Cognition & Emotion
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pcem20

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Sylvain Delplanque [a b], Christelle Chrea [a], Didier Grandjean [a b], Camille Ferdenzi [a], Isabelle Cayeux [c], Christelle Porcherot [c], Bénédicte Le Calvé [c], David Sander [a b] & Klaus R. Scherer [a]

[a] Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland

[b] Department of Psychology, University of Geneva, Geneva, Switzerland

[c] Firmenich, SA, Geneva, Switzerland

Version of record first published: 21 Feb 2012.

To cite this article: Sylvain Delplanque, Christelle Chrea, Didier Grandjean, Camille Ferdenzi, Isabelle Cayeux, Christelle Porcherot, Bénédicte Le Calvé, David Sander & Klaus R. Scherer (2012): How to map the affective semantic space of scents, Cognition & Emotion, 26:5, 885-898

To link to this article: http://dx.doi.org/10.1080/02699931.2011.628301

COGNITION AND EMOTION
2012, 26 (5), 885–898

Psychology Press
Taylor & Francis Group

How to map the affective semantic space of scents

Sylvain Delplanque[1,2], Christelle Chrea[1], Didier Grandjean[1,2], Camille Ferdenzi[1], Isabelle Cayeux[3], Christelle Porcherot[3], Bénédicte Le Calvé[3], David Sander[1,2], and Klaus R. Scherer[1]

[1]Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland
[2]Department of Psychology, University of Geneva, Geneva, Switzerland
[3]Firmenich, SA, Geneva, Switzerland

The investigation of the semantic space associated with subjective affective experiences or feelings linked to odour perception has recently emerged. Because of the specificity of the emotional effects of odours, the terms derived from traditional models of emotion are unlikely to optimally account for odour-associated feelings. In this study, sets of terms derived from two traditional models, basic emotions and valence by arousal by dominance dimensional emotions, were compared with a recently elaborated olfaction-specific set of terms (Geneva Emotion and Odour Scale; GEOS). Three main criteria were considered: (1) the feeling's intensity reported in response to odours; (2) the inter-rater agreement concerning the reported feelings; and (3) the power to discriminate feelings evoked by various odorous substances. The evidence strongly suggested that the set of terms proposed by GEOS outperformed the terms derived from the two classical models in measuring the subjective affective experience elicited by odours. These results are interpreted with respect to a good correspondence between the functions of olfaction and the meaning conveyed by GEOS terms.

Keywords: Emotion; Feeling; Olfaction; Odour; GEOS.

In most research about the relation between emotion and odours, measurement of subjective affective experience or feeling has been limited to self-report questionnaires. The supposed emotionally relevant items are, in most cases, derived from either the basic emotions theories or the dimensional theories.

On the one hand, basic emotions theories postulate the existence of a small number of basic emotions, in particular, anger, disgust, fear, enjoyment/happiness, sadness, and surprise (Matsumoto & Ekman, 2009), that are based on phylogenetically stable neuromotor programmes and are characterised by emotion-specific response patterns

Correspondence should be addressed to: Sylvain Delplanque, Swiss Center for Affective Sciences, University of Geneva, rue des Battoirs 7, 1205 Geneva, Switzerland. E-mail: sylvain.delplanque@unige.ch

This research was supported by the National Center of Competence in Research (NCCR) for the Affective Sciences, financed by the Swiss National Science Foundation (51NF40-104897) and hosted by the University of Geneva, and by grants from Firmenich, SA, to DS and PV.

http://www.psypress.com/cogemotion http://dx.doi.org/10.1080/02699931.2011.628301

(Ekman, 1984; Izard, 1993; Tomkins, 1984). In the olfactory literature, there is no consensus among authors regarding the number of terms used to target feelings, which may vary from 6 (*anger*, *disgust*, *fear*, *sadness*, *surprise*, *happiness*; e.g., Alaoui-Ismaili, Robin, Rada, Dittmar, & Vernet-Maury, 1997; Vernet-Maury, Alaoui-Ismaili, Dittmar, Delhomme, & Chanel, 1999) when authors refer to the strict definition of a basic emotion[1] (Matsumoto & Ekman, 2009) to 22 (*shame*, *jealousy*, *fear*, *anger*, *sadness*, *pride*, *hope*, *relief*, *boredom*, *contempt*, *admiration*, *disgust*, *desire*, *disappointment*, *love*, *dissatisfaction*, *amusement*, *stimulation*, *satisfaction*, *unpleasant surprise*, *enjoyment*, *pleasant surprise*; e.g., Desmet, 2005; Desmet & Schifferstein, 2008) when authors accept a broader definition.

The dimensional theories, on the other hand, assume that all affective phenomena are necessarily (but not sufficiently) described via positions in a two-dimensional valence by arousal space or a three-dimensional space that includes an additional dimension of dominance or potency (e.g., Barrett & Russell, 2009; Lang, Greenwald, Bradley, & Hamm, 1993; Mehrabian & Russell, 1974; Russell, 1980; Russell & Mehrabian, 1977; Wundt, 1909). Authors embracing this approach mainly use a Pleasure, Arousal, and Dominance (PAD) questionnaire. In this case, the affective terms are chosen to characterise the extremities of the underlying two or three bipolar dimensions (e.g., *happy/unhappy*, *excited/calm*, *powerful/without power*: Bensafi et al., 2002a, 2002b, 2002c; Chebat & Michon, 2003; Herz, Eliassen, Beland, & Souza, 2004; Heuberger, Hongratanaworakit, Bohm, Weber, & Buchbauer, 2001; Jonsson, Olsson, & Olsson, 2005; Morrin & Ratneshwar, 2000; Pössel, Ahrens, & Hautzinger, 2005; Schifferstein & Tanudjaja, 2004; Spangenberg, Crowley, & Henderson, 1996; Warrenburg, 2005).

