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Flavour as a psychological construct: implications for perceiving and measuring the sensory qualities of foods

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Abstract

While flavours comprised of simple taste/odour combinations can be easily decomposed, there is evidence that the individual components are seldom perceived independently. Manifestations of interactions include smell/taste confusions, attribution of taste properties such as sweetness or sourness to odours, and the enhancement and suppression of tastes by such odours. These phenomena are probably the result of blurring of the perceptual boundaries of odour and taste properties during repeated pairings as flavours. Following such pairings in the laboratory, odours can be shown to increase in perceived taste properties. It is proposed that during flavour formation, the components are encoded in memory in such a way that a later odour stimulus also elicits taste properties. Sensory properties such as sweetness can thus be seen as cognitive phenomena associated with both tastes and odours, in the latter case residing in memory. However, unlike some odour combinations, flavours, although usually perceived as a functional whole, are not indivisible synthetic entities. Perceptual interactions between odours and tastes are dependent on the extent to which an analytical approach is taken to the measurement of flavour qualities. Thus, odour enhancement of sucrose sweetness is not observed when the intensities of all the components in a flavour are rated. This has been interpreted as a consequence of rating strategies. However, the data are more consistent with a perceptual/cognitive interpretation. Recent research from our lab has shown that the cognitive strategy employed during the pairing of odours and tastes will also determine whether taste/odour interactions occur. The question of how to measure flavour properties is raised by these findings. Whether panellists focus on the sensory source of, for example, sweetness will depend upon the perceptual strategy they adopt. Asking panellists to focus only on the taste sweetness, while possible, may be assuming that odour and taste properties are independent within foods.

1. Introduction:

1.1. *Flavour as a unique sense*

It is well known that consumers will use the terms "taste" and "flavour" interchangeably when referring to the sensory qualities of foods. In doing this, they implicitly ignore the contribution of the olfactory component of flavour. In fact, very many people are surprised to learn that the defining sensory characteristics of foods are primarily odours. This use of the word "taste" is generally regarded by sensory scientists as simply imprecise use of language based on ignorance of the underlying sensory mechanisms. However, another possibility, and one of the issues explored in this review paper, is that the consumer is reflecting more or less accurately the way that we are predisposed to perceive the sensory properties of foods. The most obvious indication that this is the case is the well known illusion of olfactory qualities of foods appearing to originate in the mouth. This illusion is both strong and pervasive, despite the fact that we are frequently presented with evidence of the importance of the olfactory component in flavours, e.g. through a blocked nose during a head cold or through the well known technique of making the medicine go down easier by holding the nose.

Why is this olfactory location illusion so compelling? One possibility is that it results from the high survival value of correctly identifying food sensory properties. Since the mouth acts as the gateway to the gut, our chemical senses can be seen as part of a defence system to protect our internal environment. Such a system has two functions: (1) to recognise nutrients (e.g., as indexed by taste qualities such as sweet and salty) and those objects that we know from past experience to be foods (as recognised through olfactory qualities); and (2) to

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provide warning signals based on the sensory properties (e.g. bitterness, pungency) of substances which might have inherently toxic qualities, or qualities (again, olfactory) that we have learned to recognise as inappropriate foods or, perhaps, have yet to recognise. The defence system is activated once something is placed in the mouth, when it becomes important to decide whether this is an appropriate food or not.

Rozin (1982) has suggested that, in serving this role, olfaction can be seen as two functionally distinct senses: one sense for identifying objects at a distance (orthonasal perception), and another sense that contributes to flavour and hence food identification in the mouth (retronasal perception). While these two "senses" physiologically differ perhaps only in efficiency of delivery of odours to the olfactory epithelium (Voirol & Daget, 1986; Pierce & Halpern, 1996), the information delivered by each may differ in its cognitive impact. Thus, it makes sense, in the identification of foods, to combine the food's qualities (tastes and retronasal odours) into a unitary perception. Consumers' initial responses to foods strongly suggest that this is how sensory properties are perceived, in that their responses are usually both global and hedonic which, in turn, may serve to ensure that the signals of the defence system are acted upon. Such responses are also consistent with the more general notion that, although we perceive through multiple senses, sensory information is commonly integrated to produce a whole percept. This may be especially true when considering the sensory properties of foods since, when food is in the mouth, taste, olfactory, chemesthetic and tactile senses are concurrently stimulated. According to Marks (1991), such sensory interactions sometimes lead to information conflict, e.g. the "ventriloquism effect" of identifying a sound source using visual cues. In the case of foods, the olfactory location illusion can be seen as an equivalent phenomenon.

