a</sup>	RMSEA	CFI
Geneva, CH <sup>b</sup>	1401	36	6	2262.37	579	0.046	0.924
Liverpool, UK <sup>c</sup>	2448	37	7	2358.47	608	0.034	0.943
Fayetteville, AR, USA	2104	37	6	2482.05	614	0.038	0.966
Davis, CA, USA	2100	37	7	2906.65	608	0.042	0.952
Campinas, BR	1717	33	7	1967.63	474	0.043	0.952
Singapore, SG <sup>c</sup>	1554	36	7	1625.03	573	0.034	0.947
Beijing, CN	2117	37	7	1328.50	608	0.024	0.983

<sup>a</sup> df = degrees of freedom.

<sup>b</sup> Data presented in Chrea et al. (2009).

<sup>c</sup> Data presented in Ferdenzi et al. (2011).

**Table 3a** Emotion and Odor Scales developed in Switzerland, United Kingdom and the United States (Arkansas and California): the title of the category appears in bold together with the Cronbach's alpha ( $\alpha$ , inter-rater agreement) per category; Est.: parameter estimate given by the Confirmatory Factor Analysis; Alpha: Cronbach's alpha per term. In grey: categories common to at least four of the seven studied geographic areas.

Geneva, CH			Liverpool, UK			Fayetteville, AR, USA			Davis, CA, USA		
<b>DISGUST/IRRITATION (<math>\alpha=.92</math>)</b>	Est.	Alpha	<b>DISGUST/IRRITATION (<math>\alpha=.94</math>)</b>	Est.	Alpha	<b>DISGUST/IRRITATION (<math>\alpha=.95</math>)</b>	Est.	Alpha	<b>DISGUST/IRRITATION (<math>\alpha=.93</math>)</b>	Est.	Alpha
unpleasant (désagréable)	1.00	0.93	unpleasant	1.00	0.96	unpleasant	1.00	0.96	unpleasant	1.00	0.94
disgusted (dégoûté)	0.92	0.93	disgusted	0.94	0.95	disgusted	0.97	0.96	disgusted	0.97	0.94
unpleasantly surprised (désagréablement surpris)	0.88	0.92	repelled	0.88	0.94	dissatisfaction	0.97	0.95	repulsed	0.97	0.94
sickening (nauséux)	0.83	0.89	sick	0.88	0.94	repulsed	0.96	0.95	dissatisfaction	0.90	0.92
dissatisfaction (insatisfaction)	0.78	0.90	nauseous	0.83	0.94	unpleasantly surprised	0.88	0.93	nauseous	0.89	0.93
dirty (sale)	0.67	0.90	unpleasantly surprised	0.80	0.93	irritated	0.87	0.94	irritated	0.87	0.92
irritated (irrité)	0.67	0.87	uncomfortable	0.79	0.94	nauseous	0.86	0.94	sick	0.85	0.92
angry (en colère)	0.42	0.78	dirty	0.74	0.94	dirty	0.82	0.95	unpleasantly surprised	0.78	0.90
<b>HAPPINESS/WELL-BEING (<math>\alpha=.89</math>)</b>			<b>HAPPINESS/WELL-BEING (<math>\alpha=.93</math>)</b>			<b>HAPPINESS/WELL-BEING (<math>\alpha=.96</math>)</b>			<b>HAPPINESS/WELL-BEING (<math>\alpha=.93</math>)</b>		
pleasant (agréable)	1.00	0.92	in a good mood	1.00	0.93	delighted	1.00	0.96	happy	1.00	0.93
well-being (bien être)	0.94	0.90	pleasantly surprised	0.94	0.93	happy	1.00	0.96	delighted	0.99	0.93
pleasantly surprised (agréablement surpris)	0.94	0.87				smiling	0.98	0.96	pleasure	0.97	0.93
happiness (bonheur)	0.90	0.87				joyful	0.98	0.96	satisfaction	0.95	0.93
attracted (attiré)	0.85	0.83	<b>SENSUALITY/DESIRE (<math>\alpha=.86</math>)</b>			likeable	0.97	0.96	fantastic	0.87	0.92
feeling awe (émerveillé)	0.66	0.77	attracted	1.00	0.88	pleasantly surprised	0.97	0.96			
			romantic	0.93	0.89	satisfaction	0.95	0.96			
			sensual	0.91	0.85	pleasure	0.95	0.96	<b>SENSUALITY/DESIRE (<math>\alpha=.88</math>)</b>		
<b>SENSUALITY/DESIRE (<math>\alpha=.78</math>)</b>			desire	0.91	0.84	fantastic	0.89	0.96	romantic	1.00	0.89