Recently, Chrea et al. (2009) established a systematic, empirically derived taxonomy of olfactory-induced discrete feelings by conducting two studies to investigate the nature and organisation of the semantic space associated with the subjective experience of emotional responses to odours. The originality of the methodology adopted was twofold: (1) the initial list of 480 affective terms used in this study included (among others) the terms of the different versions of the PAD questionnaire, the most exhaustive list of terms derived from the basic emotions approach applied to olfaction (22 terms from Desmet, 2005; Desmet & Schifferstein, 2008), and terms derived from other discrete emotions approaches (e.g., Scherer, 2005); and (2) the authors did not impose a strong theoretical framework in the selection of the relevant terms, this choice being based on a data-driven approach derived from respondents' evaluations. Six main classes or categories of feelings experienced in reaction to odours (i.e., pleasant feeling, unpleasant feeling, relaxation, refreshment, sensuality, and sensory pleasure) emerged from this psychometric approach and constitute the Geneva Emotion and Odour Scale (GEOS). Each class of feelings is characterised by three representative affective terms and is evaluated with the help of a feelings' intensity scale varying from not experienced or not intense at all to strongly experienced or intense (see Chrea et al., 2009; Porcherot et al., 2010, for more details).

However, it remains to be formally established which of these sets of terms (i.e., derived from basic emotions, tridimensional, or GEOS approaches) is optimally suited to verbally measure the subjective affective response or feeling

[1] *Stricto sensu*, basic emotions share a common set of characteristics that consist of specific neural, bodily, expressive, and feeling components (Izard & King, 2009; Matsumoto & Ekman, 2009). Consequently, using terms describing emotions without bringing arguments about the "basic" nature of those emotions, as described earlier, means that one refers to the concept of basic emotions too roughly, without fully considering the underlying assumptions carried by this theory, omitting many required criteria for an emotion to be considered as basic.

associated with odours. When developing GEOS, the selection of the relevant terms was based on a data-driven approach. If the existing terms derived from classical emotional models had been best suited to reflect the feeling evoked by actual odours, they would have been selected by the respondents as such. However, results from Chrea et al. (2009) showed that some of the terms from the basic emotions approach were pertinent and some were not, and the affective space shaped by the remaining pertinent terms was different from a two- or three-dimensional bipolar space. This point was statistically tested by using confirmatory factorial analyses on the data by imposing different dimensional structures (see Chrea et al., 2009, Table 5).

Although the GEOS foundation article (Chrea et al., 2009) suggested that feelings elicited by odours would not be optimally described with terms derived from either the basic emotions theory or the PAD approach, it did not demonstrate this. A growing number of studies has recently emerged proposing sets of emotional terms that describe feelings in relation to various olfactory stimuli or products. However, few of them have made direct comparisons with existing sets of terms. In our opinion, this is problematic because using a specific set of terms is worthwhile only if it truly provides advantages over other existing sets. Therefore, the aim of the present paper was to offer such a demonstration. Moreover, showing which proposed set is best suited to study odour-elicited feelings is not enough, as it is crucial to understand the criteria (e.g., pertinence of the terms, consensus among raters) on the basis of which each proposed set of terms shows its strengths and weaknesses. To evaluate the comparative suitability of the three sets of terms, we used a procedure that is commonly used in studies of moods and emotions (see Fontaine, 2009): we examined how intensely (measured on analogical scales) the respondents experienced feelings in response to several odorants. The feelings were described in terms derived from basic emotions, PAD, or GEOS approaches. The comparative validity was based on three criteria: (1) the intensity of the reported feelings; (2) the inter-rater agreement in using the different sets of terms; and (3) the ability of the three sets of terms to discriminate the feelings related to different olfactory stimuli. The rationale behind these criteria was that if one term perfectly describes the participant's feeling in response to a particular odorant, then the feeling intensity rating should be higher, at least for this term, than for the other terms that do not match this particular experienced feeling. Thus, the more adequate a given set of terms is in capturing feelings associated with many odours, the higher the intensity ratings (at least for one term of the set; i.e., validity criterion), but also the better the agreement between the raters (i.e., reliability criterion) and the better the discrimination among odorous substances based on the ratings of the feelings (see also Zentner, Grandjean, & Scherer, 2008).

METHOD

Feeling scales

A computer-based questionnaire was designed for three experimental conditions. In the GEOS condition, six analogical scales (headed *pleasant feeling*, *unpleasant feeling*, *sensuality*, *relaxation*, *refreshment*, and *sensory pleasure*), each being defined by three representative terms (see Table 1), were used to evaluate the set of terms proposed by Chrea et al. (2009). In the basic emotions condition, six scales (headed *joy*, *surprise*, *anger*, *disgust*, *fear*, and *sadness*), each being defined by three representative terms, were used to evaluate the basic emotions terms (Ekman, 1984; Matsumoto & Ekman, 2009). The selection of the representative terms was based on a French adaptation of Izard's Differential Emotions Scale (Izard, 1990; Ouss, Carton, Jouvent, & Wildlocher, 1990) and was used in previous studies (e.g., Zentner et al., 2008). In the dimensional emotion condition, six scales (headed *activation*, *deactivation*, *pleasure*,

Table 1. *Main feeling terms and three subheading representative terms for each emotion model*

Model	*Main feeling term*	*Representative terms*
GEOS	Relaxation	Relaxed–serene–soothed
	Unpleasant feeling	Disgusted–irritated–unpleasantly surprised
	Sensuality	In love–desire–romantic
	Refreshment	Revitalised–invigorated–clean
	Sensory pleasure	Nostalgic–amusement–salivating
	Pleasant feeling	Happiness–well-being–pleasantly surprised
Basic	Surprise	Surprised–amazed–stunned
	Anger	Angry–furious–outraged
	Sadness	Downcast–sad–discouraged
	Disgust	Gutted–disgusted–repelled
	Joy	Delighted–cheerful–happy
	Fear	Terrified–frightened–scared
Tridimensional	Activation	Excited–alert–stimulated
	Dominance	Dominant–powerful–under control
	Pleasure	Happy–delighted–glad
	Submissiveness	Submissive–without control–without power
	Unpleasant	Unhappy–displeased–discontented
	Deactivation	Calm–rested–asleep

Note: GEOS = Geneva Emotion and Odour Scale.

displeasure, *dominance*, and *submissiveness*[2]), each also being defined by three representative terms, were used to evaluate the PAD terms (Mehrabian & Russell, 1974; Russell, 2003; Watson, Wiese, Vaidya, & Tellegen, 1999).