The concept of flavours as products of sensory integration is consistent with Gibson's (1966) ecological view of perception. He proposed that the physiological origin of sensations was less important than that the sensations could be used to identify objects. Hence, what matters is that the *object itself* has certain qualities which can be identified (indeed, sensory scientists commonly refer to the *sensory properties* of foods). This view also necessarily entails that input from different sensory systems will be integrated, so that the olfactory component of flavours, while physiologically crucial, is of less importance than the fact that, together with tastes and other sensory properties, it uniquely identifies the foods located in the mouth. The implication of this interpretation for the perception of foods is that flavour is a functionally distinct sense which is cognitively "constructed" from the integration of distinct physiologically defined sensory systems (olfaction and gustation) in order to perceive and identify objects that are important to our survival.

This notion of a functionally distinct flavour sense receives support from studies of the neural processing of odours and tastes in both animals and humans. These studies provide evidence that, under conditions of perceptual co-location in the mouth, tastes and odours are encoded in the brain as part of a unique perceptual system, in the form of distinct flavour "entities". Thus, Rolls and Bayliss (1994) demonstrated the existence of multimodal neurons in the caudo-lateral orbito-frontal cortex of monkeys—neurons that responded to both taste and olfactory, or taste and visual inputs. Many of these neurons responded specifically to qualities that occur together in flavours, e.g. the sweetness of glucose and fruit odours, rather than to incongruous combinations such as saline and these same odours. Rolls (1997) suggested that these multimodal neurons develop from unimodal neurons through learning of appropriate combinations of signals during repeated pairing of particular tastes and odours. In studies of perceptual discrimination in the rat, Schul, Slotnick, and Dudai (1996) found that damage to cortical olfactory areas led to impaired ability to distinguish flavours from their components, although detection of these odours and tastes remained unimpaired, again arguing for distinct neural coding of flavours. In humans, Small, Jones-Gotman, Zatorre, Petrides, and Evans (1997) used positron emission tomography, a technique for measuring cerebral blood flow (CBF) which reflects regional activity of neurons in processing information, to evaluate differential processing of olfactory, gustatory and combined olfactory and gustatory (flavour) stimuli. They found significant CBF decreases in primary gustatory, and secondary gustatory and olfactory cortices, during simultaneous presentation of odours and tastes that occur together in flavours, compared with independent presentations of identical stimuli, suggesting that flavour is not represented by a simple convergence of its component senses, but rather is processed as a unique sensory experience.

2. Odour/taste interactions

One implication of both these findings and Gibson's (1966) view of perception is that the sensory qualities within flavours are unlikely to be independent. Research that has examined the relative contribution of odours and tastes to overall flavour intensity has generally only shown small to moderate degrees of sub-additivity in the intensity of odour/taste mixtures relative to the added intensities of the unmixed components (Murphy, Cain, & Bartoshuk, 1977; Murphy & Cain, 1980; Garcia-Medina, 1981). However, stronger evidence for the lack of independence comes from two distinct sets of findings that are interpretable as being the observable consequences of a psychologically real flavour sense and demonstrate that tastes and odours, when encoded together as a flavour, influence the perception of one another. Odours that are co-encoded with tastes in flavours have been shown to be significantly altered both when the odour component is experienced orthonasally (sniffed) and also when it is added to taste solutions (retronasally). The orthonasal effect is the widely observed phenomenon of attributing taste qualities to odours (Burdach, Kroeze, & Koster, 1984). For example, in Dravnieks' (1985) *Atlas of Odor Character Profiles*, 65 and 53% of his panel saw sweetness as an appropriate descriptor for the odour of Allyl Caproate and Vanillin, respectively. Likewise, 33% of his panel described the odour of Hexanoic Acid as being sour. Again, the question arises as to whether these are just cases of imprecise language or even metaphor, given that the odour name is likely to refer to an object, which might also be sweet or sour. An alternative, in line with Gibson's (1966) reasoning, however, is that such qualities are part of the object that the odour uniquely identifies, and that sniffing the odour elicits retrieval of the taste qualities from memory. Thus, sniffing caramel odour activates memorial representations of caramel flavoured foods which includes a significant sweet component. In other words, the taste property of the odour is cognitive in nature.

