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Odor, taste, and flavor perception of some flavoring agents

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Abstract

Psychophysical functions for the odor, taste, and flavor of five common flavorings were obtained by the method of magnitude estimation. The stimuli included three simple compounds (vanillin, piperonal, and benzaldehyde) and two complex ones (natural vanilla extract and artificial almond essence). The odor intensity of all the flavorings grew much less rapidly with concentration than did taste intensity. The growth of flavor for the complex substances and piperonal behaved very much like taste. For vanillin and benzaldehyde, the flavor functions resembled taste functions at high concentrations but showed a tendency to flatten at lower concentrations. These findings implied that, at least for some flavorings, the growth of flavor reflects the most salient feature on the particular concentration range studied. At low concentrations odor seems to be the most important feature and so flavor functions are generally flat, but at high concentrations taste becomes the salient feature and so flavor functions steepen.

Key words: almond odor, benzaldehyde, flavor, flavorings, odor, olfaction, piperonal, taste, vanilla, vanillin

Introduction

Food and food additives have various sensory attributes including odor, taste, pungency, texture, and temperature. For many foods, odor and taste are the most salient attributes. Interestingly, the modalities of olfaction and taste are characterized by different stimulus-response (psychophysical) functions. Functions for odor intensity typically are relatively flat (Cain, 1969). That is, it commonly takes a large change in concentration to produce a substantial change in odor intensity. Functions for taste intensity are relatively steep, especially when the stimulus is sipped (Meiselman, 1971; Bartoshuk, *et al,* 1977). Hence, a tenfold change in the concentration of a stimulus will generally cause at least a fourfold change in taste magnitude, but perhaps only a twofold change in odor magnitude.

The present research explores the difference in rate of growth of sensory magnitude for five substances that stimulate both olfaction and taste. One question of interest is whether the change in the flavor (as total sensory attribute) of these substances reflects primarily stimulation of taste or stimulation of olfaction.

The study deals with the perception of three aromatic aldehydes and two other complex flavorings. Small but significant changes made in the aldehyde's structure produce three quite distinguishable odors: vanillin with a vanilla fragrance; piperonal with a heliotrope fragrance; and benzaldehyde with an odor of almonds. The complex flavorings comprised a natural one, natural vanilla extract, and an artificial one, artificial almond essence, with organoleptic qualities similar to vanillin and benzaldehyde, respectively. The paper shows the growth of sensation of odor, taste (nostrils stopped up), and flavor (nostrils free) of all five substances.

Materials

Vanillin (4-hydroxy-3-methoxybenzaldehyde), piperonal (3,4 methylenedioxy-benzaldehyde) and benzaldehyde (Figure 1), kindly furnished by Sabores y Fragancias S.A., complied with the specifications of the U.S. Food Chemical Codex for purity. Natural vanilla extract, also provided by Sabores y Fragancias S.A., complied with the specifications of the U.S. Food and Drug Administration. Firmenich S.A. furnished the artificial almond essence.

The diluents used were: (a) odorless diethyl phthalate for the experiments on the odor of simple compounds (obtained from Kay-Fries Chemicals, Inc.), and (b) deionized and distilled water for the experiments on the odor of the complex substances (natural vanilla extract and artificial almond essence) and the experiments on flavor and taste of all five compounds.

