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Relevant psychological dimensions in the perceptual space of perfumery odors

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Abstract

Odor databases are compilations of odor descriptions based on semantic or numeric methods. One of the largest databases of numeric odor profiles was obtained by Boelens and Haring [Boelens, H., & Haring, H. G. (1981). Molecular structure and olfactive quality. Bussum, The Netherlands: Internal Report, Naarden International] from a panel of perfumers. Each panelist smelled 309 compounds and rated the smell similarity to 30 standards. Most of these references were perfume raw materials. Hence, this database contains valuable information to understand the underlying psychological dimensions in the perceptual space of perfumery scents. A principal component analysis was applied to this database. The first principal component (PC1) was interpreted as a dimension of freshness, and the second component (PC2) discriminated feminine versus masculine cosmetic odors. The hedonic dimension did not clearly show up, though different studies have revealed that it is the most salient dimension if a wide range of odors is assessed. The loading plot corresponding to PC1–2 explains 32% of the data variance and provides a low-dimensional representation of olfactory perception space that may lead to the development of meaningful sensory maps for perfumery odors.
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1. Introduction

Odors are usually described by means of semantic methods, assigning the words that come to mind when smelling a substance (Wise, Olsson, & Cain, 2000). These words are called odor character descriptors or odor aspect attributes. Another method consists on rating on a numeric scale the descriptors that best apply to describe the odor character. If these odor profiles are obtained for a set of compounds, the resulting database contains useful information to study the similarities and dissimilarities between odor descriptors. Using semantic methods, two or more descriptors will be similar if they are often applied together to describe the character of a given smell. Using numeric methods, similar descriptors will be those that present a significant positive correlation, and they can be considered as an underlying dimension of odor character.

The application of multivariate statistical methods to numeric odor profile databases might identify correlation structures comprised by descriptors with a different odor character that share some psychological aspect such as pleasantness, intensity, familiarity, edibility, cosmetic acceptability, etc. For clarity purposes, these correlation structures will be referred to hereafter as psychological dimensions of olfactory perception.

Several odor databases publicly available contain semantic odor profiles for a large number of odorant compounds (Arctander, 1969; Sigma–Aldrich, 2003). Different studies have analyzed these data, and odor descriptors were classified in about 20–30 classes (Abe, Kanaya, Komukai, Takahashi, & Sasaki, 1990; Chastrette, Elmouaffek, & Sauvegrain, 1988; Madany-Mamlouk, Chee-Ruiter, Hofmann, & Bower, 2003; Zarzo & Stanton, 2006). However, few of these studies have interpreted the underlying correlation

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structures as psychological dimensions in odor perception. By contrast, reported evidence suggests that the hedonic dimension (i.e. pleasant/unpleasant character) is often the most salient in the statistical analysis of odor databases based on numeric methods (Davis, 1979; Schiffman, Robinson, & Erickson, 1977; Yoshida, 1975).

One of the largest databases of numeric odor profiles was obtained by Boelens and Haring (1981), that will be referred to hereafter as B–H database. A panel of six perfumers smelled 309 chemical compounds and rated the odor similarity to 30 standards on a scale from 0 to 9. Most of these references are raw ingredients to formulate fragrances. Hence, the multivariate statistical analysis of this database might lead to a better understanding of the underlying psychological dimensions in the perceptual space of perfumery scents. This database was analyzed by Ennis, Boelens, Haring, and Bowman (1982) using principal component analysis (PCA) and cluster analysis. The results allowed the classification of compounds into 27 groups, but no interpretation was proposed for the relevant components. The same database was reanalyzed here attempting to provide a meaningful interpretation of the underlying dimensions.

2. Materials and methods

Data from the original publication (Boelens & Haring, 1981) were copied and arranged in a matrix with 309 chemicals by 30 variables (in columns). The elements of this matrix, x_{ij}, represent the similarity of odorant i compared with the odor reference j, according to the panel. Each reference material was selected as a standard for a certain odor descriptor (e.g. lavender oil was chosen for 'lavender', lemon oil for 'lemon', etc.).