This interpretation is even more clearly suggested by the effects of some odours experienced retronasally. A number of studies have shown that certain odours, when added to tastes, can modify the taste intensity (Frank & Byram, 1988; Frank, Ducheny, & Mize, 1989; Frank, van der Klaauw, & Schifferstein, 1993; Cliff & Nobel, 1990; Bingham, Birch, de Graaf, Behan, & Perring, 1990; Clark & Lawless, 1994). The most common finding relates to the ability of food odours such as strawberry or vanilla to enhance the sweetness of sucrose solutions (Frank & Byram, 1988). This phenomenon, illustrated in Fig. 1, is clearly psychophysical in nature, rather than chemical since pinching the nose during evaluation to prevent volatiles reaching the olfactory receptors abolishes the effect. It is also both taste and odour specific—Frank and Byram (1988) showed that strawberry, but not peanut butter odour, enhanced the sweetness of sucrose; conversely, saltiness was not enhanced by strawberry.

It is likely that these findings of orthonasal taste qualities and retronasal taste enhancement are both aspects of the same phenomenon. Chifala and Polzella (1995), for example, found through multidimensional scaling of similarity data, that the same dimension of sweet–sour was important in both the orthonasal and retronasal discrimination of a selection of liqueurs. This is also suggested by studies of the relationship between tasted sweetness of odours plus sucrose and smelled

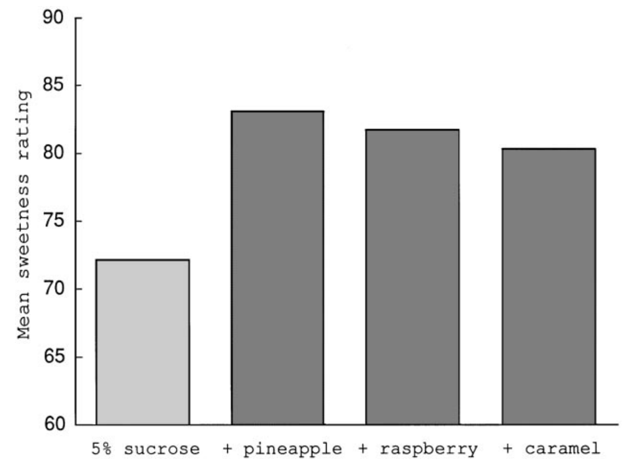

Fig. 1. The impact of the addition of three common food odours which are all judged as smelling "sweet" to a solution of 5% sucrose. In each case, ratings of the sweetness of the sucrose were increased. Prior pilot testing had establish that none of these odours in water had any taste qualities.

sweetness (Prescott, Stevenson, & Boakes, 1996), undertaken as a direct test of the hypothesis that the ability to enhance sweetness was a function of smelled sweetness. In this study, subjects were asked to rate the smelled sweetness of a variety of odourants (including both food related odours such as lychee, caramel, and mango, and non-food odours) as well as their tasted sweetness as flavours in 10% sucrose. Smelled sweetness was found to be a strong predictor ($r = 0.67$) of the extent to which the odour modified the tasted sweetness of the sucrose solution.