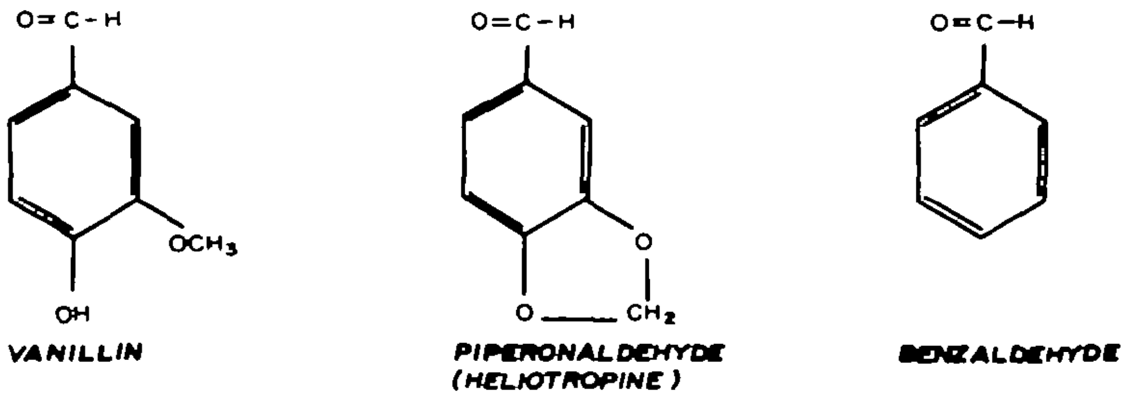

Figure 1. Structural formulas of the three simple compounds employed in this study.

The concentrations employed in each case are listed in Table **I.**

Methods

Subjects

For the first part of the study, ten subjects (both sexes) from a pool of 20 were chosen to scale the odor, taste, and flavor of each stimulus. All subjects were young professionals or advanced university students with an average age of 26.5 ± 6 years of age, ranging from 19 to 40 years of age. They participated in a total of 15 sessions.

In the second part of the study (flavor of the three simple compounds over a wide range of concentration), another 13 subjects (both sexes) took part. They were also young professionals or university students averaging 23.5 ± 3.0 years of age and ranging from 20 to 30 years of age. They participated in a total of three sessions (one for each simple compound).

Procedure

The method of magnitude estimation (S.S. Stevens, 1957) without a prescribed modulus was used throughout. In each session, the series of stimuli for one sense modality (e.g. taste) of one substance (e.g. natural vanilla extract) was presented in random order of concentration. The subjects made at least two replicate estimations per concentration.

In the odor experiments, 30 sec elapsed between successive presentations in order to avoid problems with adaptation (Cain and Engen, 1969; Pryor, *et al,* 1970; Cain, 1974a). A "sniff bottle" technique was used, and the sessions took place in a large room with good ventilation to minimize odor contamination.

Table I. Concentrations employed for the five stimuli in the first and second part of the study.

Compounds	Concentrations Tested		
	First Part		Second Part
	Odor (Molar)	Taste and Flavor (Molar)	Flavor (Molar)
			6.57×10^{-4}
		3.30×10^{-3}	1.31×10^{-3}
Vanillin	3.29×10^{-2}	1.31×10^{-2}	3.29×10^{-3}
	3.29×10^{-1}	3.29×10^{-2}	6.57×10^{-3}
	9.86×10^{-1}	6.57×10^{-2}	1.31×10^{-2}
			3.29×10^{-2}
			6.57×10^{-2}
	6.67×10^{-2}	1.67×10^{-3}	6.66×10^{-4}
	3.33×10^{-1}	3.33×10^{-3}	1.67×10^{-3}
Piperonal	1.33×10^{0}	6.66×10^{-3}	3.33×10^{-3}
	4.00×10^{0}	1.33×10^{-2}	6.66×10^{-3}
			1.33×10^{-2}
	9.80×10^{-3}		4.71×10^{-4}
	4.92×10^{-2}	2.45×10^{-3}	9.80×10^{-4}
Benzaldehyde	9.83×10^{-2}	4.90×10^{-3}	2.46×10^{-3}
	4.92×10^{-1}	9.80×10^{-3}	4.92×10^{-3}
	1.97×10^{0}	1.97×10^{-2}	9.84×10^{-3}
	9.83×10^{0}		1.97×10^{-2}
	(% v/v)	(%v/v)	
Natural Vanilla Extract	0.5	1.0	
	2.0	2.5	
	10.0	5.0	
	50.0	10.0	
Artificial Almond Essence	0.5	0.5	
	2.0	1.0	
	5.0	2.0 (taste)	
	10.0	2.5 (flavor)	
		5.0	

In the taste and flavor experiments, the subjects rinsed their mouth with distilled and deionized water before the first presentation and between successive presentations, until any previous sensations disappeared. The "sip and spit" procedure was used throughout. In the flavor experiments, the subjects estimated total intensity of the sensation. For these experiments, each solution was held in the mouth for 10 sec. In the taste experiments, the subjects stopped up their nostrils with stoppers that completely prevented nasal inspiration in order to eliminate the olfactory component of the stimuli and thereby to evaluate only taste and any possible pungency aroused by the stimuli (Murphy and Cain, 1980). When judging taste, the subject held the solutions in the mouth for just 7 sec in order to avoid distraction from the need to hold their breath. Pilot experiments showed that the intensity of taste and flavor reached an approximate steady state over the first 6 or 7 sec and then stabilized.