sensual (sensuel)	1.00	0.82	sexy	0.82	0.83	bliss	0.88	0.95	affectionate	0.99	0.90
desire (désir)	1.00	0.76	in love	0.81	0.84				attracted	0.97	0.90
romantic (romantique)	0.95	0.83	to feel intimacy	0.74	0.80				desire	0.97	0.88
in love (amoureux)	0.95	0.80	lustful	0.74	0.77	<b>SENSUALITY/DESIRE (<math>\alpha=.92</math>)</b>			sensual	0.96	0.84
sexy (sexy)	0.86	0.75				romantic	1.00	0.93	intimate	0.94	0.86
admiration (admiration)	0.73	0.64				passionate	0.99	0.93	in love	0.93	0.88
excited (excité)	0.70	0.63	<b>ENERGY (<math>\alpha=.92</math>)</b>			sensual	0.99	0.93	sexually aroused	0.77	0.78
			refreshed	1.00	0.94	intimate	0.97	0.92			
<b>ENERGY (<math>\alpha=.88</math>)</b>			clean	0.95	0.94	sexy	0.96	0.92	<b>ENERGY (<math>\alpha=.90</math>)</b>		
revitalized (revitalisé)	1.00	0.87	revitalized	0.85	0.89	desire	0.94	0.93	enthusiastic	1.00	0.92
invigorated (tonifié)	0.98	0.86	rejuvenated	0.76	0.88	in love	0.93	0.93	excited	0.97	0.88
energetic (énergique)	0.93	0.86	stimulated	0.70	0.80	sexually aroused	0.81	0.88	jolly	0.95	0.91
refreshed (rafraîchi)	0.92	0.90	energetic	0.69	0.84				energetic	0.93	0.90
clean (propre)	0.91	0.90				<b>ENERGY (<math>\alpha=.94</math>)</b>					
stimulated (stimulé)	0.90	0.83	<b>SOOTHING/PEACEFULNESS (<math>\alpha=.89</math>)</b>			refreshed	1.00	0.96	<b>SOOTHING/PEACEFULNESS (<math>\alpha=.93</math>)</b>		
shivering (frissonnant)	0.38	0.38	relaxed	1.00	0.90	revitalized	0.97	0.96	peaceful	1.00	0.92
			soothed	0.99	0.92	energetic	0.86	0.95	soothed	1.00	0.92
<b>SOOTHING/PEACEFULNESS (<math>\alpha=.81</math>)</b>			peaceful	0.97	0.89	interesting	0.66	0.90	relaxed	0.99	0.91
relaxed (relaxé)	1.00	0.81	comforted	0.96	0.91	wild	0.50	0.77	calm	0.98	0.91
serene (serein)	0.96	0.81	dreamy	0.86	0.86				refreshed	0.95	0.95
soothed (apaisé)	0.95	0.80	meditative	0.65	0.70	<b>SOOTHING/PEACEFULNESS (<math>\alpha=.95</math>)</b>			serene	0.95	0.90
reassured (réconforté)	0.90	0.80	protected	0.51	0.63	comfortable	1.00	0.95	clean	0.88	0.95
light (léger)	0.73	0.82	drowsy	0.21	0.52	soothed	0.99	0.95			
						comforted	0.99	0.95	<b>HUNGER/THIRST (<math>\alpha=.89</math>)</b>		
<b>SENSORY PLEASURE (<math>\alpha=.79</math>)</b>			<b>HUNGER/THIRST (<math>\alpha=.77</math>)</b>			relaxed	0.96	0.94	mouth-watering	1.00	0.93
nostalgic (nostalgique)	1.00	0.77	mouth-watering	1.00	0.81				thirsty	0.60	0.75
amusement (amusement)	0.98	0.76	thirsty	0.68	0.60	<b>HUNGER/THIRST (<math>\alpha=.92</math>)</b>					
mouth-watering (salivant)	0.92	0.82	famished	0.54	0.61	mouth-watering	1.00	0.95	<b>NEGATIVE FEELINGS (<math>\alpha=.87</math>)</b>		
						thirsty	0.49	0.82	stressed	1.00	0.87
			<b>NOSTALGIA (<math>\alpha=.73</math>)</b>						sad	0.65	0.72
			sentimental	1.00	0.81				ashamed	0.56	0.68
			nostalgic	0.82	0.54						

**Table 3b** Emotion and Odor Scales developed in Brazil and Asian countries (China and Singapore): the title of the category appears in bold together with the Cronbach's alpha ( $\alpha$ , inter-rater agreement) per category; Est.: parameter estimate given by the Confirmatory Factor Analysis; Alpha: Cronbach's alpha per term. In grey: categories common to at least four of the seven studied geographic areas.

