

## Influences of Food-Name Labels on Perceived Tastes

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### Abstract

We examined whether food identity information presented as name labels would influence perception of basic tastes. To test this hypothesis, we used 10 aqueous taste solutions consisting of 2–3 of the 5 basic tastes in different ratios and presented them with one of these food names: “lemon,” “coffee jelly,” “caramel candy,” and “consomme soup.” Forty-six participants tasted samples presented with either food-name labels or random number labels. We found that participants who tasted samples with food-name labels rated tastes with significantly higher liking and familiarity scores than those presented with random numbers, especially when the names and tastes were perceived as being congruent. Though an effect on perceived intensity was not as prominent, we observed cases in which intensity ratings significantly changed. Effects of identity information have been shown in olfaction and flavors. This study demonstrates the first experimental evidence that identity information given as names also influence the perception of unimodal basic tastes.

**Key words:** familiarity, hedonicity, identity information, intensity, pleasantness, verbal context

### Introduction

In our daily lives, we almost always experience taste through foods. Such experience may eventually lead us to develop associations between certain combinations of tastes and foods, which may, in turn, create a pathway for modifying taste perception.

We can see this possibility in studies examining the influence of nongustatory senses on taste perception. A number of studies have reported the influence of specific odors (e.g., strawberry odor for sweetness) on the perception of specific tastes (Frank et al. 1989, 1993; Clark and Lawless 1994; Schifferstein and Verlegh 1996; Stevenson et al. 1999; Dalton et al. 2000; Sakai et al. 2001; Frank 2002; Djordjevic et al. 2004a, 2004b). In most of these studies, the effective combinations were shown to be congruent, possibly due to food consumption experiences (Stevenson et al. 1995). Similarly, specific colors have been found to influence the perception of specific tastes (Maga 1974; Johnson and Clydesdale 1982; Johnson et al. 1982). Recent studies have provided evidence that these effects are mediated by the central, rather than peripheral nervous system (Sakai et al. 2001; Djordjevic et al. 2004a, 2004b), and can be seen even with imagined odors, albeit in a more limited manner (Djordjevic et al. 2004a, 2004b). Given that experience-based cross-modal effects on taste perception are mediated centrally, it is possible that

these sensory cues form food identity information in the brain and that this influences taste perception. However, as those studies have used sensory contexts, it is still unclear whether the food identity information itself can influence taste perception.

Examining the influence of food-name labels is an alternative way of exploring this possibility. In fact, this has been done in other sensory domains with positive results. Several olfactory studies have revealed that odor-identity information presented as object names affects olfactory perception. Herz and von Clef (2001) presented odors with name labels such as “cheese” or “vomit.” The same odor was perceived to be more pleasant when it was labeled with pleasant, rather than unpleasant, names. They also found differences in perceived familiarity and intensity for some combinations of names and odors. There are multiple supportive studies reporting consistent effects of names on odor perception, especially on its hedonic aspect (Ayabe-Kanamura et al. 1997; Herz 2003; Bensafi et al. 2007; Djordjevic et al. 2008). In addition, there is a study showing the effect of food identity information presented as food names on the liking of food, in which the evaluation was performed on food that gives rise to flavor where the component sensory stimuli included appearance, odor, taste, and texture (Tuorila et al. 1994).

As in those studies on odor and flavor, food-name labels might influence the perception of pure taste. However, the influence on taste perception might differ from that of odor or flavor as it lacks an olfactory component. Odors, which generally take on the name of their source (e.g., “the odor of cheese”), are strongly associated with their source and considered to be source attributes. In contrast, tastes are identified with specific expressions, such as “sweet.” Moreover, odor, but not taste, has been suggested to confer information about a food’s identity (Mozell et al. 1969). The different roles of taste and odor can be easily experienced by pinching our nose while drinking fruit juice. This shuts out odor, making it difficult to identify the kind of fruit used in the juice. Considering these factors, the association of food names with tastes may be weaker than that with odors, if not nonexistent.