The main feeling terms were written in capital letters and the three representative terms in subheadings in lowercase letters (in French). The six scales were displayed on the same screen and each feeling scale was presented as a continuous scale from 0 (*not at all intense*) to 200 (*extremely intense*).

Odorant stimuli

Eight odorant stimuli (strawberry, grapefruit, synthetic body odour, lavender, lilac, peppermint, beef, and juniper/cade, provided by Firmenich, SA) were selected on the basis of previous work (Chrea et al., 2009; Delplanque et al., 2008) for their representativeness in covering a large range of odorant types. These stimuli corresponded to everyday odours, including familiar–nonfamiliar odours and pleasant–unpleasant odours, and belong to diverse odour families such as sweet, savoury, cosmetic, woody, fruity, floral, animal, and medicine. Odorants were diluted in odourless dipropylene glycol to obtain a similar mean subjective intensity (see Chrea et al., 2009; Delplanque et al., 2008). Solutions (3 ml) were injected into the tampon of cylindrical felt-tip pens (14 cm long, inner diameter 1.3 cm). The use of these highly practical devices (provided by Burghart, Germany) avoids any contamination of the environment. Each odorant was coded by a random 3-digit code.

[2]Traditionally, only three scales are used to assess the three dimensions of arousal, valence, and dominance. For instance, participants are requested to evaluate their feelings on continuum scales varying from relaxed to excited, unpleasant to pleasant, and without control to under control, respectively. We decided to represent each dimension by two scales and not one in order to equalise the dimensionality of the three models. Indeed, comparing six-scale questionnaires with a three-scale one could have been criticised from a statistical point of view and would have automatically biased the result of the comparisons (e.g., a decrease in dimensionality will automatically reduce the inter-rater agreement because the Cronbach's α increases as a function of the number of items).

Procedure

A computer-based questionnaire was administered in two locations: in a public fair devoted to education and training that takes place annually in Geneva, and in the cafeteria of Geneva-based Firmenich, SA. The experimental setting consisted of an open space within the location ($\approx$15 m^2) that included a large table with two computers, allowing two participants to provide feeling ratings for the set of odorants. Participants were approached by an experimenter who explained the procedure to them. Individuals who agreed to participate sat in front of one of the two computers and were told how to complete the questionnaire. Information about the participants' age, gender, and mother tongue was requested at the beginning of the questionnaire. Participants were then presented with the instructions for the feeling rating task. Participants were instructed that when they saw the 3-digit code on the screen, they had to: (1) take the corresponding pen from the display shelf; (2) open the cap of the pen and breathe evenly with the odorant pen opened near the nose (about 1 cm below both nostrils); (3) rate the six scales; and (4) close the pen, replace it on the display shelf, and wait for the signal to proceed to the next trial. More precisely, after having smelled the odour, respondents were asked to rate the intensity of their feelings with the help of six scales defined by representative affective terms, summarised by a main feeling term (see Table 1) and placed near each scale. For instance, on one scale, participants who used the PAD questionnaire were asked to report the intensity of their feeling of pleasure (from *not at all* to *extremely*), pleasure being defined by the representative terms happy, delighted, and glad. The presentation order of the odorants was different for each respondent. The procedure took approximately 10 to 15 minutes.

Participants

In total, 111 French-speaking volunteers participated: 41 participants in the GEOS condition (12 males; average age 30 ± 10.2 years), 36 participants in the dimensional emotion condition (10 males; average age 35.2 ± 11.7 years), and 34 participants in the basic emotions condition (10 males; average age 32.5 ± 9.6 years). All the participants reported a normal sense of smell, were completely naïve concerning the objective of the study, and did not know that other participants used different sets of terms. Moreover, Firmenich employees who participated in this study did not belong to the Research and Development Division, where specific adaptations of GEOS are developed (see Porcherot et al., 2010).

RESULTS

Intensity ratings of feelings

For each scale of the three sets of terms, we determined the highest feeling intensity rating for each participant across odours. We then averaged those maximum values across participants to obtain a mean maximum rating for each scale of the three sets. The results of this calculation are represented in Figure 1A.

To evaluate which set of terms gave rise to the highest intensity ratings of feelings, we used a bootstrap procedure because the values were not normally distributed (Shapiro–Wilks' W tests, all significant at $p < .05$). Thus, traditional analyses of variance (ANOVAs) would not be well suited for these values (Davison & Hinkley, 1997; Mooney & Duval, 1993). Specifically, for each set of terms, 1,000 random resamples, with replacement at the participant level, were drawn from the maximum ratings calculated across scales and for each odour (the odour being the common variable between the three different sets of terms). The mean was then calculated for each new sample. The distributions of the estimated mean maximum ratings are represented in Figure 2A for each set. To formally test the significance of the differences between these three distributions of means, we computed 1,000 random differences between resample means taken from the different sets of scales, allowing us to derive a distribution of the differences. Differences are significant when the distribution of the differences does not include the 0 value in the confidence interval