Stimulus presentation

For odor experiments, the odorants were presented in 120 ml caramel colored bottles with a bakelite screw top. Each bottle contained a 10-ml solution of odorant either in diethyl phthalate in the case of simple compounds or in water in the case of complex substances. For taste and flavor experiments, the stimuli were presented in 15-ml conical cups containing a 5-ml aqueous solution of each substance.

Data treatment

To obtain each psychophysical function, the numbers given by the subjects were normalized according to a procedure described by Lane, Catania, and Stevens (1961). This procedure eliminated differences in modulus from subject to subject. The data are summarized in terms of geometric means and standard deviations.

Results

Power functions were fitted to the stimulus-response data obtained for odor and taste (Figures 2 and 3). The exponents (β), or slopes when plotted in log-log coordinates, for the odor functions (Figure 2) were: 0.20 for natural vanilla extract; 0.25 for vanillin; 0.28 for artificial almond essence; 0.30 for benzaldehyde and 0.37 for piperonal. They averaged 0.31 ± 0.06. These values correspond well with those obtained by other investigators for the same stimuli (Berglund *et al.,* 1971; Patte *et al.,* 1975; Doty, 1975; Moskowitz *et al.,* 1976).

Taste intensity functions (Figure 3) had the following exponents: 0.57 for natural vanilla extract, 0.59 for vanillin, 0.61 for piperonal, 0.62 for artificial almond essence and the somewhat higher value of 0.92 for benzaldehyde. Excluding benzaldehyde, the average taste exponent was 0.60 ± 0.02. The subjects found the taste quality of all five flavorings bitter at low concentrations and pungent at the highest one. Exponents for a typical bitter compound (quinine sulfate), obtained with the sip and spit procedure, have averaged about 0.6 regardless of temperature in the range 25 to 50°C (Meiselman, 1971; Moskowitz, 1973).

Flavor intensity functions (Figure 4) could also be fitted by a single straight line in log-log coordinates in the case of those stimuli that showed no flattening at the lowest concentrations. The exponents for these compounds were 0.65 for artificial almond essence, 0.68 for natural vanilla extract, and 0.83 for piperonal.

These values roughly resembled those of the taste functions for the same substances, except for piperonal where the flavor exponent is higher than that for taste.