Campinas, BR			Beijing, CN			Singapore, SG		
<b>DISGUST/IRRITATION (<math>\alpha=.89</math>)</b>	Est.	Alpha	<b>DISGUST/IRRITATION (<math>\alpha=.91</math>)</b>	Est.	Alpha	<b>DISGUST/IRRITATION (<math>\alpha=.92</math>)</b>	Est.	Alpha
unpleasant (desagradável)	1.00	0.91	to have an aversion to (对...产生厌恶)	1.00	0.92	unpleasant	1.00	0.93
bothered (incomodado)	0.98	0.90	disgusted (厌恶的)	1.00	0.92	horrible	0.96	0.93
nauseous (enaseado)	0.93	0.90	boredom (厌烦)	0.98	0.93	disgusted	0.95	0.92
disgusted (enojado)	0.92	0.89	sick (恶心的)	0.98	0.93	uncomfortable	0.95	0.93
to have an aversion to (ter aversão a)	0.92	0.89	dissatisfaction (不满)	0.94	0.91	sick	0.88	0.91
dissatisfaction (insatisfação)	0.90	0.89	annoyed (使烦闷的)	0.88	0.91	irritated	0.82	0.89
unpleasantly surprised (desagradavelmente surpreso)	0.88	0.88	unpleasant (不愉快的)	0.87	0.89	unpleasantly surprised	0.67	0.84
irritated (irritado)	0.80	0.85	irritated (恼怒的)	0.84	0.90	dirty	0.62	0.89
			dirty (肮脏的)	0.84	0.89			
<b>HAPPINESS/WELL-BEING (<math>\alpha=.92</math>)</b>			<b>HAPPINESS/WELL-BEING (<math>\alpha=.93</math>)</b>			<b>HAPPINESS/WELL-BEING (<math>\alpha=.88</math>)</b>		
well-being (bem-estar)	1.00	0.93	agreeable (使人愉快的)	1.00	0.94	pleasant	1.00	0.91
happy (feliz)	0.97	0.92	titillated (使愉快的)	0.99	0.94	relaxed	0.94	0.90
comfortable (confortável)	0.97	0.92	jovial (愉快的)	0.99	0.93	comforted	0.89	0.87
joyful (contente)	0.94	0.92	in a good mood (心情好的)	0.99	0.93	happiness	0.85	0.86
amusement (diversão)	0.77	0.88	cheerful (使人感到愉快的)	0.99	0.92	pleasantly surprised	0.76	0.83
			beaming (喜悦的)	0.98	0.94	well-being	0.72	0.83
			happy (幸福的)	0.97	0.92			
<b>SENSUALITY/DESIRE (<math>\alpha=.87</math>)</b>			delighted (高兴的)	0.97	0.93	<b>SENSUALITY/DESIRE (<math>\alpha=.76</math>)</b>		
charmed (seduzido)	1.00	0.89	euphoric (欣快的)	0.95	0.92	charmed	1.00	0.80
desire (desejo)	1.00	0.87	feeling of plenitude (满足感)	0.92	0.92	romantic	0.99	0.81
passionate (apaixonado)	0.99	0.90	pleasantly surprised (惊喜的)	0.86	0.91	adoring	0.95	0.78
sensual (sensual)	0.98	0.86				desire	0.92	0.70
romantic (romântico)	0.96	0.90	<b>SENSUALITY/DESIRE (<math>\alpha=.90</math>)</b>			in love	0.91	0.77
sexy (sexy)	0.96	0.85	romantic (浪漫的)	1.00	0.93	sensual	0.88	0.75
sexually aroused (excitado (sexualmente))	0.85	0.84	charmed (迷人的)	0.98	0.89	admiration	0.76	0.65
fiery (fugoso)	0.79	0.78	desire (渴望)	0.97	0.90	sexy	0.76	0.62
						sexually aroused	0.60	0.41
<b>ENERGY (<math>\alpha=.91</math>)</b>			<b>ENERGY (<math>\alpha=.91</math>)</b>			<b>ENERGY (<math>\alpha=.89</math>)</b>		
refreshed (refrescado)	1.00	0.93	rejuvenated (恢复青春活力的)	1.00	0.92	refreshed	1.00	0.92
purified (purificado)	0.99	0.90	animated (生气勃勃的)	0.99	0.92	revitalized	0.90	0.87
invigorated (revigorado)	0.97	0.89	energetic (精力充沛的)	0.98	0.90	energetic	0.65	0.84
			vitality (活力)	0.97	0.92			
<b>SOOTHING/PEACEFULNESS (<math>\alpha=.90</math>)</b>			revitalized (恢复生机的)	0.97	0.91	<b>NEGATIVE FEELINGS (<math>\alpha=.64</math>)</b>		
relaxed (relaxado)	1.00	0.91	refreshed (恢复精神的)	0.95	0.90	stressed	1.00	0.70
comforted (confortado)	0.98	0.91				depressed	0.80	0.57
at peace (em paz)	0.98	0.89	<b>SOOTHING/PEACEFULNESS (<math>\alpha=.91</math>)</b>			angry	0.71	0.68
calm (calmo)	0.96	0.89	comforted (宽慰的)	1.00	0.93	sad	0.58	0.44
relieved (aliviado)	0.87	0.88	relaxed (得到安宁的)	0.95	0.91	boredom	0.43	0.08
<b>HUNGER/THIRST (<math>\alpha=.88</math>)</b>			<b>AROUSAL (<math>\alpha=.66</math>)</b>			<b>INTELLECTUAL STIMULATION (<math>\alpha=.76</math>)</b>		
mouth-watering (com água na boca)	1.00	0.89	impressed (印象深刻的)	1.00	0.71	interesting	1.00	0.70
famished (faminto)	0.67	0.83	psychologically affected (心理上有影响的)	0.98	0.44	fascinated	0.94	0.77
						amusement	0.60	0.44
<b>NOSTALGIA (<math>\alpha=.73</math>)</b>			<b>MELANCHOLY (<math>\alpha=.82</math>)</b>			<b>SPIRITUALITY (<math>\alpha=.60</math>)</b>		
homesick/nostalgic (saudosos)	1.00	0.78	depressed (沮丧的)	1.00	0.87	spiritual feeling	1.00	0.55
nostalgic (nostálgico)	0.79	0.66	sad (伤心的)	0.95	0.77	religious feeling	0.40	0.61
			melancholic (忧郁的)	0.94	0.80			
			sentimental (伤感的)	0.92	0.80			