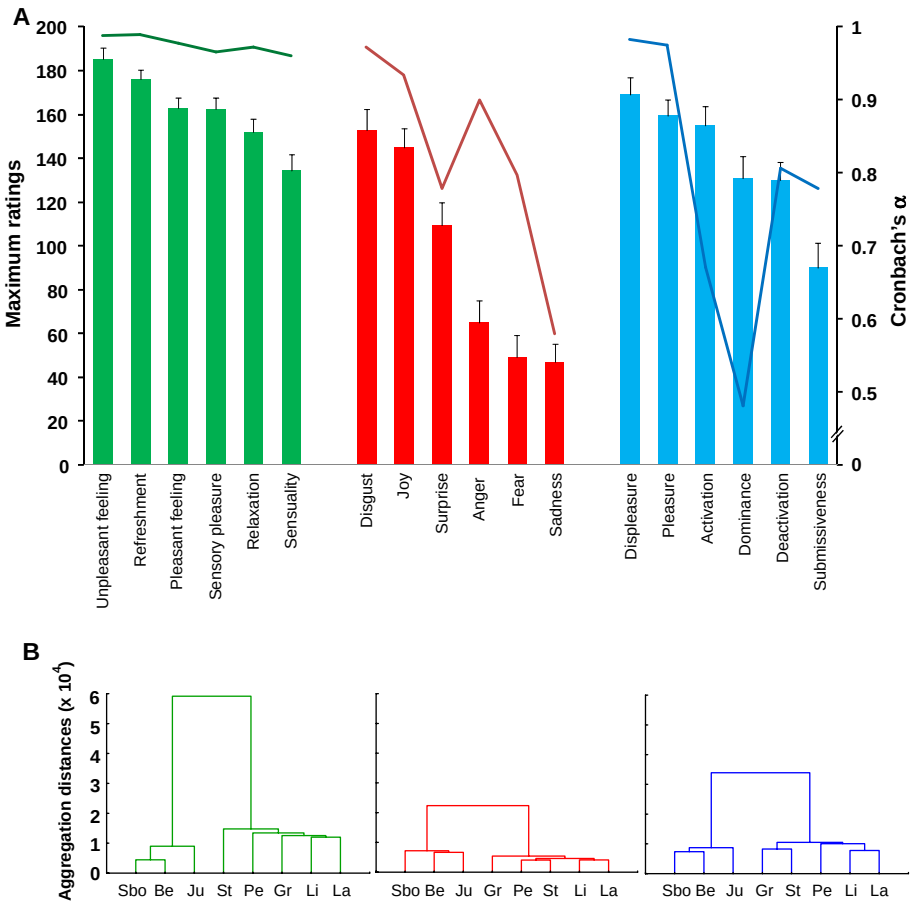

Figure 1. *(A) Mean maximum ratings for each scale (histogram with SEM bars) and mean Cronbach's α (lines) for GEOS (green), the basic emotions scales (red), and the dimensional scales (blue). (B) Grouping of the eight odours (horizontal axis) based on cluster analyses. Note that the higher the distance of aggregation, the better the discriminative power of the set of scales. Sbo = synthetic body odour, Be = beef, Ju = juniper/cade, St = strawberry, Pe = peppermint, Gr = Grapefruit, Li = lilac, La = lavender. To view this figure in colour, please see the online issue of the Journal.*

(Davison & Hinkley, 1997). All of these analyses were performed with Matlab™ software; a detailed description of the bootstrap procedure is available from the authors. For simplicity, we hereafter use the expressions *basic emotions scales* and *PAD scales* to indicate the basic emotions and tridimensional approaches, respectively.

On the basis of the confidence interval of the differences between the basic emotions scales and GEOS, we rejected the null hypothesis of the equivalence of the means ($p < .05$; Table 2 and Figure 2A). Thus, GEOS gave rise to significantly higher maximum intensity ratings than did the basic model. Neither the difference between the PAD scales and GEOS nor the difference between the PAD scales and the basic emotions scales reached significance (Table 2 and Figure 2A).

Inter-rater agreement

To examine to what extent people agreed on their reported feelings, as induced by the eight olfactory stimuli when using the three sets of scales, we evaluated the inter-rater agreement for each scale by computing Cronbach's α with Statistica

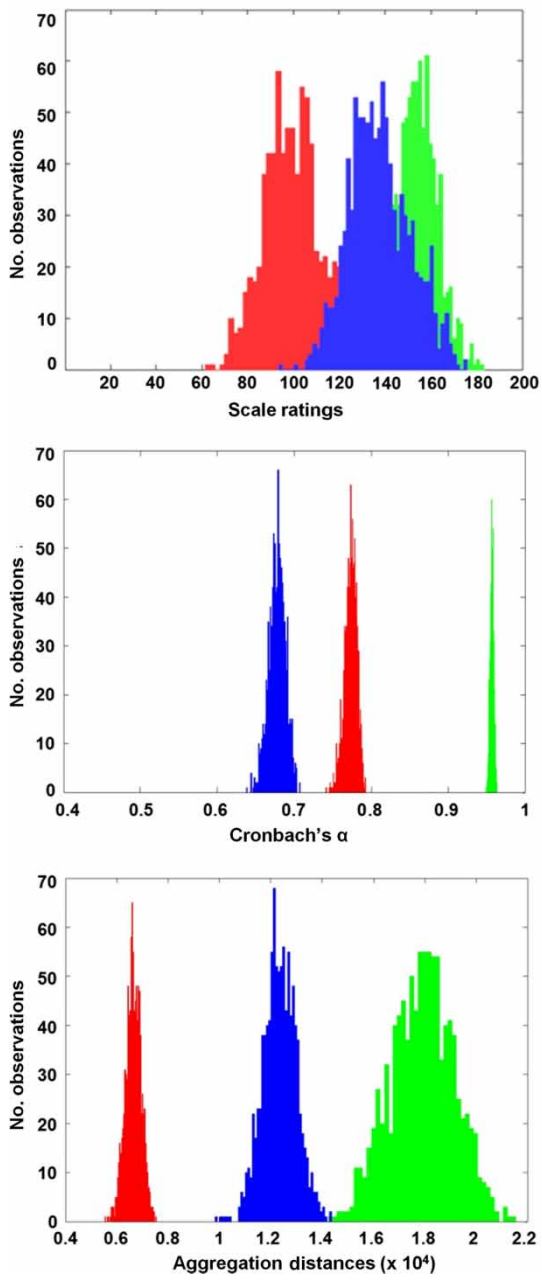

Figure 2. *Distributions obtained by the bootstrapping method for GEOS (green), basic emotions scales (red), and dimensional scales (blue) for the estimated mean (A) maximum ratings, (B) Cronbach's α, and (C) distances of aggregation. To view this figure in colour, please see the online issue of the Journal.*