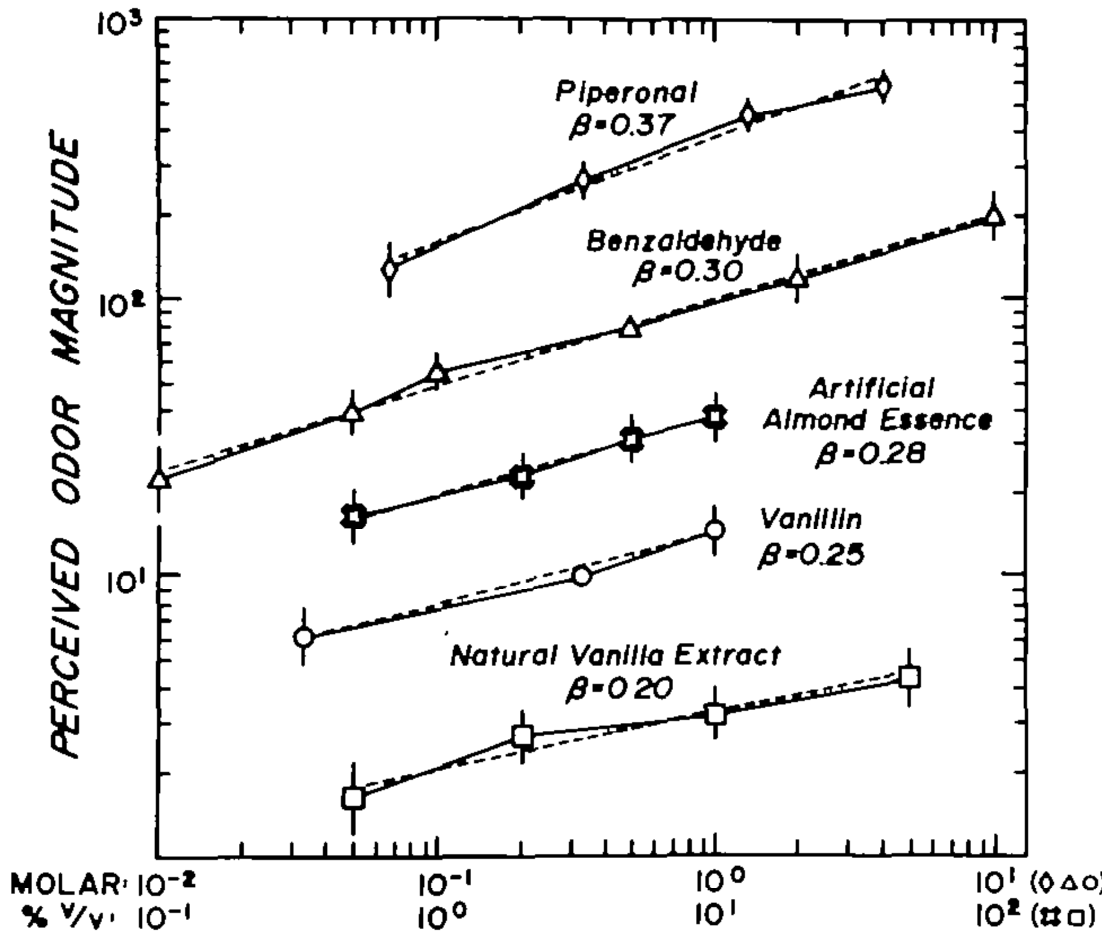

Figure 2. Perceived odor magnitude as a function of concentration for the five flavorings under study. Units of concentration are molar in the case of vanillin, benzaldehyde and piperonal (upper abscissa) and % V/V in the case of artificial almond essence and natural vanilla extract (lower abscissa). Each point represents a geometric mean of 20 estimates. The bars indicate standard deviations and the dotted lines represent the best fitting straight line. The slopes are shown. The functions are arbitrarily shifted along the ordinate in order to avoid overlap.