3. Origins of odour-induced taste enhancement

Frank and Byram (1988) suggested perceptual similarity between a particular taste such as sweetness and particular odours in foods might arise through a history of association of these qualities in foods (e.g. sweetness plus strawberry or caramel). In turn, perhaps because of the perceptual integration of the different sensory qualities during co-occurrence in the mouth, this leads to uncertainty regarding the "boundaries" of the odour and taste. In effect, these sensory qualities become blurred (van de Klaauw & Frank, 1996). With odours which "possess" a taste quality such as sweetness, it may be unclear to the assessor where the odour sweetness ends and the taste sweetness begins in a flavour solution, resulting in addition of the odour and taste sweetness qualities. Thus, association during food consumption leads to sweet odours and a subsequent ability of these odours to enhance sweetness in solution.

There is empirical support for this explanation. Recent studies have shown that the co-occurrence of sweet or sour tastes with relatively unfamiliar odours can result in an increase in the perceived smelled sweetness or sourness of those odours. Stevenson, Prescott, and Boakes (1995) and Stevenson, Boakes, and Prescott (1998) repeatedly paired odours that, when sniffed, were judged to have moderate sweetness and relatively low sourness, with either sucrose or citric acid on multiple occasions over several days. Even under conditions where subjects were unaware of the specific odour/taste pairing, the odours increased in smelled sweetness or sourness, depending upon the taste with which they were paired. Although the effect was most strongly manifest in orthonasal perception, and an increase in tasted sweetness or sourness of the odour/taste mixture was not found, the origin of this effect appears to be co-occurrence in the mouth, as the effect persists even when orthonasal olfactory cues are eliminated by sampling the odour/taste combination through a straw (Stevenson et al., 1998).

van der Klaauw and Frank's (1996) interpretation of enhancement effects, together with these associative learning data (Stevenson et al., 1995, 1998) suggests that, during association under the conditions of the location illusion, as the boundaries between taste and smell can become increasingly blurred, they are perceived as dimensions of the same compound stimulus, the flavour. This concept has been previously proposed as an explanation for differences in the strength of learning of associations between simultaneous and successive presentations of both tastes, and auditory and visual stimuli in animal learning (Rescorla, 1980). Thus, Rescorla (1980, p. 215) notes in explaining the superiority of simultaneous over successive stimulus presentation for learning: "it is possible that with simultaneous stimulus presentation the organism does not separately represent the individual elements and then form an association between those representations. Rather, it may represent the total stimulus as a single unit, to which the later separate element presentations are identified as similar". Rescorla (1980) further notes that under such learning conditions, one component of the compound stimulus (odour) may elicit the whole stimulus (flavour) because of the similarity between the compound and its components. Critical for this is the illusion that tastes and odours are spatially co-located in the mouth, although Rescorla (1980) seems to suggest that the odour and taste are presented at the same time is also critical. In the case of odours and tastes, however, temporal and spatial co-occurrence are inextricably linked. Thus, von Bekesy (1964) showed that the perceived spatial location of an odour/taste mixture can be manipulated by varying the time delay between the two components, with perceived location moving from the tip of the nose to the back of the throat to the tip of the tongue as the odour first precedes, then is simultaneous with, and finally is preceded by, the taste.

Rozin (1982) also gives an account of this phenomenon in human perception, suggesting that the olfactory component of a flavour becomes part of an emerging percept in which it loses its separate identity. As a result, tastes and odours become increasingly difficult to separate from one another (perceptual similarity), which leads to confusion and increased influence. In fact, such perceptual similarity has been seen as an example of a "learned synaesthesia" (Stevenson et al., 1998) in which qualities in one sensory system (olfaction) are able to evoke qualities in another (taste) through frequent co-occurrence. The fact that the ability of odours to take on taste qualities can be learned further supports the view of a cognitive interpretation of odour/taste interactions.