Hence, we asked whether food identity information presented as food-name labels would influence the perception of basic tastes. Basic tastes are rarely described using food names unless they are perceived with odors, and in past studies involving verbal descriptions of basic tastes, most of the words collected were directed to taste quality but not to food (O’Mahony and Ishii 1986; Ishii and O’Mahony 1987). Therefore, we first screened a pool of taste samples for tastes related to food names. Using the screened samples, we compared the intensity, hedonicity, and familiarity ratings, the 3 commonly used aspects of taste, through participants who tasted samples with or without food-name labels.

## Materials and methods

### Participants

Forty-six university students participated in this study. All participants’ native language was Japanese, and all had

a self-reported normal sense of taste. None of them had been involved with any stage of sample or food-name screening. Participants were randomly assigned to 1 of 2 groups: food-name label (FL,  $N = 27$ ) and control (CL,  $N = 19$ ). We assigned a greater number of participants to the FL than the CL group because we were considering subdividing the FL group into those who perceived the taste appropriate to the label and those who did not. The FL and CL groups were similar with respect to age ( $21.8 \pm 3.36$  and  $21.2 \pm 1.95$ , range 18–32 and 18–25, respectively) and gender (FL, 12 females, 15 males, and CL, 10 females, 9 males). They were informed of the general procedure but not the purpose of the experiment, and all participants gave their written consent. The study was approved by the institutional ethics committee of the National Food Research Institute.

### Sample screening

We prepared aqueous taste solutions using the 5 basic tastes: sucrose (sweet), sodium chloride (salty), tartaric acid (sour), quinine sulfate (bitter), and monosodium glutamate (savory/umami). To find taste samples that fit with food names, we made a large pool of taste samples and tasted them to screen for food-like samples.

A detailed description of the sample screening process is provided in the Supplementary Material. In brief, we first constructed a sample pool consisting of 211 taste samples containing 1–5 of the 5 basic tastes in all possible combinations, each with 2 intensity levels. All the samples were given potential food names. As these included local foods, the food names were then screened for their recognizability, and, after evaluation, 4 food names and 10 taste samples were selected (Table 1).

**Table 1** Taste samples, food-name labels, and congruency rating values

Sample ID	Sucrose (Sweet)	NaCl (Salty)	Tartaric acid (Sour)	Quinine (Bitter)	Monosodium glutamate (Umami/savory)	Food-name label	Congruency		FLC <i>N</i>	FLI <i>N</i>
							Median	(IQR)		
1			0.0130	0.0012		Lemon	–34	(91)	9	18
2	1.28		0.0208			Lemon	31	(72)	18	7
3	2.84	0.08	0.0116			Lemon	–31	(91)	8	18
4		0.51	0.0043		0.07	Consomme soup	0	(103)	13	13
5	1.07	0.13			0.28	Consomme soup	8	(99)	15	11
6	0.71	0.34			0.19	Consomme soup	18	(84)	17	10
7	3.20			0.0012		Coffee jelly	–23	(89)	9	17
8	4.27		0.0043	0.0004		Coffee jelly	–31	(84)	9	17
9	4.27			0.0004	0.07	Caramel candy	0	(60)	12	13
10	4.27	0.13		0.0004		Caramel candy	23	(104)	17	9

The second to sixth columns display sample composition in terms of gram solute per 100 ml ultrapure water (total organic carbon < 1 ppb). The seventh column displays food-name labels for each sample. The third from the last column gives congruency rating values obtained from the FL group, and the last 2 columns give number of participants assigned for the FLC and FLI groups, respectively (for details, see congruency section under Results). *N*, number of participants; IQR, Interquartile range.

## Design and procedure

Using a between-participant design, each participant was assigned to either the FL or the CL group. Experiments for these groups were conducted on separate days at the same approximate time (2–4 p.m.), using 5–10 participants at a time for easy observation.