Table 2. *Distribution means for the different models and confidence intervals of the three criteria distribution differences (calculated between models)*

	Mean maximum rating	*Cronbach's α*	*Aggregation distance*
Distribution means			
GEOS	150.7	.96	17953.59
Basic	109.8	.78	7789.80
Dim	137.5	.67	12372.00
Lower and upper limits (95%) of confidence intervals for distribution differences			
GEOS vs. Basic	[4.52, 77.34]*	[.17, .19]*	[7578.85, 12655.67]*
GEOS vs. Dim	[−12.22, 38.59]	[.25, .33]*	[2759.97, 8219.32]*
Dim vs. Basic	[−2.87, 58.37]	[.07, .14]*	[3012.58, 6191.71]*

Note: *$p < .05$. Dim = Dimensional.

Software (Statistica 8.0, Statsoft, Tulsa, OK). The results of this analysis are represented in Figure 1A.

We again used a bootstrap procedure to estimate the significance of the difference between the three sets of scales for inter-rater agreement. The distributions of the estimated mean of Cronbach's α are represented in Figure 2B for each set. On the basis of the confidence interval of the distribution differences calculated for the basic emotions scale and GEOS, we rejected the null hypothesis of the equivalence of the means ($p < .05$; Table 2 and Figure 2B), with inter-rater agreement being higher for GEOS. Similarly, the difference between the PAD scale and GEOS was also significant ($p < .05$; Table 2 and Figure 2B), showing higher inter-rater agreement for GEOS. Finally, the basic emotions scale led to significantly higher inter-rater agreement than did the PAD scale ($p < .05$; Table 2 and Figure 2B).

Power to discriminate feelings induced by the odorous substances

The last step was to examine which of the three sets of terms gave rise to better discrimination of the different feelings induced by the eight odorant stimuli used in this study. For each of the sets, we calculated the mean intensity ratings of the odours across participants obtained for each of the six scales. These values were then subjected to hierarchical cluster analysis by using Ward's method (Ward, 1963). Discriminative power was evaluated by the distances of aggregation (using Manhattan distances[3]); the higher the distance of aggregation, the better the discriminative power of the set of terms. The results of this analysis are represented in Figure 1B.

To formally test the hypothesis of the differential power of odour discrimination between the three sets of scales, we conducted a bootstrap analysis from the estimated mean aggregation distances by using the same procedure as described earlier. The distributions of the estimated mean aggregation distances are represented in Figure 2C for each scale. The differences of mean aggregations between GEOS and the basic emotions scale were significant ($p < .05$; Table 2 and Figure 2C), with higher linkage distances for GEOS. The differences between the PAD scale and GEOS also reached significance ($p < .05$; Table 2 and Figure 2C), with higher linkage distances for GEOS. Finally, the differences were

[3]City-block (Manhattan) distance is simply the mean 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 because they are not squared. Ward's method uses an analysis of variance approach to evaluate the distances between clusters. In short, this method attempts to minimise 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; however, it tends to create clusters of small size (see *Electronic Statistics Textbook* for further details; StatSoft, Inc., 2011).

also significant between the PAD and basic emotions scales ($p < .05$; Table 2 and Figure 2C), with higher aggregation distances for the PAD scale.

DISCUSSION

The present research directly compared the suitability of a recently elaborated set of terms designed to verbally measure odour-elicited feelings (GEOS; Chrea et al., 2009) with other sets of terms derived from the two prominent emotion models used in olfactory research: basic emotions and PAD approaches. The results of this study showed that GEOS outperformed the other two proposed sets, showing higher intensity ratings than the basic emotions set and higher inter-rater agreement and better ability to discriminate among the feelings related to olfactory stimuli than the other two tested sets. The results lend support to the claim that neither of the two major methods for measuring self-reported emotional experience—the list of basic emotions or valence, arousal, and dominance dimensions—is best suited to achieve this task reliably.

Indeed, by focusing on a small number of evolutionarily based basic emotions, one downplays the more complex forms of emotional processes, especially affective feeling states produced by odours that do not directly serve adaptive behavioural functions linked to olfaction, such as nostalgia. Our results showed that the scales derived from the basic emotions model gave rise to inferior results compared with GEOS. This result is consistent with that of other studies (Alaoui-Ismaili et al., 1997; Bensafi et al., 2002c; Chrea et al., 2009; Desmet, 2005; Desmet & Schifferstein, 2008; Robin, Alaoui-Ismaili, Dittmar, & Vernet-Maury, 1999), showing that the emotional responses, states, and descriptions in response to odours do not match basic emotions categories such as anger, fear, or sadness (see Porcherot et al., 2010, for a recent discussion on this point). If one keeps in mind that the majority of basic emotions are unpleasant (e.g., anger, disgust, sadness, and fear), this finding could be surprising at first glance because of the reported prominence of the unpleasant pole in olfactory hedonicity (Boisson, 1997), showing a greater intra- and intercultural agreement than the pleasant pole (Schaal et al., 1998). Thus, one could have expected the basic emotions scales to be highly relevant, consensual, and discriminative in this regard. Our interpretation is that the terms inspired by the basic emotions approach used to characterise the unpleasant pole of olfactory hedonicity are not pertinent because they require more specific conditions to be evoked (see also Desmet, 2005). Indeed, participants were not given specific situations when assessing their feelings so that a wide range of experiences could be sampled. What remains to be tested is the possibility that many feelings require an appropriate—possibly motivational or social—context to be elicited via odours. However, if the odour presentation is contextualised, it cannot be ruled out that the emotion is due to situational factors rather than to the odour per se. This question needs to be investigated by taking into account the social context of the emergence of feelings related to odours.