4. Taste enhancement and rating scale effects

There is an alternative account of this phenomenon, however, which suggests that sweetness enhancement by odours is an example of dumping of similar qualities onto ratings of sweetness rather than "real enhancement". In apparent support of this view is the finding (Frank et al., 1993; Clark & Lawless, 1994) that the taste enhancement effect can disappear when subjects are asked to rate other sensory qualities in addition to the taste. For example, Frank et al. (1993) found that the addition of strawberry odour enhanced the sweetness of a sucrose solution when only sweetness was rated; when sweetness, sourness, and fruitiness of the mixture were rated, this effect disappeared. In another condition in which subjects rated total intensity of the mixture, and then broke this rating down into six separate ratings: sweetness, sourness, saltiness, bitterness, fruitiness, and "other", sweetness of sucrose was actually suppressed (see Fig. 2). Although this "halo-dumping" explanation is not inconsistent with the associative account of how odours become similar (in this interpretation, halo effects), it suggests that when subjects are not able to express their ratings of other sensory qualities that may be present (e.g. fruitiness in an fruit odour/sucrose mixture) on an appropriate scale, they will use scales that are present when the qualities have some perceptual similarity. In other words, enhancement represents the product of a ratings strategy and is a function of the number of scales used. Thus, Clark and Lawless (1994) suggest that "sweet" odours don't enhance sweetness, they enhance sweetness ratings. In this view, taste enhancement effects are thus cast as ratings biases. This raises the question for sensory evaluation of which are the right scales to use in rating flavour qualities (see below).

However, there are data which cast doubt on this interpretation of scale effects. Firstly, although ratings do have an impact on the ability of odours to influence tastes, it also seems to be the case that such abilities are

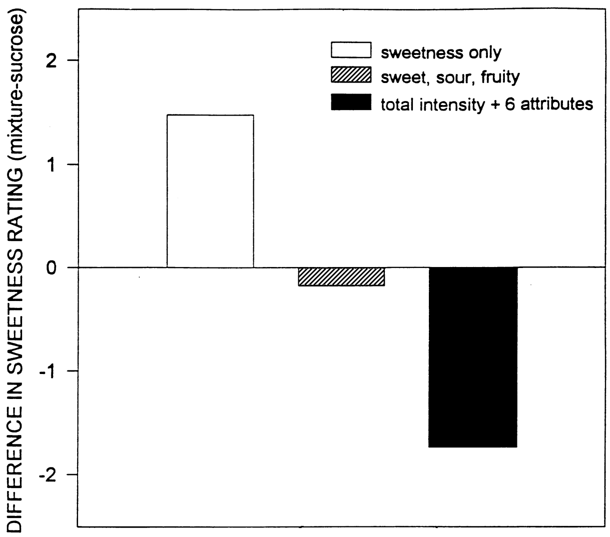

Fig. 2. A mixture of strawberry and sucrose is judged sweeter than sucrose alone when only sweetness is rated. When other appropriate attributes for the mixture (sour, fruity) are also rated, the enhancement disappears, and when total intensity is first rated and then broken down into multiple other ratings, sweetness suppression is observed. Figure taken from van der Klaauw and Frank (1996) with permission of author and publishers.

also a function of the odour itself (Prescott et al., 1996). While certain odours enhanced sweetness in solution (lychee, caramel), other odours that rated very low in smelled sweetness were actually able to suppress the sweetness of sucrose. Moreover, in a second study, Prescott et al. (1996) actually showed that, while keeping the number of rating scales constant, a sweet smelling odour (caramel) was not only able to enhance the sweetness of sucrose in solution, but also suppressed the sourness of citric acid, suggesting not only that the "taste" qualities are resident in the odour, but that the odour sweetness behaved like "real" (taste) sweetness which typically shows suppression of sourness in taste mixtures.

In addition, van der Klaauw and Frank (1996) were able to eliminate taste enhancement by directing panellists' attention to the appropriate attributes in a taste/odour mixture, even when they were only required to rate sweetness. In other words, rating all appropriate attributes of a mixture is not a pre-requisite to eliminate taste enhancement. Similarly, Clark and Lawless (1994) note that prior knowledge of which attributes are to be rated should also abolish any halo-dumping effects even if these are rated in succession since the subjects realises that there is no need to "dump" qualities. In their study, however, this effect was not shown.