For both groups, we stated that the purpose of the experiment was to collect subjective ratings of taste samples for use in future studies. Then, the participants were given a brief practice session where they were presented with unmixed aqueous solutions of sucrose (6.4 g per 100 ml), sodium chloride (0.76 g per 100 ml), tartaric acid (0.026 g per 100 ml), quinine sulfate (0.002 g per 100 ml), and monosodium glutamate (0.42 g per 100 ml). The concentration of these sample tastes was set at  $\tau$  3 of the gust scale proposed by Indow (1966) so that the perceived intensities were similar across tastes (for details, see Supplementary Material). The solutions were presented in cups with labels of sweet, salty, sour, bitter, and umami (savory), respectively. We stated that these stimuli were examples of the taste qualities indicated on the labels.

After a 10-min interval, each participant took part in an experiment session. Participants in the FL group were presented with 10 stimuli in cups labeled with food names and those in the CL group were presented with the same 10 stimuli in cups labeled with 3-digit, random numbers. We used different digits as labels for all samples presented to the CL group. The order of the stimuli was randomized across participants.

Participants rated each sample on intensity, liking, and familiarity. For intensity, we asked for the overall intensity of the solution and the intensity of each component of the 5 basic tastes. We used the labeled magnitude scale, a semantic scale of perceptual intensity characterized by quasi-logarithmic spacing of its verbal labels (Green et al. 1996) with the labels translated into Japanese. For familiarity and liking, we used a 201-point scale where +100 was “familiar” or “likable,” –100 was “unfamiliar” or “dislikable,” and 0 was “neither familiar nor unfamiliar” or “neither likeable nor dislikable.” For familiarity, we asked participants to rate samples that had tastes they would encounter in daily life, rather than those that they encountered during the experiment, as familiar. For the FL group, the congruency of the FL and the taste sample were rated on a 201-point scale with “congruent” for +100, “incongruent” for –100, and “neither congruent nor incongruent” for 0. The order for rating items was the same across samples and participants, as were intensity, liking, familiarity, and congruency (FL only).

The procedure that participants followed for tasting and rating each solution was as follows. 1) Write the name of the solution (as on the label of the cup) on the rating sheet. 2) Rinse the mouth with water. 3) Read the rating items on the sheet. 4) Take all the solutions in the cup into the mouth, taste it, and spit it out. 5) Fill in the rating form. Under all

conditions, the sample volume was 10 ml and was presented in a disposable, clear plastic cup (Asahi Kasei Pax Co., Tokyo, Japan, EI-75D, polystyrene resin). The taste samples were served at room temperature.

Participants in the FL group filled out a postexperiment questionnaire in which they were asked to rate their impressions (liking, familiarity, and intensity) of the food names used for the labels. The same scale was used as in the main experiment.

## Results

### Congruency

Perceived congruency between tastes and names observed in the FL group are summarized in Table 1. As congruency ratings varied across participants, in subsidiary analysis, we subdivided the FL group into those who perceived name and taste as FL congruent group (FLC group, congruency rating greater than 0) and FL incongruent group (FLI group, congruency rating less than 0) as shown in Table 1.

### Impression of food names

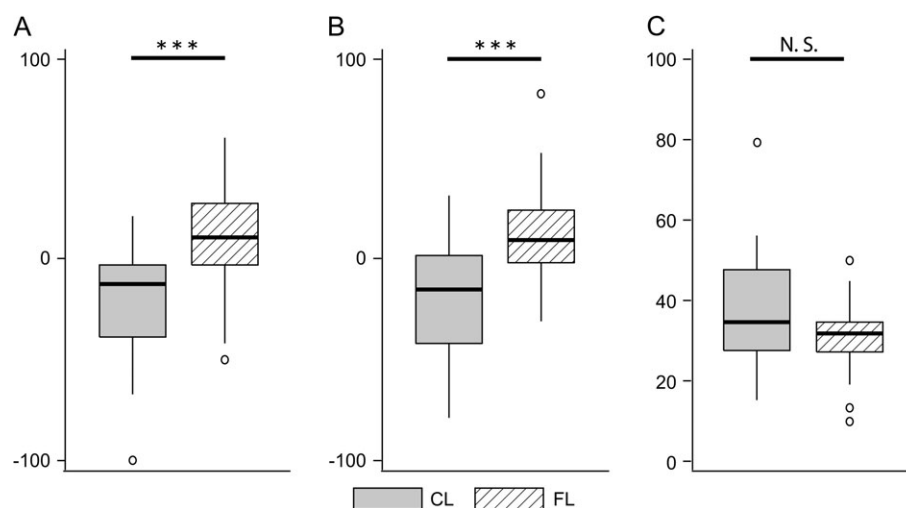
Ratings of the taste impression of food names obtained from the postexperiment questionnaire are summarized on the right side of Figure 2. Impressions of the anticipated tastes of foods, as remembered by the participants, were positive in liking (Figure 2A) and familiarity (Figure 2B), with various intensities (Figure 2C). Impressions of the intensity for each taste quality are summarized in Supplementary Figure 1.