In the same vein, the approach based on bi- or tridimensional models has been used broadly to address issues related to odours and emotions (Bensafi et al., 2002a, 2002b; Chebat & Michon, 2003; Herz et al., 2004; Heuberger et al., 2001; Jonsson et al., 2005; Morrin & Ratneshwar, 2000; Pössel et al., 2005; Spangenberg et al., 1996; Warrenburg, 2005) because, for experimental and practical reasons, reporting an emotion on scales of pleasantness and arousal is advantageous, as it is less cognitively demanding. The reason that the approach based on this kind of model gave rise to inferior results compared with the approach based on GEOS may be that a description limited to two or three dimensions loses most of the important qualitative differences between the affective effects of different types of odorous substances (as demonstrated by the weaker discriminative power). We argue, rather, that at least six classes of feelings are necessary to get a more comprehensive picture of the possible odour-elicited feelings verbally reported. Thus, even if

those feelings could be positioned in the tridimensional space of PAD, as feelings associated with basic emotions can be, the use of a simple valence by arousal representation may not be sufficient to answer relevant questions related to olfaction (e.g., Fontaine, Scherer, Roesch, & Ellsworth, 2007; Zentner et al., 2008). This point was also underlined by Rétiveau, Chambers, and Milliken (2004), who observed that some fragrances that were similarly evaluated in a valence by activation space were clearly differentiated when participants evaluated them with several mood adjectives (see also Porcherot et al., 2010, for a recent discussion on this point).

The psychometric space described by GEOS is shaped by affective terms gathered in six classes of feelings that we named *pleasant feeling*, *unpleasant feeling*, *relaxation*, *refreshment*, *sensuality*, and *sensory pleasure* (see Chrea et al., 2009; Porcherot et al., 2010, for more details). We could question the extent to which these terms represent or capture *true emotions*. The first way to answer this question is to notice that there is no agreement among researchers in the field about what an emotion is (Frijda & Scherer, 2009). At least there is an agreement that emotions contain subjective feeling, action tendencies, physiological arousal, cognitive processes, and expressive motor behaviour. Thus, we can assert only that we have identified "potential emotions", as the current differentiation on the feeling level needs to be confirmed by differentiations on a cognitive, behavioural, or physiological level to be fully considered as true emotions (see Zentner et al., 2008, for a discussion on this topic). Another way to answer this question is to examine the extent to which the terms provided by GEOS are related to the putative functions of emotions. Whatever the theoretical point of view adopted, from an evolutionary perspective adopted by the majority of the basic emotions theorists (e.g., Matsumoto & Ekman, 2009) to the constructionist viewpoints mostly adopted by the advocates of the dimensional theories (see Scherer, 2009a), emotions are viewed as intelligent interfaces that mediate environmental input to adaptive output (Scherer, 1994). Emotions are thought to allow an adjustment or to solve survival-relevant problems, such as forming attachments, maintaining cooperative relations, or avoiding physical threats (see Keltner & Gross, 1999, for a review about the functions of emotions). More particularly, the feeling component of an emotional episode integrates and regulates the other components (cognitive, behavioural, expressive, and physiological) to motivate the response that fits the demands of the physical and social environment (Scherer, 2009b). Thus, the terms provided by GEOS represent the way that respondents' subjective affective experiences or feelings are related to the different functions of olfaction. Experiencing those feelings will motivate the individual to adopt the optimally suited response to the physical and social environment.

In a recent review on the functions of human olfaction, Stevenson (2010) defined three major classes of functions related "to Ingestion (Detection/identification prior to ingestion; Detection of expectancy violations; Appetite regulation; Breast orientation and feeding), Avoiding environmental hazards (Fear related; Disgust related), and Social Communication (Reproductive [Inbreeding avoidance, fitness detection in prospective mates]; Emotional contagion [fear contagion, stress buffering])" (p. 3). Keeping in mind these functional aspects of olfaction, most of the terms gathered under the GEOS class of feelings called "Disgust–Irritation" could reflect the unpleasant subjective affective experience associated with the detection of "*expectancy violation*" or "*environmental hazards*", described as key functions of olfaction. Those unpleasant feelings could, for instance, motivate a withdrawal behaviour. The terms from the "*Well-being–Happiness*" category could reflect the feeling associated with the fulfilments of "*expectancies*" or "*food intake*". We can also mention that the terms gathered in the "*Sensuality*" category could reflect the feelings associated with many situations of "*social communication*". The terms gathered in the "*Energising–Refreshing*" and "*Soothing–Peacefulness*" categories could depict the feelings that motivate responses in relation to many functions of olfaction, such as being energised prior to ingestion to enhance the search for food, or feeling relaxed after

smelling the known odour of the partner. Even the less obvious "*Sensory pleasure*" class of feelings contained terms referring to the affective experience in relation to memory aspects, a crucial cognitive capacity that is at the root of the above-mentioned olfactory functions. In summary, we argue that the set of terms proposed by GEOS are deeply emotional in the sense that the feelings they depict motivate the individual to adjust or to solve olfactory-linked survival-relevant problems, a key function of emotion.