5. A cognitive interpretation of taste enhancement

An alternative explanation for the effects of variations in rating scales on taste enhancement, consistent with the cognitive view of flavour effects, lies in the notion that the odour sweetness is perceptually real but that it can be manipulated by the perceptual approach taken during evaluation. The apparent influence of the number of rating scales on odour/taste interactions results from a failure to clearly distinguish between the number of scales used and the impact of these scales on perceptual strategy. In other words, asking panellists to rate different number of scales will influence how they perceive the odour/taste mixture.

Although there is debate on the usefulness of such distinctions, the notions of synthetic and analytic combinations have been used to describe odour/odour and taste/taste interactions, respectively. Thus, taste interactions are typically seen as analytic, because they do not combine to form new tastes. In contrast, blending of odours to form entirely new odours is commonplace, and hence is referred to as synthetic interaction. McBurney (1986) has suggested a further category of interaction, namely fusion, the notion of sensations combined to form a perception, rather than combining synthetically to form a new sensation. He argues that this applies to perception of flavours which remain analysable into their components, even when perceived as a whole.

Whether or not this occurs may be a function of the congruence of the odour and taste components. Schifferstein and Verlegh (1996) note the importance of the cognitive approach that is taken during evaluation by suggesting that evaluating taste or odour intensities is primarily analytical, except when the stimulus components are perceptually similar, they form a congruent whole when they are treated as a synthetic perception. Whether an odour/taste combination is seen as congruent is dependent upon familiarity, or experience with the components as a combination, that is, it is a product of association of the qualities within a flavour. Certainly, there is evidence that taste enhancement only occurs for congruent odour/taste pairs (Frank, Shaffer, & Smith, 1991; Schifferstein & Verlegh, 1996). Thus, Frank et al. (1991) found that the degree of enhancement produced by an odour for a particular taste was significantly correlated with ratings of the perceived similarity of the odourant and tastant.

Presumably many of the common odour/taste pairs experienced during food consumption would be rated highly in terms of stimulus similarity. The components of these flavours may not be treated separately when judged in terms of sweetness or other single characteristics. When instructions require separation of the components, however, this can be done. Thus, when the components of a flavour are evaluated individually, sweetness enhancement disappears. van der Klaauw and Frank (1996, p.26) note that "providing appropriate response alternatives will encourage observers to separate the component attributes of a complex stimulus, whereas they are more likely to integrate dimensions when their response alternatives are limited''. In other words, rating requirements can influence the degree of perceptual integration which occurs, and different instructional sets lead to different perceptual approaches (analytical or synthetic).

In these terms, consumer perception of flavours would typically be synthetic in that differentiation between the odour and taste components of flavours is not only unnecessary, but is undermined by the olfactory location illusion. However, the components of these ''synthetic wholes'', can be made independent if an analytical approach is taken. Thus, Bingham et al. (1990) found that a consumer panel demonstrated enhancement of sucrose sweetness by maltol. However, for the same task, a trained panel did not show sweetness enhancement, even when rating just sweetness, supporting the notion that adopting an analytical approach is responsible for eliminating the enhancement effect.

6. Perceptual strategies and flavour formation

Disentangling so-called perceptual effects from ratings effects is, however, a difficult task since ratings are used to infer perceptual processes. One way of assessing the impact of perceptual strategies on the perception of flavours may be to predispose panellists to adopt different strategies while maintaining the same ratings task. If it is the case that odour/taste interactions can be influenced by the extent to which an analytical or synthetic perceptual approach is taken during rating, this suggests the possibility that the formation of a synthetic/analytic flavour perception might similarly be determined by the way in which the components of the flavour are associated during their joint exposure. This may also determine the extent to which the odours and tastes become perceptually similar. Previous research in which odours and tastes have been experimentally paired (Stevenson et al., 1995) failed to show an increase of perceptual blurring as indexed by the ability to produce sweetness enhancement. This may have been due to the manner in which the pairing was constructed, that is, in the form of simple exposures in which the panellist's task (a triangle test) required no evaluation of the mixture other than to attempt to differentiate it from other identical mixtures. More focussed forms of exposure in which subjects are forced to treat the odour/taste combination in ways that encourage synthesis may impact on the formation of the flavour as a perceptual whole more directly. This would support the cognitive interpretation of odour induced sweetness enhancement by providing evidence of the differing impacts of analytical and synthetic perceptual strategies.