### Overview of the name effect

In order to produce an overview of the name effect, we first analyzed the data from all 10 samples together (collapsed across samples) and compared rating scores between the CL and FL groups. The data from about half of the participants for all rating items revealed significant deviation from the normal distribution (Kolmogorov–Smirnov normality test,  $P < 0.05$ ). Therefore, we used the median as the within-subject summary statistics and applied the Mann–Whitney  $U$  test. The FL group rated taste with significantly higher liking ( $U = 112.5, P < 0.001$ ) and familiarity ( $U = 104.0, P < 0.001$ ) scores than did the CL group (Figure 1A,B). Meanwhile, no significant difference was seen in overall intensity ratings ( $U = 198.0, P = 0.05$ , Figure 1C) or for each component of the taste (data not shown).

### Sample-wise analysis

As the name effect may differ for each sample, we examined the ratings from the FL and CL groups for each sample independently using the Mann–Whitney  $U$  test. In most samples, the FL group rated tastes with higher liking and familiarity scores than the CL group. The differences for liking were significant in 6 samples ( $P < 0.05$ , Figure 2A;



**Figure 1** Overview of the name effect. Box-and-whisker plots showing taste ratings from the CL and FL groups collapsed across 10 samples. Middle line in the box, median; upper and lower edges of the box, upper and lower quartile; upper and lower ends of whiskers, maximum and minimum values within 1.5 interquartile range from the first and the third quartiles. Observations outside of the whiskers are indicated as circles. **(A)** Liking ratings, **(B)** familiarity ratings, **(C)** ratings for the overall intensity. Asterisks above horizontal bars indicate  $P$  values obtained by the Mann–Whitney  $U$  test ( $***P < 0.001$ ). N.S., not significant at  $\alpha = 0.05$ .

sample ID 1, 2, 3, 7, 8, and 10) and for familiarity in 5 samples ( $P < 0.05$ , Figure 2B; sample ID 2, 7, 8, 9, and 10). Meanwhile, the name effect on intensity ratings was significant only in sample ID 7 for overall intensity ( $P < 0.05$ , Figure 2C) and 3 samples (sample ID 1, 7, and 8) for individual taste qualities as shown in Figure 2D ( $P < 0.05$ ).

### Subsidiary analysis

Because the name effect might differ depending on perceived congruency of name and taste, we conducted a subsidiary analysis comparing the ratings from the CL, FLC, and FLI groups. The Kruskal–Wallis test was followed by a post hoc analysis using Mann–Whitney  $U$  test with the Steel–Dwass correction.

For liking and familiarity, ratings significantly differed in 8 samples among all groups (Figure 2A,B). Post hoc analysis indicated that participants in the FLC group rated tastes with significantly higher liking and familiarity scores than the CL group (Sample ID 2, 3, 4, 5, 7, 8, and 10 for liking, Figure 2A, and Sample ID 2, 3, 5, 7, 8, 9, and 10 for familiarity, Figure 2B) and than the FLI group (Sample ID 2, 3, 4, 6, 7, and 10 for liking, Figure 2A, and Sample ID 2, 3, 5, 6, 7, 8, 9, and 10 for familiarity, Figure 2B). There was only 1 sample where familiarity values were significantly different (lower) in the FLI group than in the CL group (sample ID 6). Regarding intensity, the comparison between the CL, FLI, and FLC groups only revealed significant differences in sample ID 3, presented with the label “lemon,” where the perceived intensity was higher in the FLC than in the FLI.