In order to determine if pleasantness is a salient dimension of this database, it is necessary to estimate the hedonic tone of the 30 descriptors. For this purpose, the most appropriate procedure would be to take the same reference materials that were used in the original study, and to ask a panel to smell them and score the perceived pleasantness. Unfortunately this information is not available. An alternative procedure would be to use hedonic tones reported in the literature. But taking hedonic judgements obtained in one context and applying them in a different context is unrealistic because they are strongly affected by factors such as age, gender and personal experience. The methodology proposed to overcome this limitation consists of using three series of hedonic tones, each one obtained under a different context. The effect of context could be considered irrelevant if the results are similar in all cases.

Dravnieks, Masurat, and Lamm (1984) asked a panel of about 120 individuals to rate the hedonic tone of 146 odor descriptors on a numeric scale ranging from −4 for the most unpleasant to +4 for the most pleasant. These hedonic tones will be called HT_{D84}. In a subsequent study (Dravnieks, 1985), the same panel was requested to smell 138 pure odorant chemicals and to score each based on the applicability of the 146 descriptors. A recent work has conducted a PCA of this database (Khan et al., 2007), and the first principal component (PC1) was interpreted as the hedonic dimension. Hence, the contributions of variables (i.e. odor character descriptors) in the formation of PC1, that are called $p[1]$ loadings, can be considered as hedonic scores. These $p[1]$ values were obtained conducting a PCA of the Dravnieks' database after discarding the six descriptors with lowest scores. The analysis was carried out using the software SIMCA-P 10.0 (www.umetrics.com). Data were autoscaled (i.e. centered and scaled to unit variance) prior to the analysis, which is a common data pretreatment in PCA. The $p[1]$ loadings were multiplied by 100, resulting a handy scale from about −20 to 20 that will be referred to hereafter as HT_{D85}. The correlation between HT_{D85} and HT_{D84} is statistically significant ($r = 0.75$, p-value < 0.0001), which supports the hypothesis that PC1 of the Dravnieks' database is related to the hedonic dimension.

Hedonic tones HT_{D84} and HT_{D85} were assigned to each odor descriptor of the B–H database once it was paired with the corresponding Dravnieks' descriptor (Table 1). Most of the 30 odor attributes in the B–H database are included in the Dravnieks' list of 146 descriptors (e.g. floral, lavender, honey, etc.). 'Smoky' was paired with 'fresh tobacco smoke', that is not so unpleasant as 'stale tobacco smoke' or 'burnt-smoky'. I applied similar criteria to other B–H attributes with more than one correspondence with

Table 1
Hedonic tone of Dravnieks' descriptors and their correspondence with 24 odor descriptors included in the B–H database (Boelens & Haring, 1981)

B–H descriptor	Dravnieks' descriptor	HT_{D84} [a]	HT_{D85} [b]
Floral	Floral	2.79	14
Citrusy	Fruity, citrus	2.72	8
Minty	Minty, peppermint	2.50	6
Lavender	Lavender	2.25	10
Fruity	Fruity (non-citrus)	2.23	11
Vegetable	Fresh green vegetables	2.19	−2
Green	Herbal, green, cut grass	2.14	9
Honey	Honey	2.08	4
Buttery	Buttery	2.04	−2
Sweet	Sweet	2.03	18
Spicy	Spicy	1.99	7
Aromatic	Aromatic	1.41	16
Anisic	Anise (licorice)	1.21	3
Woody	Woody, resinous	0.94	3
Powdery	Dry, powdery	−0.07	3
Smoky	Fresh tobacco smoke	−0.66	0
Coniferous	Turpentine (pine oil)	−0.73	4
Medicinal	Medicinal	−0.89	2
Metallic	Metallic	−0.94	−6
Erogenic	Seminal, sperm-like	−1.04	−2
Animal	Animal	−1.13	−16
Sourish	Sour, vinegar	−1.26	−16
Fatty	Oily, fatty	−1.41	−13
Earthy	Musty, earthy, moldy	−1.94	−11

[a] Hedonic tone according to Dravnieks et al. (1984).
[b] Hedonic tone obtained from a PCA of the Dravnieks' Atlas, and calculated as $100 \cdot p[1]$.