Several caveats and limitations of the study need to be mentioned. First, it can be argued that GEOS is a subtle and differentiated set of terms and it is obvious that the comparison with more general terms derived from the classical models of emotions would lead to better results for GEOS. In particular, this superiority could be brushed aside if GEOS was compared with other sets of more differentiated emotional terms. Recent studies have proposed different sets of emotional terms to qualify the subjective affective experience in response to specific products (for fragrances, see Desmet, 2005; for wine, Ferrarini et al., 2010; for food, Desmet & Schifferstein, 2008; King & Meiselman, 2009). However, many emotional terms recently proposed were included in the first step of developing GEOS and were often not retained because they were not judged relevant enough (see Chrea et al., 2009, for more information). Moreover, the majority of authors are still using terms derived from the classical emotional approaches, particularly terms derived from the PAD approach. In a similar manner, one can argue that other dimensional models—or circumplex models (Barrett & Russell, 2009)—exist and could have led to better results than the PAD version we used. However, the different versions of those dimensional models (e.g., the positive and negative affect model, the tension versus calmness and energy versus tiredness; see Barrett & Russell for more details) constitute different rotations within the same dimensional space (Yik, Russell, & Barrett, 1999). Thus, our criticism concerning the limitation for two or three dimensions to optimally account for qualitative differences between the affective effects of odours remains pertinent. Our main message is that, in this burgeoning field, researchers should not neglect to directly compare their sets of terms with already existing terms to reinforce the validity and reliability of their proposed sets. Second, GEOS has been elaborated in only one cultural sample (the French part of Switzerland), and it does not provide any evidence for its reliability in cultures that differ in their odour-related habits. Other sets of terms—selected with the same approach as for GEOS—are now available for different cultures (Ferdenzi et al., 2011) and could be compared with PAD and basic emotions terms that, by contrast, have been extensively used all around the world. Third, GEOS is derived from a statistical, normative approach and such an approach is limited because it accounts for responses in the majority of people with a normal sense of smell, whereas select individuals and subgroups may show different emotional response patterns. Further studies should determine the appropriateness of using GEOS or other sets of terms in particular populations or with more specific categories of odours.

The results of this study provide the first evidence that an olfactory-specific set of terms is needed to provide an efficient verbal report of feelings elicited by odours. As demonstrated for music (Zentner et al., 2008), domain-specific sets of affective terms seem better suited to optimise a fine-grained description of feelings elicited through specific sensory modalities. We hypothesised that such superiority occurs because the terms fit with feelings that motivate the individual to adopt the optimally suited response to the physical and social environment. In that sense, future research could aim at developing new affective semantic spaces in response to other modalities (e.g., touch), conjunctions of modalities (e.g., taste, olfaction, touch for flavour), or even specific classes of objects within a modality (e.g., faces, voices) and comparing them with more general sets of affective terms. This strategy should help to precisely quantify the advantages and limits of domain-specific approaches.

Manuscript received 7 March 2011
Revised manuscript received 6 July 2011
Manuscript accepted 20 September 2011
First published online 16 February 2012

REFERENCES

Alaoui-Ismaili, O., Robin, O., Rada, H., Dittmar, A., & Vernet-Maury, E. (1997). Basic emotions evoked by odorants: Comparison between autonomic responses and self-evaluation. *Physiology and Behavior*, *62*, 713–720.

Barrett, L. F., & Russell, J. A. (2009). Circumplex models. In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 85–88). Oxford, UK: Oxford University Press.

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. *Chemical Senses*, *27*, 703–709.

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., & Holley, A. (2002b). Influence of affective and cognitive judgments on autonomic parameters during inhalation of pleasant and unpleasant odors in humans. *Neuroscience Letters*, *3193*, 162–166.

Bensafi, M., Rouby, C., Farget, V., Bertrand, B., Vigouroux, M., & Holley, A. (2002c). Psychophysiological correlates of affects in human olfaction. *Neurophysiologie Clinique—Clinical Neurophysiology*, *325*, 326–332.

Boisson, C. (1997). La dénomination des odeurs: Variations et régularités linguistiques. *Intellectica*, *24*, 29–49.

Chebat, J. C., & Michon, R. (2003). Impact of ambient odors on mall shoppers' emotions, cognition, and spending: A test of competitive causal theories. *Journal of Business Research*, *56*, 529–539.

Chrea, C., Grandjean, D., Delplanque, S., Cayeux, I., Le Calvé, B., Aymard, L., et al. (2009). Mapping the semantic space for the subjective experience of emotional responses to odours. *Chemical Senses*, *34*, 49–62.

Davison, A. C., & Hinkley, D. V. (1997). *Bootstrap methods and their application*. Cambridge, UK: Cambridge University Press.

Delplanque, S., Grandjean, D., Chrea, C., Aymard, L., Cayeux, I., Le Calvé, B., et al. (2008). Emotional processing of odours: Evidence for a non-linear relation between pleasantness and familiarity evaluations. *Chemical Senses*, *33*, 469–479.

Desmet, P. M. A. (2005). Typology of fragrance emotions. *Proceedings of the Fragrance Research Conference* (pp. 1–14). Amsterdam, The Netherlands: ESOMAR.

Desmet, P. M. A., & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite*, *50*, 290–301.

Ekman, P. (1984). Expression and the nature of emotion. In K. R. Scherer & P. Ekman (Eds.), *Approaches to emotion* (pp. 319–344). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ferdenzi, C., Schirmer, A., Roberts, S. C., Delplanque, S., Porcherot, C., Cayeux, I., et al. (2011). Affective dimensions of odor perception: A comparison between Swiss, British, and Singaporean populations. *Emotion*, *11*, 1168–1181.

Ferrarini, R., Carbognin, C., Casarotti, E. M., Nicolis, E., Nencini, A., & Meneghini, A. M. (2010). The emotional response to wine consumption. *Food Quality and Preference*, *21*, 720–725.

Fontaine, R. J. (2009). Dimensional emotion models. In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 119–120). Oxford, UK: Oxford University Press.

Fontaine, R. J., Scherer, K. R., Roesch, E., & Ellsworth, P. C. (2007). The world of emotions is not two dimensional. *Psychological Science*, *18*, 1050–1057.

Frijda, N. H., & Scherer, K. R. (2009). Emotion definitions (psychological perspectives). In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 142–144). Oxford, UK: Oxford University Press.

Herz, R. S., Eliassen, J., Beland, S., & Souza, T. (2004). Neuroimaging evidence for the emotional potency of odor-evoked memory. *Neuropsychologia*, *423*, 371–378.