We undertook research to evaluate this and to test the notion that the cognitive strategy employed is crucial in the formation of flavours which show strong interactions in their elements (Francis & Prescott, submitted). In addition, the nature of the odours used, e.g. the degree to which an odour is already familiar and its degree of initial sweetness, may be an important factor determining how different forms of exposure (training strategies) will impact on how tastes and odours are perceived within a flavour. Given the interpretation above, we expected that:

1. Odours paired with a taste (e.g. sweetness) in a way that encourages synthesis between the elements should be most likely to increase in sweetness; this should be most pronounced for relatively unfamiliar odours. Since there may be a ceiling to odour sweetness, the effect might be most obvious with odours that are low-moderate in sweetness. Such odours may in turn change from having no impact on sweetness in solution to producing sweetness enhancement.
2. Odours paired with a taste (e.g. sweetness) in such a way that an analytical approach is taken should be most likely to decrease in sweetness, again especially if the odour is unfamiliar. If such an odour is relatively high in sweetness, this may result in change from sweetness enhancement to failure to enhance sweetness.

These hypotheses were examined using 46 untrained subjects who rated the smelled and tasted sweetness (both in and out of 0.3 M sucrose) of four odours shown in pilot studies to factorially vary in sweetness (Low and High) and familiarity (Low and High). The subjects were then randomly allocated to one of three exposure groups: Forced Integration (FI, a synthetic approach), in which subjects received taste/odour pairs which were rated only for overall mixture intensity; Forced Separation (FS, an analytical approach), in which the taste/odour pairs were rated for taste and odour intensity; and an Exposure Control (EC), in which the taste and odour components were received and rated separately. Subjects received 12 exposures of each odour/taste mixture, or odour and taste separately, after which they again rated the odours, both smelled and tasted, with and without sucrose.

As expected, the properties of the odours changed as a function of group, and also as a function of initial odour characteristics. When the odours were sniffed, there was an increase in sweetness as a result of exposure for initially unfamiliar odours in the FI group but little change in the other groups (see Fig. 3). When tasted in sucrose, odours that were either low familiarity or low sweetness increased in sweetness from pre- to post-exposure, an effect which did not occur when the odours were tasted without sucrose.

The impact of these changes in odour sweetness on total mixture sweetness can be seen in Fig. 4. The two

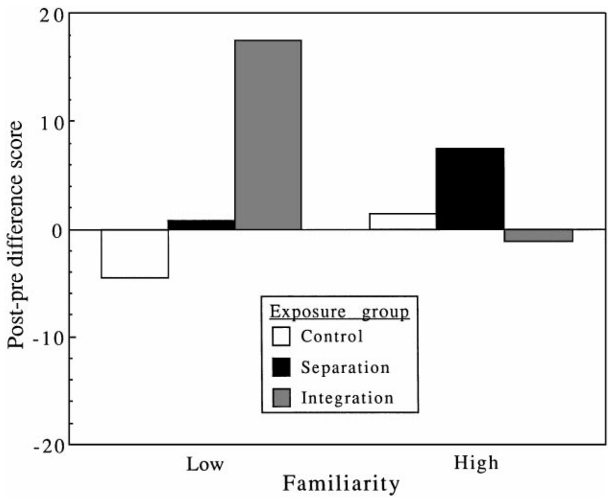

Fig. 3. Changes in ratings by the three exposure groups from pre-test to post-test of the smelled sweetness of the odours that were low (*Oolong tea*; *Water chestnut*) and high (*Peanut butter*; *Raspberry*) in initial familiarity. The forced integration group showed a significant increase in smelled sweetness, but only for low familiarity odours.

initially low sweetness odours (*Oolong tea* and *Peanut butter*) suppressed sweetness during the pre-test. Following exposure, *Peanut butter* produced sweetness enhancement while *Oolong tea* now had no impact on sweetness intensity. The low familiarity odour that was also moderate-high sweetness (*Water chestnut*) changed from an odour which did not influence sweetness intensity to one which produced enhancement. However, contrary to expectations, these changes were independent of group.