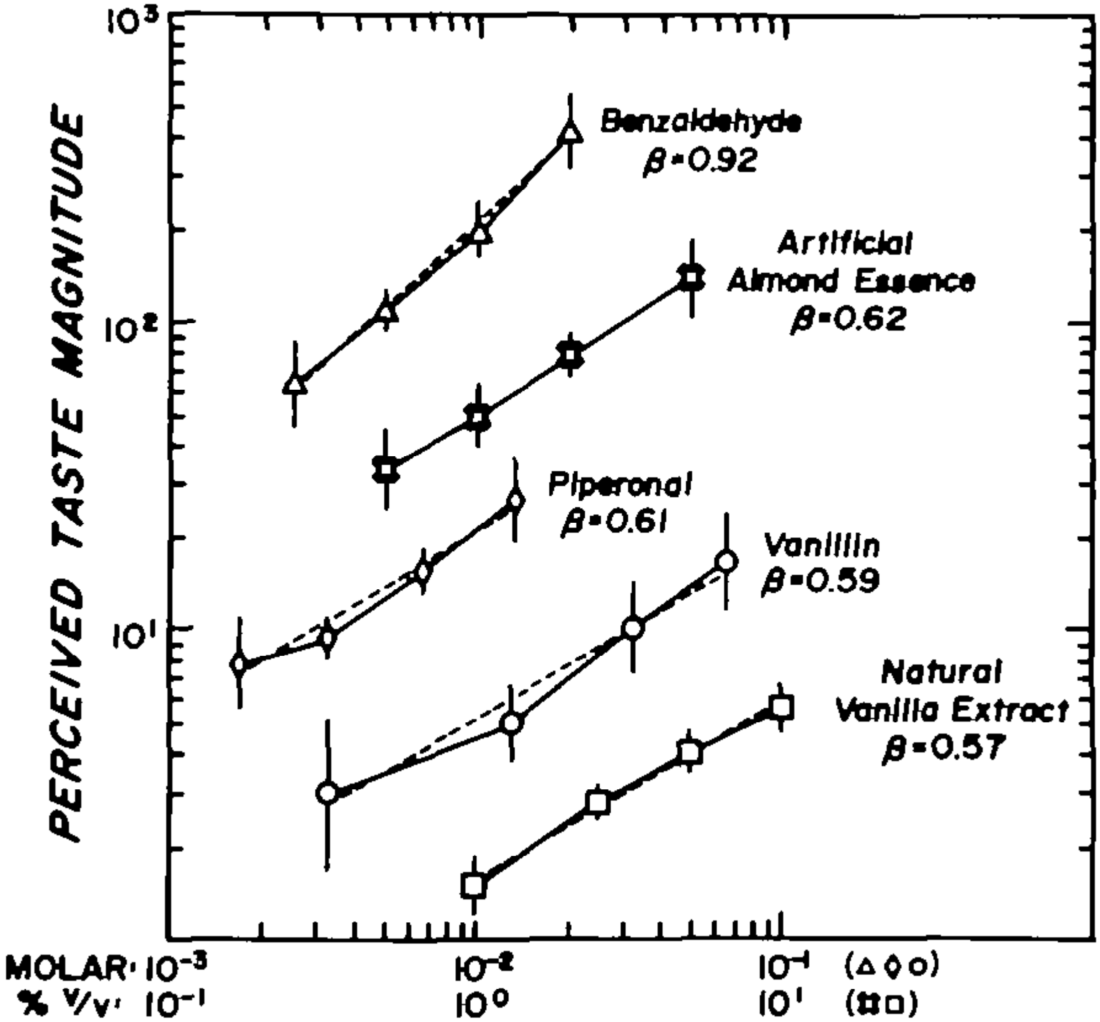

Figure 3. Perceived taste magnitude as a function of concentration, molar in the case of vanillin, piperonal and benzaldehyde (upper abscissa) and % V/V in the case of natural vanilla extract and artificial almond essence (lower abscissa). Each point represents a geometric mean of 30 estimates. The bars indicate standard deviations and the dotted lines represent the best fitting straight lines. The slopes are shown. The functions are arbitrarily shifted along the ordinate in order to avoid overlap.