Table 2
Comparison between reference materials used by Boelens and Haring (1981) and odorant materials used by Moncrieff (1966) to obtain odor preference rankings (PR_M)

Boelens and Haring (1981)		Moncrieff (1966)	
Descriptor	Reference material	Odorant material	PR_M
Lavender	Lavender oil	Lavender oil, English	30.1
Medicinal	Methyl salicylate	Methyl salicylate	71.1
Animal	Civet absolute	Civet, 5% tincture in alcohol	98.5
Erogenic	Ambergris/costus oil	Ambergris, best grey natural	75.1
Sweet	Heliotropin	Heliotropin cryst. (piperonal)	53.6
Aromatic	Vanillin	Vanillin 100%	43.3
Spicy	Eugenol	Eugenol	49.2
Dusty	Patchouli oil	Patchouli oil Singapore	71.2
Smoky	Cade oil	Cade oil	88.6
Metallic	Bay oil	Bay leaf, dried	41.6
Citrusy	Lemon oil	Lemon flavoring essence	28.9
Minty	Peppermint oil	Peppermint flavoring essence	26.9
Powdery	Musk ketone/ coumarin	Musk ambrette/tonka beans	47.8[a]
Floral	Jasmine absolute	Rose absolute, attar	37.6
Fruity	Hexadecanal	Amyl butyrate[b]	50.6

[a] Average value of 43 (musk ambrette) and 52.6 (tonka beans). The latter smells like coumarin (Poucher, 1974).
[b] Odor description: strong, penetrating, banana, pineapple, fruity (Sigma–Aldrich, 2003).

Dravnieks' descriptors. Six attributes of the B–H database were discarded because there are no similar terms in the Dravnieks' list.

Hedonic tones were also estimated from preference rankings for odors reported by Moncrieff (1966). A panel of 12 individuals smelled 132 odorant materials and arranged them in order of preference. Each panelist assigned a preference ranking for each odorant (1 for the most liked, 2 for the next most liked, and so on). Next, the rankings were averaged for each odorant. If the list of materials used by Moncrieff (1966) is compared with the reference materials used by Boelens and Haring (1981), it results a subset of 15 odorants in common or at least with a direct correspondence (Table 2). The preference ranking of these materials (PR_M) can be used as an indirect estimation of the hedonic tone.

Next, the B–H database was analyzed with PCA using the software SIMCA-P 10.0. Data were autoscaled prior to the analysis. Attempting to determine if pleasantness is a salient dimension of this database, a linear regression was conducted between the hedonic tones (HT_{D84}, HT_{D85} and PR_M) and the loadings in the formation of the relevant PCs, up to PC5.

Taking into account the descriptors with highest contributions in PC1, this component was interpreted as a psychological dimension in the perception space of perfumery odors. The loading plot corresponding to PC1 and PC2 can be regarded as some sort of odor map for perfumery scents, and it was compared with the classification of commercial fragrances proposed by Glöss (1991). The results led to a meaningful interpretation of PC2.

3. Results and discussion

3.1. Searching for the hedonic dimension

Principal components are directions of maximum data variance obtained as linear combinations of the original variables. One criterion commonly applied in PCA is to focus the attention on those PCs with an eigenvalue greater than 1. Conducting a PCA with the B–H database, this condition is satisfied by PC1 and further components up to PC9 (Table 3). Another criterion is based on the goodness-of-fit by cross-validation (Q^2). Generally speaking, if this parameter is positive for a given component, it is supposed to provide relevant information (Krzanowski, 1987). Nonetheless, the software SIMCA-P 10.0 is more restrictive and considers in this case that the cross-validation criterion is satisfied by those components with $Q^2 > 0.035$. Only PC1 and PC2 comply with this condition (Table 3), but PC3 and PC4 are close to this threshold value. The descriptors 'aldehyde' and 'fatty' present the highest contributions in PC3, suggesting certain odor similarity. Interestingly, decanal was the selected reference for 'aldehyde', and this compound smells somewhat fatty (Poucher, 1974). PC4 is basically determined by 'minty' and 'coniferous', that share certain camphoraceous note (Abe et al., 1990). The Q^2 of PC5 is negative, and hence further PCs were not considered in Table 3.