To further examine the influence of congruency on the taste ratings, we also calculated the Spearman’s rank corre-

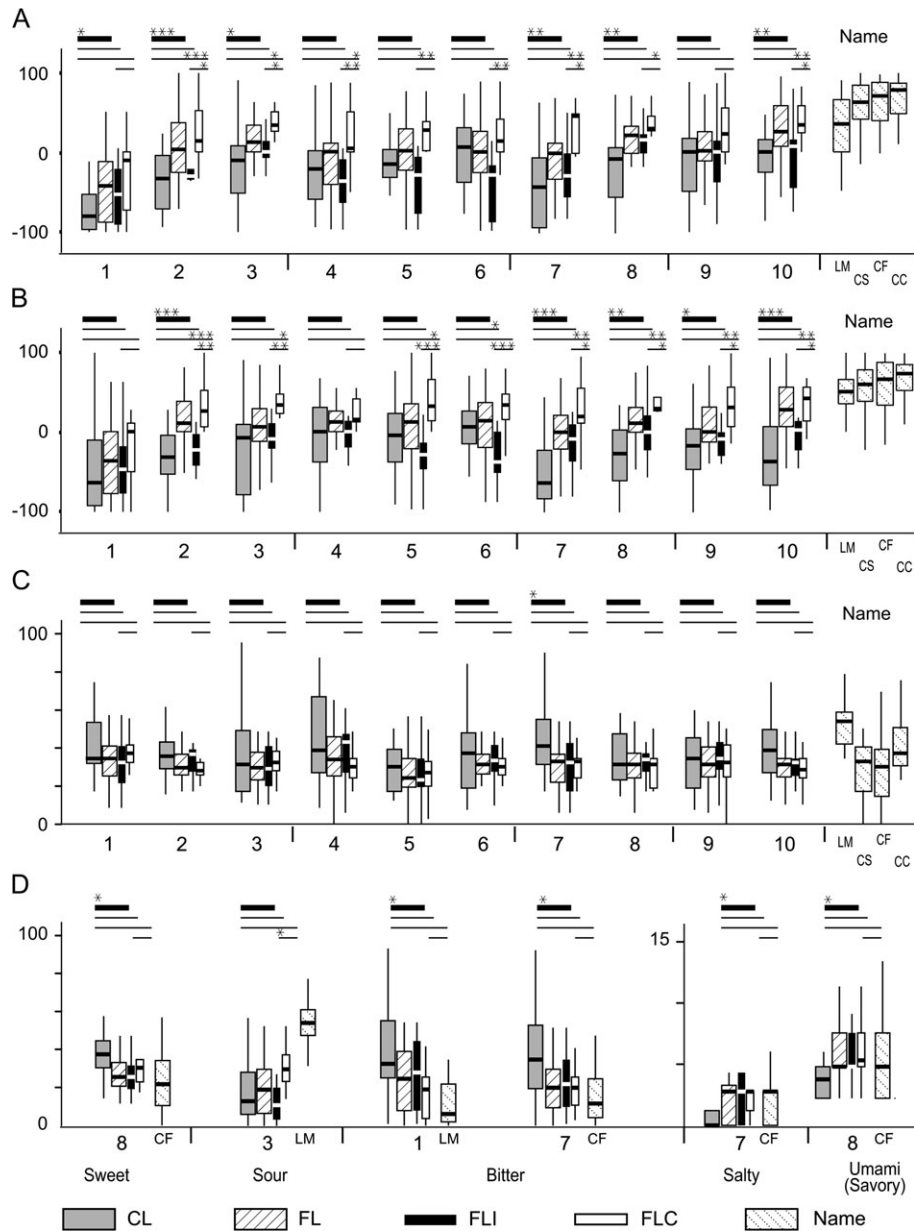
lation coefficient between congruency and each rating item. A high correlation was observed with liking and familiarity scores in most of the samples (Table 2), whereas the correlation with intensity was low, with only 3 samples exhibiting significant correlation (sample ID2 for saltiness,  $\rho = -0.45$ ; sample ID10 for bitterness,  $\rho = -0.48$ ; and sample ID4 for umami,  $\rho = 0.45$ ).

