

Smell and Taste Classification of the Same Stimuli

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ABSTRACT. Although it has long been known that the perception of flavor depends on olfactory sensations originating within the mouth (i.e., retronasal perception), little is known about how olfactory input is integrated in the flavor complex. In the present study, the qualitative contribution of odor to flavor was explored. Participants judged the smell and taste of pairs of substances (liqueurs). Each set of judgments was analyzed by means of multidimensional scaling, and the scalings were then statistically compared. The results revealed specific perceptual dimensions, namely, *sweet-sour*; *harsh-mellow*, which underlie both sensory modalities. In contrast to previous findings, the results show that the characteristics of flavor reflect olfactory attributes that can be apprehended outside the mouth.

WHAT IS COMMONLY REFERRED TO AS TASTE is really a complex sensation that includes information about odor, temperature, texture, and consistency, in addition to information received from the specific receptors for taste—the taste buds (Bartoshuk & Beauchamp, 1994). This complex sensation is more properly called *flavor* (see Rozin, 1982). The olfactory contribution to flavor is particularly important. Although psychologists have long recognized that the distinctive characteristics of flavor reflect olfactory sensations stimulated from within the mouth (Külpe, 1901), the contribution of these retronasal sensations to the flavor complex is not fully understood.

Vanderklaauw and Frank (in press) recently demonstrated that odorants can enhance taste. Studies such as those by Gillan (1983) and Hornung and Enns (1986) have shown how smell and taste are integrated to produce an overall sen-

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sation of flavor intensity. However, little is known about how the qualitative aspects of taste and olfaction are represented in the flavor complex.

Our purpose in the present study was to explore the qualitative contribution of olfaction to flavor. Two studies have addressed this issue. Rozin (1982) argued that olfaction is "the only dual sensory modality, in that it senses both objects in the external world and objects in the body (mouth)" (p. 397). He based this argument on the fact that participants, after having learned to identify an external odor, had difficulty identifying the flavor of the same odorant. More recently, however, Rankin and Marks (1994) showed that the odorants vanillin and orange each provided similar experiences when presented orthonasally and retronasally.

Our experiment was conducted to help resolve this discrepancy. The approach was straightforward: Participants judged the smell and the taste of pairs of substances. Each set of judgments was analyzed by means of multidimensional scaling (MDS), and the scalings were then statistically compared. Note that MDS is a class of statistical techniques that uses a matrix of proximities among stimuli as input and produces an N -dimensional configuration or map of the stimuli as output. The configuration is derived in such a way that the distances in the configuration match the original proximity measures as closely as possible. More important, the locations of particular clusters of stimuli are said to reflect whatever dimensions might underlie the proximity measures. Other examples of the use of MDS to investigate gustation and olfaction include Doving (1970); Jones, Roberts, and Holman, (1978); Rankin and Marks (1994); Schiffman and Dackis, (1975); Schiffman and Engelhard, (1976); and Schiffman, Robinson, and Erickson, (1977).

Method

Participants

Four males and four females, whose ages ranged from 26 to 47, volunteered to serve as participants for the study. The participants were acquaintances of the first author. No incentives were offered for participation.

Stimuli

The stimuli consisted of 13 commercially available liqueurs, which were chosen because they are both strongly flavored and aromatic. The liqueurs were selected for their range of sensory attributes. They included *Creme de Cacao*, *Amaretto*, *B & B*, *Drambuie*, *Citro*, *Nocello*, *Grand Marnier*, *Cointreau*, *Strega*, *Galliano*, *Kahlua*, *Tia Maria*, and *Kummel*. The liqueurs represented a variety of flavoring agents (herbs, fruits, spices), bases (rum, brandy, neutral spirits), and alcohol content (24% to 43%; see Table 1.)