In general, these results support the view that the perception of the odour component of flavours, particularly the blurring of the perceptual boundaries between smelled and tasted sweetness, is influenced by the perceptual style used during exposure to odour/taste pairs. While this was only strongly evident in the perception of smelled sweetness, there were indications that perhaps with increased amounts of exposure, such as typically experienced with repeated food consumption, the same may also be true of flavours since the mean change in sweetness of the odour/taste mixtures was considerably higher in the FI group than in the FS or EC groups.

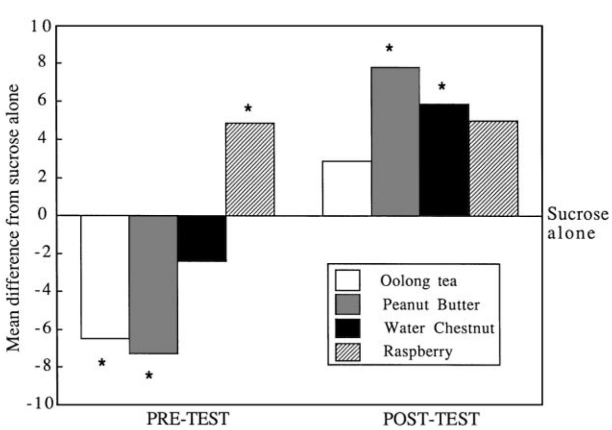

Fig. 4. Pre-test and post-test ratings of the tasted sweetness of the odour/sucrose mixture relative to sucrose alone, showing initial suppression of sucrose sweetness by low sweetness odours (*Oolong tea*; *Peanut butter*) and enhancement by the sweetest odour (*Raspberry*). Following exposure, sweetness suppression is eliminated and enhancement is shown by *Peanut butter* and *Water chestnut*. * indicates significantly different (5%) from sucrose alone.

7. Implications for the measurement of sensory qualities

What are the implications of these results for the measurement of sensory qualities? Firstly, the notion that sweetness enhancement results from dumping sensory information when scale alternatives are not available was not supported, since these changes were brought about without scale manipulation. Thus, these findings suggest that the key issue in evaluating flavours is not how many scales are used, but rather what questions are asked. Manipulation of perceptual approach during either the formation of flavours, or in the rating of the intensity of their components will determine how perceptually similar flavour qualities are combined or separated, with consequences for the intensity of sensory qualities.

This raises the question of what qualities should be measured in sensory evaluations. For example, in a complex mixture such as a sweet food, which bit is the real sweetness? Clearly, it depends on whether it is important to know about the sweetness of the flavour, or the sweetness associated with the odour or produced by the taste. However, the distinction between odour sweetness and taste sweetness may be artificial if one is evaluating flavours, rather than tastes and odours separately, since the sweetness of the flavour components may be represented cognitively, and even perhaps neurally, as equivalent. They may be functionally equivalent, as well. The fact that odour sweetness can suppress tasted sourness (Prescott et al., 1996), and that Kuo, Pangborn and Noble (1993) not only found taste enhancement of citric acid (CA) by citral, but also taste effects on retronasal odours with sucrose enhancing the retronasal intensity of vanillin which is suppressed by NaCl and CA, raises the possibility that odour sweetness is effectively no less "real" than tasted sweetness.

Frank et al. (1993) suggest that the question might be an empirical one, especially for consumers. What form of sweetness best predicts overall responses to foods? The prediction here would be that consumers' failure to distinguish between flavour components means that overall flavour sweetness is the most ecologically valid measure. In the case of trained panels, the whole point of descriptive analysis techniques is to deconstruct compound stimuli into their constituent parts. Even here, though, the question might arise of whether information is being lost by relying on the physiological origin of sensory qualities (e.g. taste qualities perceived via taste receptors), rather than on their functional perceptual representations (e.g. taste as a cognitive representation). This may be especially the case if trained panel data are being used to interpret and explain consumer responses.

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