### Discussion

This study revealed that food-name labels on solutions of basic tastes enhance liking and familiarity more than random number labels, especially when the names and tastes are perceived as being congruent. Although a statistically significant effect on intensity ratings was observed in some cases, the effect on intensity was not as prominent.

#### Liking and familiarity

It has been shown that hedonic evaluation of stimuli is influenced by information in 1 of 2 ways: assimilation and contrast. In assimilation, a participant’s evaluation leans toward the value represented, whereas in contrast, it goes counter to it. For odors, the effects of identity information have been assimilation, where the pleasantness of an odor was increased by pleasant and decreased by unpleasant identity information (Ayabe-Kanamura et al. 1997; Herz and von Clef 2001; Herz 2003; Djordjevic et al. 2008). In the current experiment, postexperiment questionnaires revealed that all the food names used had positive liking scores and that the food-name labels raised liking scores. Therefore, it is likely that the food identity information had a hedonic assimilation effect for tastes, as with for odors.



**Figure 2** Sample-wise analysis of the name effect. Taste ratings of CL and FL for each sample are shown. Values from the FLI and FLC groups, the subdivision of the FL group, are also shown. Format of the box-and-whisker plots is the same as in Figure 1, except that observations outside of the whiskers are omitted for clarity. The upper bold horizontal bars indicate comparisons between the FL and CL groups, and the asterisks above these bars indicate  $P$  values obtained using the Mann–Whitney  $U$  test ( $*P < 0.05$ ,  $**P < 0.01$ ,  $***P < 0.001$ ). The lower 3 horizontal bars indicate the results of post hoc analysis conducted for CL versus FLI, CL versus FLC, and FLI versus FLC comparisons with asterisks above these bars indicating  $P$  values obtained using the Mann–Whitney  $U$  test ( $*P < 0.05$ ,  $**P < 0.01$ ,  $***P < 0.001$ ). No asterisks indicate no significance at  $\alpha = 0.05$ . The rating values for participants' taste impressions of food names are indicated under the "Name" heading for reference. **(A)** Liking ratings, **(B)** familiarity ratings, **(C)** intensity ratings (for overall taste), and **(D)** intensity ratings (for individual taste qualities). In **(D)**, only samples that exhibited significant differences are shown for each taste quality, and the ratings for the names are indicated beside them. Complete data can be seen in Supplementary Figure 1. LM, lemon; CC, caramel candy; CS, consomme soup; and CF, coffee jelly.

Thus far, there has been only 1 study, to our knowledge, directly showing that odors are perceived as more familiar when presented with, rather than without, identity information (Ayabe-Kanamura et al. 1997). In the current study, we

observed that food-name labels increased familiarity, presenting the first experimental evidence that food identity information can enhance the familiarity of tastes. However, rather than regarding familiarity as an independent factor,



**Table 2** Spearman's rank correlation coefficient between congruency and ratings obtained from the FL group

Sample ID	1	2	3	4	5	6	7	8	9	10
Liking	0.36	0.63***	0.45*	0.72***	0.75***	0.75***	0.61***	0.58**	0.76***	0.56**
Familiarity	0.36	0.80***	0.39*	0.58**	0.80***	0.80***	0.54**	0.60***	0.83***	0.52**

Significance of the correlation coefficient is indicated as \* $P < 0.05$ , \*\* $P < 0.01$ , and \*\*\* $P < 0.001$ .