Table 3
Summary overview of the five principal components obtained from the Boelens–Haring database: variance explained (R^2_X), eigenvalues and variance explained by cross-validation (Q^2)

PCA summary overview of the Boelens–Haring database				Correlation between loadings and hedonic tones					
				HT_{D84}		HT_{D85}		PR_M	
PC	R^2_X	Eigenv.	Q^2	r	p-value	r	p-value	r	p-value
1	0.175	5.25	0.102	0.04	0.846	−0.27	0.208	−0.48	0.067
2	0.142	4.26	0.106	0.40	0.051	0.37	0.071	−0.35	0.201
3	0.084	2.53	0.030	0.50	0.012	0.43	0.033	−0.43	0.109
4	0.066	1.98	0.011	0.12	0.573	0.15	0.478	−0.23	0.399
5	0.058	1.73	−0.030	0.17	0.414	0.02	0.933	−0.02	0.939

Data were autoscaled prior to the PCA. Correlation coefficient (r) and p-value of a simple regression conducted between p[i] (loadings in the formation of the ith PC) versus the hedonic tones HT_{D84}, HT_{D85} (Table 1) and the preference ratings PR_M (Table 2).

After calculating the loadings for PC5 and previous components, a multiple linear regression was conducted to determine if HT_{D84} could be predicted as a function of $p[1]$ and $p[1]^2$. The same analysis was repeated for $p[2]$ and so on up to $p[5]$. In all cases the effect of the quadratic term was not statistically significant (p-value > 0.1), and it was discarded from all models. The results of the simple regressions are shown in Table 3. Only a moderate correlation was obtained for PC2 ($r = 0.40$, p-value = 0.051) and for PC3 ($r = 0.50$, p-value = 0.012), as shown in Table 3. The same analysis was carried out using HT_{D85} instead of HT_{D84} and similar results were obtained, though with a slightly lower correlation. However, if this study is conducted with PR_M (Table 2), the highest correlation corresponds to PC1, though it is not statistically significant (p-value = 0.067) (Table 3). As in the previous case, none of the quadratic effects in the prediction of HT_{D85} and PR_M were statistically significant.

The moderate correlation between the three series of hedonic tones and the loadings suggests that neither PC1 nor PC2 are clearly related with the hedonic dimension. Anyway, these results are not conclusive due to the uncertainty in the estimation of hedonic tones unless further evidence is found to support a different interpretation other than pleasantness for PC1 and PC2.

3.2. Interpretation of the first principal component

The fragrance wheel proposed by Edwards (2006) classifies fragrances in five standard families: floral, oriental, woody, fougère, and fresh. The fresh family is subdivided in three categories: citrus, green, and water. Interestingly, fresh is the descriptor with highest loadings in PC1, and it is located close to 'citrusy', 'green' and 'watery' (Fig. 1). These descriptors represent a different odor character but share a fresh note. Therefore, PC1 can be interpreted as a dimension of freshness. This is a psychological aspect of odor perception that could be rated by a panel as it is the case for pleasantness or intensity (Moskowitz, 1979).

It might be argued that freshness should be considered as a qualitative dimension of odor character instead of a psychological dimension. The former applies to odors sharing certain similarity that recall some natural source. For example, a given smell is described as floral if it recalls the smell of flowers, and hence floral is a dimension of odor character. But it is uncertain what natural odor source is evoked by fresh scents, and therefore it seems more convenient to regard freshness as a psychological dimension of odor perception. Bain (1855) proposed a classification of odors based on eight categories, and one of them was 'fresh'. This author defined fresh odors as those tending to increase the activity of the lungs, such as the balmy odors of the field and garden, and the perfume eau-de-cologne. Additional studies will be necessary to further understand the nature and role of this perceptual aspect.