For smell (orthonasal) judgments, 2-mL samples of each liqueur were placed

TABLE 1
Flavoring Agents, Bases, and Alcohol Content (Proof) for the 13 Liqueurs
Chosen as Stimuli

Liqueur	Flavoring agent	Base	Alcohol content (proof)
Creme de Cacao	Cacao and vanilla beans	Neutral spirits	60
Amaretto	Apricot stones	Neutral spirits	56
B & B	Herbs and plants	Brandy	86
Drambuie	Herbs and honey	Scotch	80
Citro	Lemons	Neutral spirits	80
Nocello	Walnuts	Neutral spirits	48
Grand Marnier	Oranges	Brandy	80
Cointreau	Oranges	Neutral spirits	80
Strega	Herbs	Neutral spirits	80
Galliano	Herbs	Neutral spirits	80
Kahlua	Coffee	Neutral spirits	53
Tia Maria	Coffee	Rum	53
Getreide-Kummel	Caraway seeds	Neutral spirits	80

in 60-mL wide-mouth bottles. For flavor judgments, 1-mL samples were placed in plastic syringes.

Procedure

The experiment included two sessions lasting approximately 2 hr, including a 15-min rest between sessions. During the smell session, participants judged the stimuli using only orthonasal input; in the taste session, the same stimuli were judged on the basis of flavor (thereby allowing for retronasal stimulation). The order of sessions was counterbalanced over participants. During each session, participants made all possible pairwise comparisons of the 13 stimuli (78 comparisons), presented in random order and without benefit of visual cues.

For the smell session, the first paired liqueur was sniffed for approximately 5 s, followed, after about 5 s, by the second liqueur. After sampling each pair, the participants indicated the degree of dissimilarity by marking a 127-mm graphic scale anchored with the descriptions *exact same* and *completely different*. Following the pairwise comparisons, each liqueur was judged singly on a series of 16 adjective scales (see Appendix).

For the taste session, participants pinched their nostrils closed while injecting the first paired liqueur into the mouth, unpinched their nostrils, then tasted the liqueur for approximately 5 s. After expectorating the liqueur and rinsing their mouth with distilled water, they sampled the second liqueur for approximately 5 s, then rinsed a second time. Pairwise comparisons and adjective judgments were indicated in the same manner as for the smell session.

TABLE 2
MDS Coordinates for Olfactory and Flavor Configurations

Liqueur	Olfaction			Flavor	
	Dim 1	Dim 2	Dim 3	Dim 1	Dim 2
Cacao	-0.98	-0.81	-0.87	1.28	0.12
Amaretto	0.88	-1.67	0.19	1.22	-0.89
B & B	0.11	1.08	-1.11	-1.03	0.09
Drambuie	-0.09	1.09	-1.19	-1.08	0.41
Citro	1.22	0.55	1.19	-0.50	-1.96
Nocello	-1.34	-0.68	1.28	1.46	0.42
G. Marnier	0.61	1.10	-1.11	-1.06	-0.42
Cointreau	1.61	-0.39	-0.56	-0.15	-1.22
Strega	0.41	1.39	1.25	-1.26	-0.08
Galliano	0.66	-1.45	0.03	0.86	-0.56
Kahlua	-1.46	-0.49	-0.92	0.98	1.51
Tia Maria	-1.50	-0.49	0.26	0.19	1.74
Kummel	-0.14	0.87	1.58	-0.90	0.84