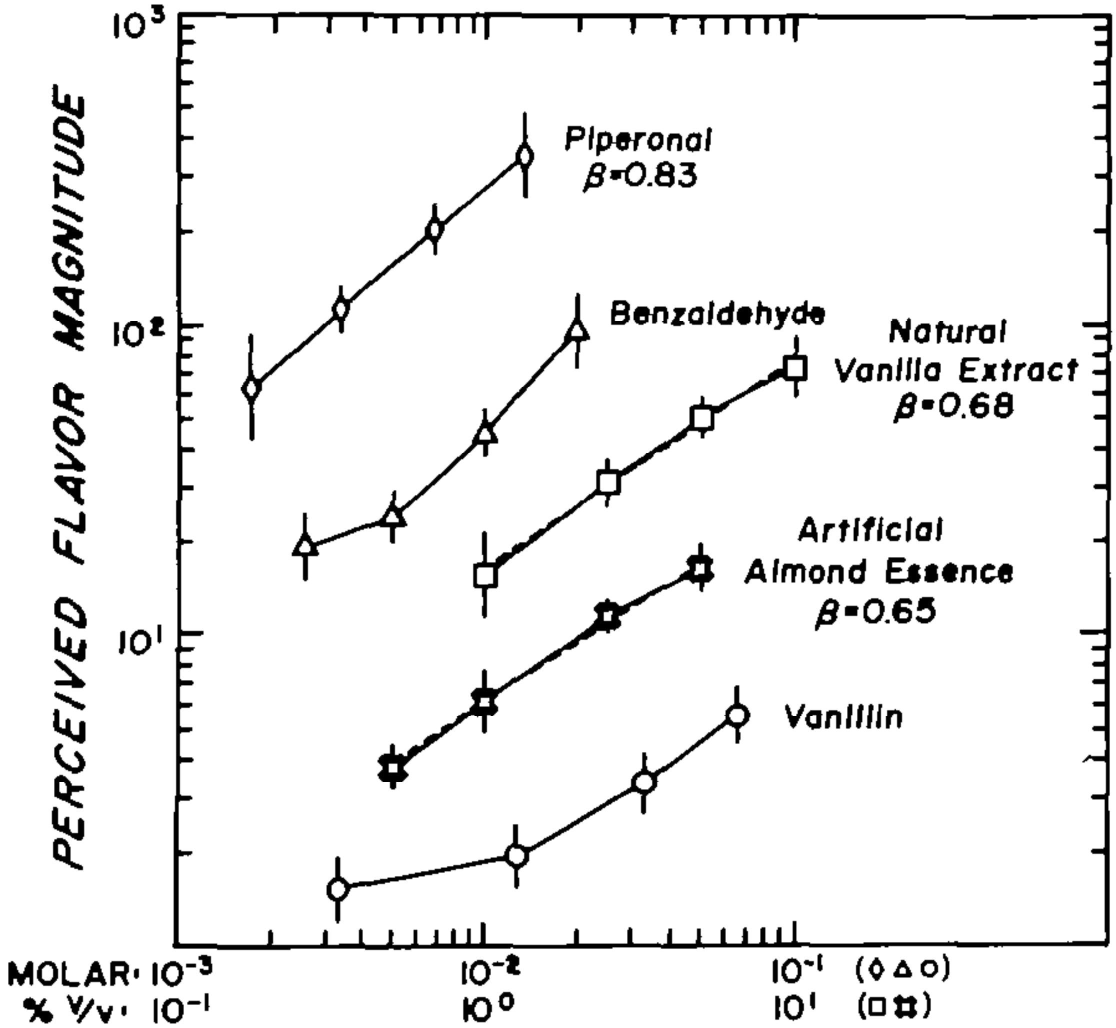

Figure 4. Perceived flavor magnitude as a function of concentration, molar in the case of vanillin, benzaldehyde and piperonal (upper abscissa) or % V/V in the case of artificial almond essence and natural vanilla extract (lower abscissa). In the case of vanillin each point represents a geometric mean of 30 estimates, in the case of all other substances each point represents a geometric mean of 20 estimates. The bars indicate standard deviations and the dotted lines represent the best fitting straight lines. The slopes are shown. The functions are arbitrarily shifted along the ordinate in order to avoid overlap.

As expected, the functions for odor grew less rapidly than those for taste. The growth of odor intensity seemed uniform. On average, a tenfold change concentration led to a twofold change in odor magnitude. The growth of taste intensity also seemed uniform except for the taste of benzaldehyde which grew more rapidly than that of the other four substances. For vanillin, piperonal, natural vanilla extract, and artificial almond essence a tenfold change in concentration led to a fourfold change in taste magnitude. For benzaldehyde, a tenfold change in concentration led to an eightfold change in taste intensity.

The steepnesses of the flavor functions, shown in Figure 4, are much more similar to those for taste than to those for odor. It therefore seems that taste was the dominating influence in the scaling of flavor intensity over the concentration ranges explored.

The flattening of the flavor functions for vanillin and benzaldehyde at the lowest concentrations suggested a possible effect of the concentration range on the stimulus-response functions.

In the second part of the study, the concentrations were chosen to span the region where flavor functions obtained previously showed an upward concavity that might have reflected a change from taste salience to odor salience. Figure 5 depicts the functions. These confirmed the tendency for vanillin and benzaldehyde to produce a flattening at lower concentrations and hence to resemble odor functions in that range. As before, these functions were steeper at higher concentrations and hence resembled taste functions in that range. The flavor function for piperonal does not show this duality but resembles a taste function throughout the range studied.