3.3. Interpretation of the second principal component

The loading plot for PC1–2 (Fig. 1) can be considered as a sensory map for perfumery scents because the B–H database was obtained in the context of perfumery. Moreover, PC1 and PC2 account for 32% of the total data variance (Table 3). Hence, it is expected to find certain correspondence between this loading plot and the classification of perfumes. The H&R Fragrance Guide (Glöss, 1991) classifies commercial feminine and masculine fragrances according to odor character (Table 4). Regarding feminine

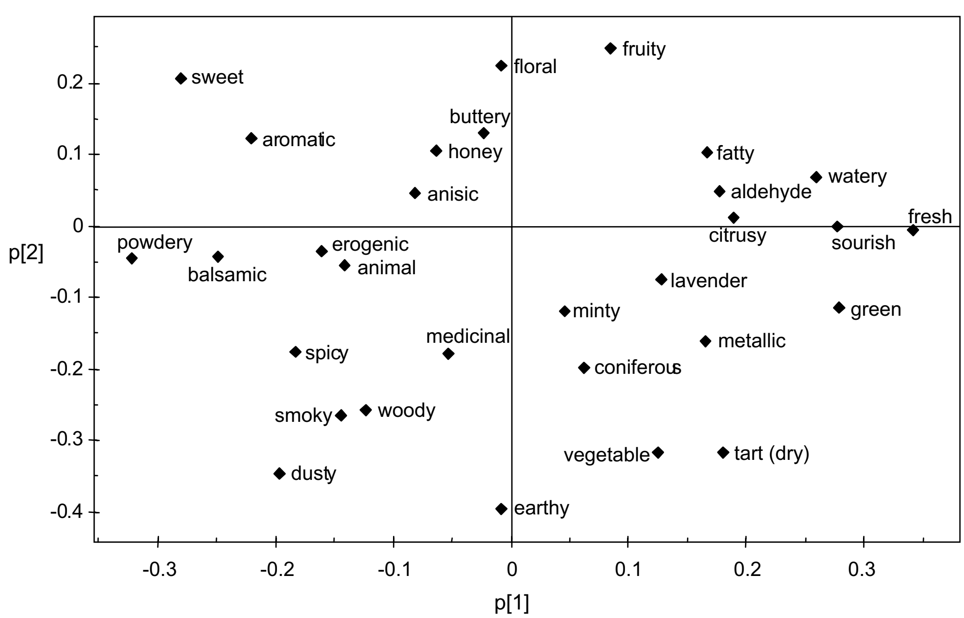

Fig. 1. Loading plot ($p[2]$ vs. $p[1]$) for the first and second principal components corresponding to the database obtained by Boelens and Haring (1981). Data were centered and scaled to unit variance prior to the analysis.

Table 4
Classification of perfumes in the H&R Fragrance Guide (Glöss, 1991)

Feminine fragrances			Masculine fragrances		
Class	Variation	N[a]	Class	Variation	N[a]
Floral	Green	20	Lavender	Fresh	7
Floral	Fruity	20	Lavender	Spicy	8
Floral	Fresh	32	Fougère	Fresh	59
Floral	Floral	85	Fougère	Floral	24
Floral	Aldehydic	71	Fougère	Woody	22
Floral	Ambery	43	Fougère	Ambery	8
Oriental	Ambery	37	Oriental	Ambery	23
Oriental	Spicy	23	Oriental	Spicy	21
Chypre	Fruity	14	Chypre	Woody	28
Chypre	Floral–animalic	39	Chypre	Leathery	59
Chypre	Floral	36	Chypre	Coniferous	17
Chypre	Fresh	9	Chypre	Fresh	13
Chypre	Green	10	Chypre	Green	14
			Citrus	Floral	7
			Citrus	Fantasy	27
			Citrus	Fresh	10
			Citrus	Green	6
(Intermediate)[b]		14	(Intermediate)[b]		14
TOTAL		453	TOTAL		367