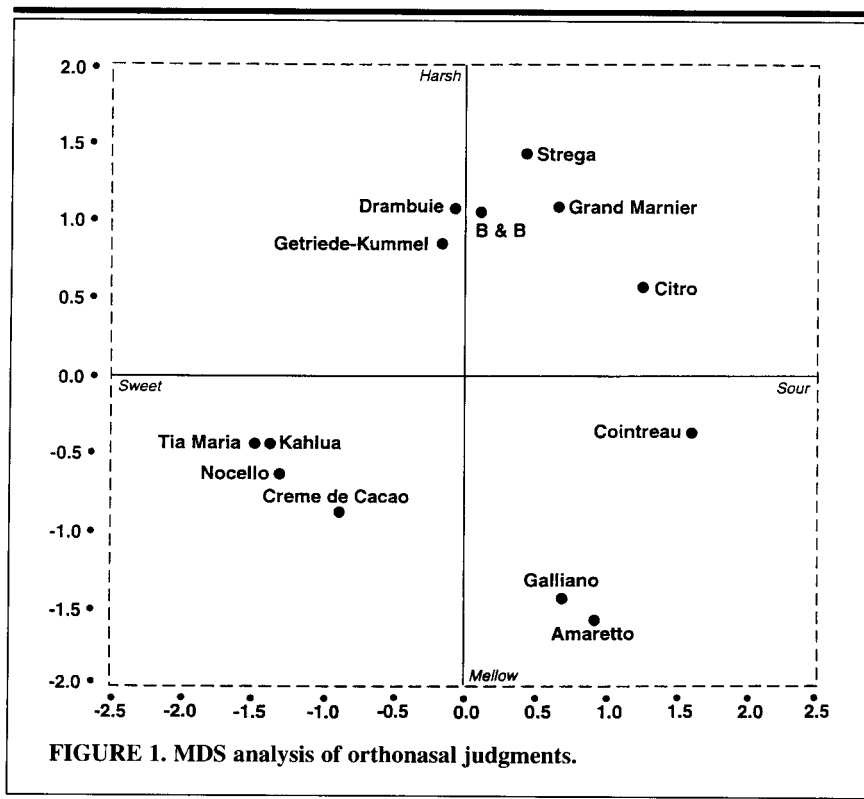
Results

Comparison data were obtained by measuring the location of participants' marks on the 127-mm graphic scale. This yielded ratings that could range from 0, *exact same*, to 127, *completely different*. The SPSS-X (1986) procedure ALSCAL was used to compute separate MDS analyses of the comparison data obtained from the olfactory and flavor sessions, respectively. A weighted-individual differences Euclidean distance model (INDSCAL) was invoked as the scaling model for the analyses.

For the olfactory data, a three-dimensional solution accounted for 44% of the variability in the optimally transformed input matrices; for the flavor data, a three-dimensional solution accounted for 38% of the variability. The respective two-dimensional solutions both accounted for 37%. These results suggest that, whereas a three-dimensional representation may be appropriate for the olfactory data, it is probably superfluous for the flavor data. The coordinates for each configuration are shown in Table 2.

The derived configurations, projected in two dimensions, are shown in Figures 1 and 2. The flavor configuration (Figure 2) was rotated to an orientation comparable to that of Figure 1. The particular rotation (90° about the *z*-axis and 180° about the *x*-axis) in no way affects the relative location of the points within the configuration; it was chosen merely to facilitate comparison of the two figures (see Freeman, 1986, pp. 3-21).

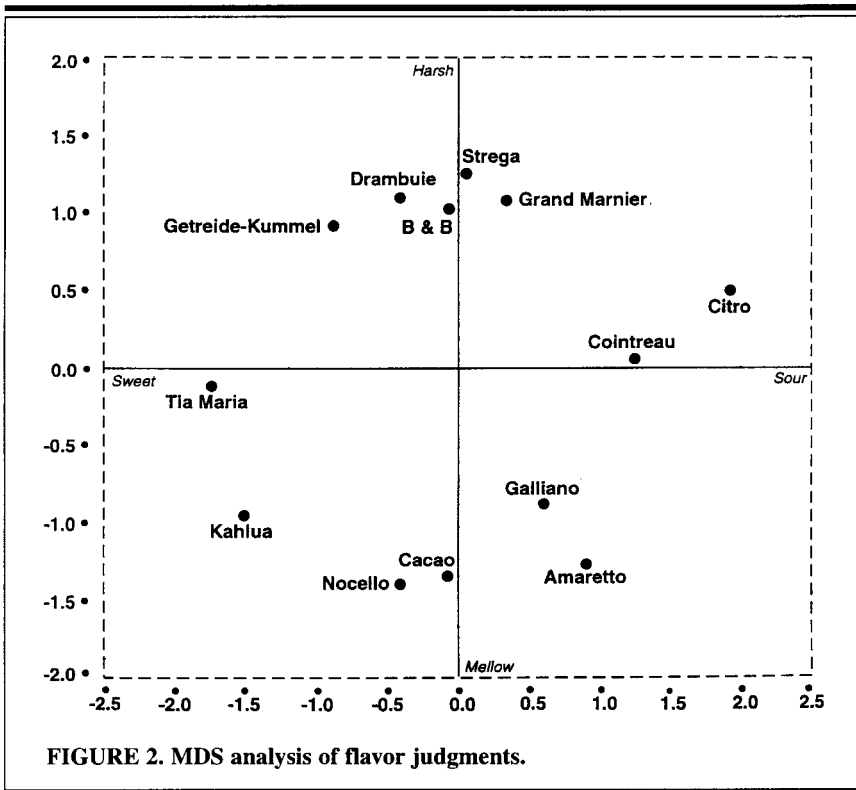
The configurations are strikingly similar. This was statistically verified in two ways. First, a matrix of interpoint distances was computed for each config-



uration, and these distances were then intercorrelated (cf. Doving, 1970; Dumont, 1989). A high degree of correspondence was evident, $r(76) = +.80$, $p < .001$. Second, each set of olfactory coordinate values (Dimensions 1, 2, and 3) were regressed, separately and in turn, on the coordinates of the flavor configuration. For Dimensions 1 and 2, the multiple R exceeded .93 ($df = 10$, $p < .001$); for Dimension 3 it was only .10.