it may be more appropriate to consider it in association with hedonicity. In fact, rating scores of liking and familiarity were positively correlated in most of the samples (data not shown). One possible factor behind the correlation may be food neophobia: the reluctance to eat, or the avoidance of, new foods (Rozin and Vollmecke 1986; Zellner 1991). Zellner et al. (1991) reported that the ability to identify odors of fruit beverages increases the liking of those odors, possibly due to the increased familiarity. In our study, familiarity ratings from the CL group showed that the samples were generally rated as unfamiliar. This changed with the presence of a food name, and the increased familiarity may have eased any unpleasant feeling resulting from neophobia.

Congruency is another factor that is likely related to liking and familiarity scores. In the current study, we found significantly higher liking and familiarity scores in the FLC group than in either the CL or FLI groups. We also found a positive correlation between congruency and liking or familiarity scores. This is in line with an earlier study examining the effect of food-related odors on taste perception, where the congruency ratings were shown to account for a significant part of the pleasantness ratings (Schifferstein and Verlegh 1996). Likewise, congruency of taste and name in our study may have enhanced the liking of tastes, although whether congruency of the names and tastes follows from or leads to an increase in the liking of a taste is unclear. A future study using a within-participant design would be able to address this issue more clearly.

On the other hand, in some samples, median rating scores were lower in the FLI than in the CL group (sample ID 5 and 6 for both liking and familiarity, Figure 2A,B), although the difference was significant only in sample ID 6 for familiarity. This may be explained by violations of food expectancies (e.g., as has been shown using color, taste, and temperature) leading to negative evaluations (Zellner et al. 1988; Rozin and Tuorila 1993; Deliza and Macfie 1996). Incongruent information may also lead to a contrast effect, as a larger degree of discrepancy between the expectation and stimulus is suggested to lead to contrast, rather than assimilation (Wilson and Klaaren 1992; Zellner et al. 2004).

Food-name labels are verbal information, and only a limited number of studies have been performed on verbal information's effects on taste perception. Although there are some studies that have examined the effect of verbal information such as brand information (e.g., Makens 1965; Moskowitz 1979), descriptive ingredient information (e.g.,

Tuorila et al. 1994; Wansink et al. 2000), and health information (e.g., Wansink et al. 2000; Stein et al. 2003) on the liking or pleasantness ratings for food taste, the stimuli used in these studies were foods that evoke not only tastes but also odors and other oral sensation. Therefore, until a recent study showing an effect of verbal information on hedonicity of pure taste, it remained uncertain that verbal information could influence the perception of pure taste (Grabenhorst et al. 2008). In that study, Grabenhorst et al. found that the same umami taste was rated as significantly more pleasant when presented with the label "rich and delicious taste" than with the label "Monosodium glutamate." Our current study is an important extension of that study, demonstrating that even without using an explicit descriptor such as "delicious," verbal information can change the hedonicity of pure basic tastes.

### Intensity

The name effect on perceived intensity, both on the overall taste and on each taste component, was much less prominent than that on liking. Intensity has been the main focus of studies examining the influence of food-related odors and colors on taste perception (Johnson and Clydesdale 1982; Johnson et al. 1982; Frank and Byram 1988; Frank et al. 1989, 1993; Clark and Lawless 1994; Schifferstein and Verlegh 1996; Stevenson et al. 1999; Sakai et al. 2001; Frank 2002; Djordjevic et al. 2004b), with the effect of odors studied more extensively than that of colors. Of the many odors tested, lemon and caramel are related to the labels in the current study (the labels we used included lemon and "caramel candy"). Although the reported effects of these odors have been significant (Schifferstein and Verlegh 1996; Stevenson et al. 1999; Frank 2002), in our study, no effect was observed with caramel candy and the lemon label had significant difference only between the FLI and FLC groups.