[a] Number of perfumes that appear under each class and variation.
[b] Perfumes classified as intermediate of two categories or subcategories.

fragrances, 60% of them appear under the floral category. By contrast, only 8% of masculine fragrances are listed under a floral subcategory of fougère or citrus. The preference of women for floral scents was also reported by a smell survey conducted at a large scale. The survey included the question: 'Would you apply something that smelled like this to your body?'. Rose was perceived as a pleasant odor by males and females (Wysocki & Gilbert, 1989). However, the percentage of females willing to wear the rose odor was about 70% (averaged for the different ages), but it resulted about 45% in the case of males (Wysocki & Pelchat, 1993). Interestingly, floral is one of the descriptors with highest loadings in PC2 (Fig. 1), which might indicate that this component could discriminate men's versus women's fragrances.

In order to further investigate this hypothesis, the following study was conducted. Floral is a class of feminine fragrances, and 'green' appears as a variation. The floral–green subcategory was located in the loading plot in the middle position between 'floral' and 'green' (Fig. 2) by computing the average coordinate of both descriptors on PC1 and PC2 (Eq. (1)). The same criterion was applied to the rest of subcategories, which leads to a map of perfume categories based on the dimensions defined by PC1 and PC2.

$$
\begin{aligned}
p[1]_{\text{floral–green}} &= 0.5 \cdot p[1]_{\text{floral}} + 0.5 \cdot p[1]_{\text{green}} \\
p[2]_{\text{floral–green}} &= 0.5 \cdot p[2]_{\text{floral}} + 0.5 \cdot p[2]_{\text{green}}
\end{aligned} \tag{1}
$$

According to the H&R Fragrance Guide, the oriental category evokes associations with the legendary fragrances of the Orient, as represented by the sweet balsams and resins of Arabia and precious spices from India (Glöss, 1991). Based on this association between balsamic and oriental scents, the position of the oriental–spicy subcategory was calculated by averaging the coordinates of 'balsamic' and 'spicy'. 'Ambery' applies to those odors resembling ambergris. Boelens and Haring (1981) selected a mixture of ambergris/costus oil as a reference for 'erogenic', and hence the subcategory oriental–ambery was located in a position intermediate of 'balsamic' and 'erogenic'.

The chypre concept is characterized by the contrast between a fresh citrus accord and oakmoss, being bergamot oil the preferred citrus component (Glöss, 1991). In the B–H study, bergamot oil and mousse de chêne resinoid (the French name for oakmoss) were the reference materials for 'fresh' and 'earthy', respectively. Therefore, the position of the chypre category was obtained by averaging the coordinates of 'fresh' and 'earthy'. According to Glöss (1991), the leathery variation of chypre represents a dry–smoky interpretation of the chypre concept. Therefore, the subcategory chypre–leathery was located between 'chypre' and 'smoky'. The position of chypre–floral/animalic was obtained by averaging the coordinates of 'chypre', 'floral' and 'animal'. The location of citrus–fantasy is uncertain and it was disregarded.

The fougère fragrance concept is based upon the interplay between lavender, oakmoss and coumarin (Glöss, 1991). Coumarin smells sweet-herbaceous, like freshly cut hay (Poucher, 1974). In the B–H study, the reference material for 'vegetable' was described as herbal, sweet and hay. Considering that coumarin can be associated with 'vegetable', the position of fougère was calculated by averaging the coordinates of 'lavender', 'earthy' and 'vegetable'.