**Table 4.** Proposed universal Emotion and Odor Scale (UniGEOS) with 9 affective categories and 25 affective terms in four languages. N is the number of geographic areas (out of the seven studied) in which the term appears.

English	French	Chinese	Portuguese
<b>1. UNPLEASANT FEELINGS</b>			
disgusted (N=7)	dégoûté	厌恶的	enojado
irritated (N=6)	irrité	恼怒的	irritado
unpleasantly surprised (N=6)	désagréablement surpris	不愉快的意外惊喜	desagradavelmente surpreso
<b>2. HAPPINESS / DELIGHT</b>			
happy (N=6)	heureux	幸福的	feliz
pleasantly surprised (N=5)	agréablement surpris	惊喜的	agradavelmente surpreso
well-being (N=3)	bien-être	安宁	bem-estar
<b>3. SENSUALITY / DESIRE</b>			
desire (N=7)	désir	渴望	desejo
romantic (N=7)	romantique	浪漫的	romântico
sensual (N=6)	sensuel	肉欲的	sensual
<b>4. ENERGY</b>			
refreshed (N=7)	rafraîchi	恢复精神的	refrescado
energetic (N=6)	énergique	精力充沛的	energético
revitalized (N=5)	revitalisé	恢复生机的	revitalizado
<b>5. SOOTHING / PEACEFULNESS</b>			
relaxed (N=7)	relaxé	得到安宁的	relaxado
comforted (N=5)	réconforté	宽慰的	confortado
soothed (N=4)	apaisé	受安慰的	sossegado
<b>6. HUNGER / THIRST</b>			
mouth-watering (N=5)	salivant	令人垂涎欲滴的	com água na boca
thirsty (N=3)	assoiffé	口渴的	sedento
famished (N=2)	affamé	极饥饿的	faminto
<b>7. INTEREST</b>			
amusement (N=3)	amusement	娱乐	diversão
interesting (N=2)	captivant	有趣的	interessante
impressed (N=1)	impressionné	印象深刻的	impressionado
<b>8. NOSTALGIA</b>			
sad (N=3)	triste	伤心的	triste
melancholic (N=1)	mélancolique	忧郁的	melancólico
nostalgic (N=3)	nostalgique	怀旧的	nostálgico
<b>9. SPIRITUALITY</b>			
spiritual feeling (N=1)	sentiment spirituel	精神感觉	sentimento espiritual