The solutions were interpreted using a standard procedure, which has been discussed and illustrated by Kruskal and Wish (1978, pp. 35-43). Participants rated the smell and taste of each stimulus on 16 adjective scales. These data were aggregated to yield 16 sets of mean stimulus ratings for smell and 16 for taste. Each set was regressed, in turn, on the corresponding multidimensional coordinate values. A scale was considered to be an appropriate label for a particular dimension if the obtained multiple R was high (exceeding .85) and the scale had a high regression weight on the dimension.

The results indicated that two principal dimensions appeared to underlie both the flavor and olfactory judgments. One dimension, *sweet-sour*, contrasts sweet liqueurs, such as Kahlua and Tia Maria, with sour, fruity ones, such as Citro and



Cointreau. A second dimension, *harsh-mellow*, contrasts intense alcoholic liqueurs, such as Strega and Drambuie, with milder ones, such as Nocello and Creme de Cacao. Although none of the adjective scales provided an appropriate label for the third olfactory dimension, it appears that this dimension contrasts liqueurs based on flavored spirits (e.g., Drambuie, Grand Marnier) with those based on neutral spirits (e.g., Kummel, Nocello).

Discussion

The results of this experiment support the long-held presumption that flavor receives its distinctive qualities from olfaction; but, more important, the results reveal two additional aspects of the flavor-olfaction relationship. The first is that specific perceptual dimensions—namely, sweet-sour and harsh-mellow—underlie both sensory modalities. The sweet-sour dimension is purely qualitative, whereas the harsh-mellow dimension likely reflects stimulation of the trigeminal system or, as it is also known, the common chemical sense (see Silver, 1987). It would be interesting to compare these results with those obtained from a sim-

ilar experiment using nonalcoholic stimuli, for which trigeminal stimulation would be less intense.

The second aspect of the flavor–olfaction relationship revealed by these results is that the characteristics of flavor reflect olfactory attributes that can be apprehended *outside the mouth*. This result supports the findings of Rankin and Marks (1994), but it is inconsistent with Rozin's (1982) conclusion that "the olfactory component of flavor differs markedly from the olfactory consequences of the same substance in the external world" (p. 400).

One explanation of this inconsistency, which was considered by Rozin (1982), is that the olfactory component in flavor may lose its identity when combined with the purely gustatory and cutaneous inputs that are also present. Our results suggest that this olfactory component is not qualitatively different from olfactory inputs from outside the mouth. It may be that the olfactory component in flavor is attenuated by the other inputs. This interpretation is supported by Hornung and Enns's (1986) finding that the judged intensity of a flavor is, on average, only about 70% of the sum of the judged intensities of the individual gustatory and olfactory components constituting the flavor.

A final consideration is the presence of an additional perceptual dimension (flavored spirit base–neutral spirit base) underlying the olfactory reactions. The basis for this finding is uncertain, but one possibility is that it reflects a difference in complexity between the two sensory systems. Indeed, whereas there is general agreement that only about four primary taste qualities underlie gustation, there may be hundreds of primary odors comprising olfaction (see Lancet & Ben-Arie, 1993).

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APPENDIX

Adjective Scales for Rating Liqueurs

Sweet—Not sweet	Woody—Not woody
Sour—Not sour	Burnt—Not burnt
Bitter—Not bitter	Caramel—Not caramel
Fruity—Not fruity	Intense—Not intense
Spicy—Not spicy	Harsh—Not harsh
Floral—Not floral	Pleasant—Not pleasant
Nutty—Not nutty	Good—Bad
Herbal—Not herbal	Familiar—Not familiar

Note. The adjective scales were anchored graphic scales like those used to make the pairwise comparisons.

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