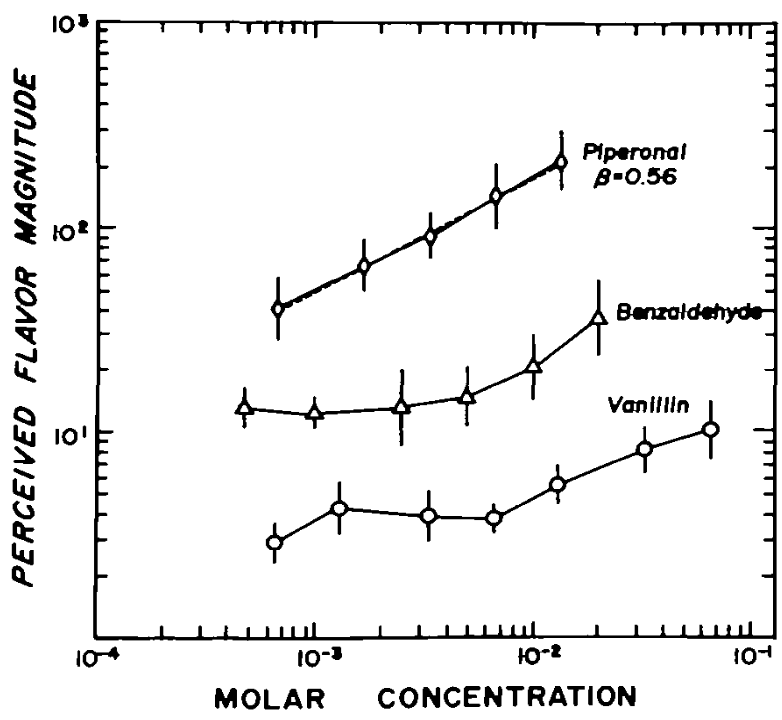

Figure 5. Perceived flavor magnitude as a function of molar concentration for vanillin, benzaldehyde and piperonal. The concentration range has been extended towards the lower end compared with the one shown in Figure 4. Each point indicates a geometric mean of 24 estimates in the case of vanillin and piperonal or 26 estimates in the case of benzaldehyde. The bars indicate standard deviations and the dotted lines represent the best fitting straight line. The slopes are shown. The functions are arbitrarily shifted along the ordinate in order to avoid overlap.

Discussion and Conclusions

The odor intensity functions of the stimuli employed here followed the characteristic pattern of odor functions, with low rates of growth as concentration was increased. Taste functions grew at much higher rates, with benzaldehyde yielding the steepest taste function. Its steepness may have derived from its influence on the trigeminal system. All subjects remarked that the high concentrations of this substance evoked pungency. It has already been seen that the trigeminal system interacts with olfaction and increases the rate of growth of the odor functions (Cain, 1974b). Something similar could happen when the trigeminal system interacts with taste.

Flavor intensity functions in Figure 4 look much more like those for taste than those for odor. Admittedly, odor judgments were made for stimuli presented outside the mouth, a situation that impairs comparability of the odor and flavor judgments. Nevertheless, Murphy and Cain (1980) found that odor magnitude also grew more slowly than taste magnitude when odors were judged in the mouth. Perhaps the growth of psychophysical functions reflects changes in the most salient attribute of flavor and, in the present case, taste happens to be most salient. When the concentration continuum is expanded to its lower end (Figure 5), flavor functions for vanillin and benzaldehyde flatten. The flattening occurs in a region where taste loses impact and, in this region, functions for flavor resemble odor functions rather than taste functions, indicating that here flavor scaling is determined primarily by odor. This duality does not hold for the other simple compound, piperonal, whose flavor functions resembled always taste in terms of their steepness.

These findings suggest that, when using a particular flavoring basically because of this odor, concentration is not very critical, since moderate changes may not be perceptually very important. But, when employing the substance because of its taste, concentration becomes more critical, since slight to moderate changes would render the product perceptually too weak or too strong and hence could impair its acceptability. The results also imply that, at least for certain flavorings, the rate of growth of flavor depends on the most salient feature in the concentration range studied. That is, at low concentrations, odor seems to be the most salient feature, and so the flavor functions are flat in that range, but, at high concentrations, taste becomes the salient feature and so the flavor functions become steeper.

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