Remarkably, most feminine subcategories appear with positive loadings in PC2, and the opposite applies to men's

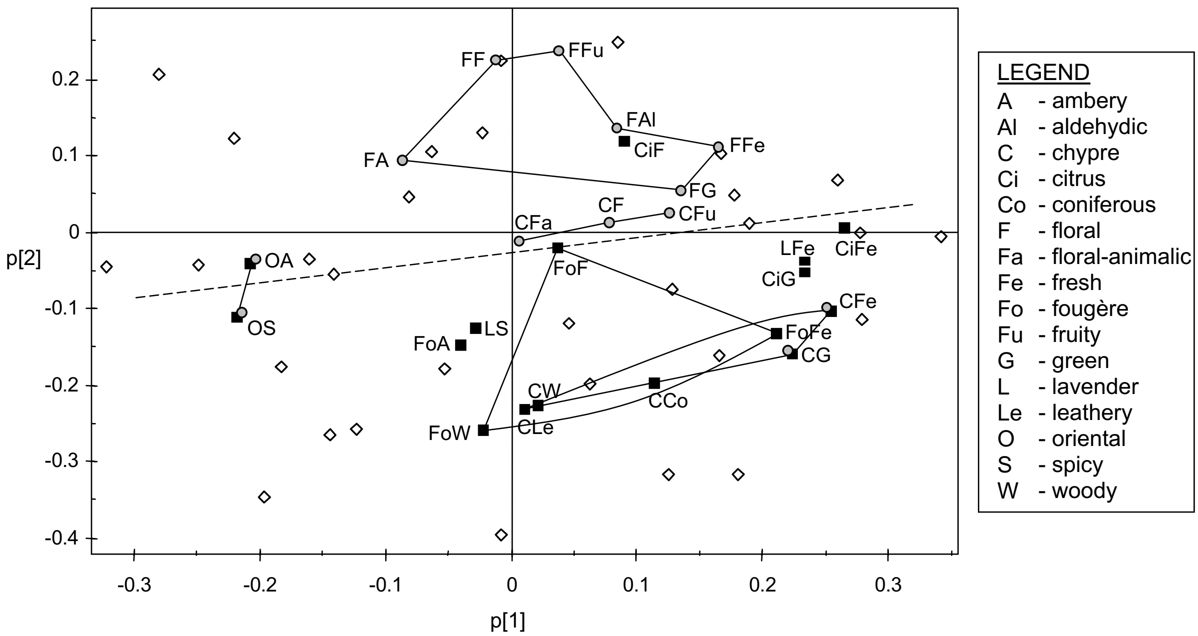

Fig. 2. Correspondence between the loading plot ($p[2]$ vs. $p[1]$) of the Boelens–Haring database (Fig. 1) and the subcategories for feminine perfumes (circles in gray) and masculine fragrances (black squares) proposed by the H&R Fragrance Guide (Glöss, 1991). Citrus–fresh (labeled as CiFe according to the legend) was located in a position intermediate of the descriptors citrus and fresh, and similarly for the rest of subcategories. Empty diamonds correspond to the odor descriptors (see Fig. 1 for labels). The most representative men's and women's subcategories (with $N > 10$ according to Table 4) are joined with solid lines.

subcategories. The dashed line drawn in Fig. 2 seems a better boundary between feminine and masculine fragrances, because it crosses the mid point of the two oriental subcategories, that comprise feminine and masculine fragrances (Table 4). Moreover, chypre–floral/animalic and citrus–fresh are correctly classified according to the dashed line, but not according to the horizontal axis corresponding to $p[2] = 0$. This boundary line crosses the fougère-floral subcategory which is intuitively appealing because fougère and floral are the main categories of masculine and feminine fragrances, respectively.

These results confirm a direct correspondence between the loading plot for PC1–2 and the olfactory perception space of perfumery scents, and provide a strong evidence for the interpretation of PC2 as a psychological dimension that discriminates feminine versus masculine cosmetic odors. The B–H database was obtained from a panel of perfumers, and their expertise is probably too heavily imprinted in the resulting perceptual space. It is uncertain if a similar interpretation for the relevant components would have been obtained with a panel of naive subjects.