Heuberger, E., Hongratanaworakit, T., Bohm, C., Weber, R., & Buchbauer, G. (2001). Effects of chiral fragrances on human autonomic nervous system parameters and self-evaluation. *Chemical Senses*, *263*, 281–292.

Izard, C. E. (1990). Facial expression and the regulation of emotions. *Journal of Personality and Social Psychology*, *58*, 487–498.

Izard, C. E. (1993). Four systems for emotion activation: Cognitive and noncognitive processes. *Psychological Review*, *100*, 68–90.

Izard, C. E., & King, K. A. (2009). Differential emotions theory. In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 117–119). Oxford, UK: Oxford University Press.

Jonsson, F. U., Olsson, H., & Olsson, M. J. (2005). Odor emotionality affects the confidence in odor naming. *Chemical Senses*, *301*, 29–35.

Keltner, D., & Gross, J. J. (1999). Functional accounts of emotions. *Cognition and Emotion*, *13*, 467–480.

King, S. C., & Meiselman, H. L. (2009). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference*, *21*, 168–177.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*, 261–273.

Matsumoto, D., & Ekman, P. (2009). Basic emotions. In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 69–72). Oxford, UK: Oxford University Press.

Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology*. Cambridge, MA: MIT Press.

Mooney, C. Z., & Duval, R. D. (1993). *Bootstrapping: A nonparametric approach to statistical inference*. Sage University Paper Series on Quantitative Applications in the Social Sciences. Newbury Park, CA: Sage.

Morrin, M., & Ratneshwar, S. (2000). The impact of ambient scent on evaluation, attention and memory for familiar and unfamiliar brands. *Journal of Business Research*, *49*, 157–165.

Ouss, L., Carton, S., Jouvent, R., & Wildlocher, D. (1990). French translation and validation of Izard's differential emotion scale. Study of the verbal qualification of emotions. *Encephale*, *16*, 453–458.

Porcherot, C., Delplanque, S., Raviot-Derrien, S., Le Calvé, B., Chrea, C., Gaudreau, N., et al. (2010). How do you feel when you smell this? Optimization of a verbal measurement of odor-elicited emotions. *Food Quality and Preference*, *21*, 938–947.

Pössel, P., Ahrens, S., & Hautzinger, M. (2005). Influence of cosmetics on emotional, autonomous, endocrinological, and immune reactions. *International Journal of Cosmetic Science*, *27*, 343–349.

Rétiveau, A. N., Chambers, I. V. E., & Milliken, G. A. (2004). Common and specific effects of fine fragrances on the mood of women. *Journal of Sensory Studies*, *19*, 373–394.

Robin, O., Alaoui-Ismaili, O., Dittmar, A., & Vernet-Maury, E. (1999). Basic emotions evoked by eugenol odor differ according to the dental experience. A neurovegetative analysis. *Chemical Senses*, *243*, 327–335.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*, 1161–1178.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, *110*, 145–172.

Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, *11*, 273–294.

Schaal, B., Rouby, C., Marlier, L., Soussignan, R., Kontar, F., & Tremblay, R. E. (1998). Variabilité et universaux au sein de l'espace perçu des odeurs: Approches inter-culturelles de l'hédonisme olfactif. In R. Dulau & J. R. Pitte (Eds.), *Géographie des odeurs*. Serie "Fondements de la géographie culturelle". Coll. "Géographie et Cultures" (pp. 25–47). Paris, France: L'Harmattan.

Scherer, K. R. (1994). Emotion serves to decouple stimulus and response. In P. Ekman & R. Davidson (Eds.), *The nature of emotion: Fundamental questions* (pp. 127–130). New York, NY: Oxford University Press.

Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information*, *44*, 693–727.

Scherer, K. R. (2009a). Emotion theories and concepts (psychological perspective). In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 145–151). Oxford, UK: Oxford University Press.

Scherer, K. R. (2009b). Feelings (psychological perspectives). In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 183–184). Oxford, UK: Oxford University Press.

Schifferstein, H. N., & Tanudjaja, I. (2004). Visualising fragrances through colours: The mediating role of emotions. *Perception*, *3310*, 1249–1266.

Spangenberg, E. R., Crowley, A. E., & Henderson, P. W. (1996). Improving the store environment: Do olfactory cues affect evaluations and behaviors? *The Journal of Marketing*, *60*, 67–80.

StatSoft, Inc. (2011). *Electronic statistics textbook*. Tulsa, OK: Author. Retrieved from http://www.statsoft.com/textbook/.

Stevenson, R. J. (2010). An initial evaluation of the functions of human olfaction. *Chemical Senses*, *35*, 3–20.

Tomkins, S. S. (1984). Affect theory. In K. R. Scherer & P. Ekman (Eds.), *Approaches to emotion* (pp. 163–196). Hillsdale, NJ: Lawrence Erlbaum Associates.

Vernet-Maury, E., Alaoui-Ismaili, O., Dittmar, A., Delhomme, G., & Chanel, J. (1999). Basic emotions induced by odorants: A new approach based on autonomic pattern results. *Journal of the Autonomic Nervous System*, *75*, 176–183.

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, *58*, 236–244.

Warrenburg, S. (2005). Effects of fragrance on emotions: Moods and physiology. *Chemical Senses*, *30*, i248–i249.

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology*, *76*, 820–838.

Wundt, W. (1909). *Grundriss der psychologie. Achte auflage* [*Outlines of psychology*]. Leipzig, Germany: Engelmann.

Yik, M. S. M., Russell, J. A., & Barrett, L. F. (1999). Structure of self-reported current affect: Integration and beyond. *Journal of Personality and Social Psychology*, *77*, 600–619.

Zentner, M. R., Grandjean, D., & Scherer, K. R. (2008). Emotions evoked by the sound of music: Characterization, classification, and measurement. *Emotion*, *8*, 494–521.