Flowers are associated with femininity in most cultures, which might explain why floral is the main category of feminine fragrances. Another hypothesis is based on the fact that 'floral' yields the highest correlation with 'sweet'. The similarity between both descriptors, that appear with high loadings in PC2 (Fig. 1), suggests an association between women's fragrances and sweet odors. In the context of perfumery, sweet and dry are opposite concepts. According to Müller (1992), feminine perfumes present floral accents. Conversely, masculine fragrances are generally less floral and contain dry notes of leather, tobacco, herbs, spices, mosses and woods. Fig. 1 suggests that sweet odors are characterized by $p[1] < 0$ and $p[2] > 0$, and hence the opposite would basically apply for dry notes. Interestingly, most masculine subcategories of fragrances appear with $p[1] > 0$ and $p[2] < 0$.

Some smells, when sniffed, are described in terms of taste qualities as a result of frequent co-occurrence with particular tastes, for example in foods (e.g. the sweet smell of honey and the sour smell of vinegar). This associative explanation has been supported by the results of a series of experiments (see Prescott, Johnstone, & Francis, 2004). A similar interpretation applies for fragrances. Kirk-Smith and Booth (1987) suggested that a fragrant scent can acquire subtle meaning through learned associations if it is experienced in a meaningful situation. Therefore, the perceived odor may evoke recognition of the source as well as any thing, place, people, or effect that might be associated with it. However, the psychological association between sweet scents and femininity is not well understood yet and will require further research.

4. Practical outcomes

PC1 and PC2 were interpreted as meaningful psychological dimensions in the perceptual space of perfumery odors. These results are of relevant interest for consumer research. In order to determine if a new fragrance should be targeted to male or female consumers, the following procedure could be applied. The fragrance should be assessed by a panel of experts as described by Boelens and Haring

(1981). The resulting data would become a new row of the B–H matrix. This new observation can be projected over PC2. A positive score in PC2 would indicate a fragrance likely to be perceived as feminine, and the opposite applies for negative scores. The advantages of mapping odors to better understand consumer preference have been discussed by Nute, Macfie, and Greenhoff (1988).

Another practical outcome of the present study concerns the development of sensory maps for perfumery scents. The idea is not new given that different two-dimensional odor representations have been derived from the statistical analysis of comprehensive odor profile databases (Abe et al., 1990; Chastrette, de Saint Laumer, & Sauvegrain, 1991; Jaubert, Tapiero, & Doré, 1995; Madany-Mamlouk et al., 2003). However, none of them provides a meaningful interpretation for the two dimensions that build up the odor map. In the context of perfumery, some authors have represented odor descriptors around a central point resembling the radii of a wheel, which is usually called 'odor wheel' (Aftelier, 2006; Edwards, 2006; Harder, 1979). These sensory maps were basically derived from the experience of perfumers. Work in progress is attempting to compare the loading plot for PC1–2 with these odor maps in order to determine which one better reflects the underlying dimensions in the perception of perfumery odors. The results might lead to the development of standard sensory maps for cosmetic scents based on psychological dimensions of odor perception.

Describing scents with the aid of odor maps becomes easier. Odor classes next to each other are supposed to be similar, while those located in opposite positions represent dissimilar smells. Therefore, sensory maps for perfumery scents are valuable tools for fragrance classification, for the training of sensory panels as well as for providing certain standards of communication among perfumers. Moreover, they might become handy tools in perfume stores. Due to the large variety available in the market, choosing a perfume to buy is not easy because, obviously, it is not possible to smell them all. Sensory maps will allow a better communication between the salesperson and the customer. Understanding the different categories of fragrances and the relationships between them will guide the process of selecting the right fragrance for each customer. A sensory map resembling Fig. 2 might become particularly useful for this purpose given that it reflects the classification of perfumes as men's versus women's.

It might be argued that the loading plot for PC1–2 only explains 32% of the data variance and hence it would be useful to understand what is left in the remaining 68%. PC3 and PC4 account for 15% of the variance and, as discussed above, they reflect certain similarity between particular odor descriptors that seems to be related with some common note shared by their respective reference materials. PC5 and further components do not satisfy the cross-validation criterion ($Q^2 < 0$) suggesting that about 50% of the total data variance cannot be explained by relevant correlation structures among variables. This result was not unexpected because the reference materials in the B–H database were chosen to account for rather independent odor descriptors.

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