Does this mean that the effects of odors on taste intensity are generally stronger than those of verbal information? A number of studies have shown an effect of odors on perceived taste intensity, on taste threshold (Dalton et al. 2000; Pfeiffer et al. 2005), and on taste detection (Djordjevic et al. 2004a) under a wide variety of experimental conditions. Therefore, the effect of odors on taste intensity perception seems to be robust. However, there are studies suggesting that the observed effects differ depending on experimental conditions such as rating methods and experimental instructions (Frank et al. 1993; Clark and Lawless 1994; Frank

2002) or concentrations of tastants (Frank et al. 1989, 1993; Schifferstein and Verlegh 1996; Djordjevic et al. 2004b). Because the current study is the first to focus fully on food labels, it is still too early to conclude that odor is more tightly linked to perceived intensity of tastes than labels are. Further investigation directly comparing the effects of labels and odors using comparable experimental conditions will clarify this issue.

### Limitations

There were certain technical limitations in our study. First, in the current study, ratings of taste were taken after participants spit out the taste solution. We chose this method to avoid dilution of the taste solution. However, this procedure made it difficult to distinguish whether the effects observed on the ratings were functions of perceived taste or taste in memory. Second, we must consider the possibility that the rating differences reflected response bias rather than a change of perception. Response bias has been suggested in studies of taste–odor mixtures (Frank et al. 1993; Clark and Lawless 1994, Frank 2002), where odor-induced changes of taste ratings were seen when participants were asked to rate only taste but not when they were asked to rate odors in addition to taste. They suggested that, in the former condition, subjects tended to expand their concept of taste to include similar sensory attributes (odor in this case) in their judgments, and thus, the change of taste ratings reflected response bias. As we studied taste–name combinations, we consider that a similar concept expansion is unlikely because a name is not a sensory attribute but rather a higher cognitive attribute. However, this should be confirmed in a future study.

### Future perspective

As demonstrated, food identity information presented as food-name labels influences the liking, familiarity, and, in some cases, perceived intensity of pure basic tastes. To date, the effect of food identity information on the perception of pure tastes has been only indirectly suggested by studies examining the effect of odors or colors, and the mechanisms of those effects are not yet fully elucidated. Is there a common mechanism between the influences of food names, odors, or colors on taste? Future studies comparing the effect of labels and sensory cues may shed light on the mechanisms of the effect of both sensory and verbal cues related to food identity on taste perception.

### Supplementary material

Supplementary Figure 1 can be found at: <http://www.chemse.oxfordjournals.org/>.

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### References

- Ayabe-Kanamura S, Kikuchi T, Saito S. 1997. Effect of verbal cues on recognition memory and pleasantness evaluation of unfamiliar odors. *Percept Mot Skills*. 85:275–285.
- Bensafi M, Rinck F, Schaal B, Rouby C. 2007. Verbal cues modulate hedonic perception of odors in 5-year-old children as well as in adults. *Chem Senses*. 32:855–862.
- Clark CC, Lawless HT. 1994. Limiting response alternatives in time-intensity scaling: an examination of the halo-dumping effect. *Chem Senses*. 19: 583–594.
- Dalton P, Doolittle N, Nagata H, Breslin PA. 2000. The merging of the senses: integration of subthreshold taste and smell. *Nat Neurosci*. 3:431–432.
- Deliza R, Macfie HJH. 1996. The generation of sensory expectation by external cues and its effect on sensory perception and hedonic ratings: a review. *J Sens Stud*. 11:103–128.
- Djordjevic J, Lundstrom JN, Clement F, Boyle JA, Pouliot S, Jones-Gotman M. 2008. A rose by any other name: would it smell as sweet? *J Neurophysiol*. 99:386–393.
- Djordjevic J, Zatorre RJ, Jones-Gotman M. 2004a. Effects of perceived and imagined odors on taste detection. *Chem Senses*. 29:199–208.
- Djordjevic J, Zatorre RJ, Jones-Gotman M. 2004b. Odor-induced changes in taste perception. *Exp Brain Res*. 159:405–408.
- Frank RA. 2002. Response context affects judgments of flavor components in foods and beverages. *Food Qual Prefer*. 14:139–145.
- Frank RA, Byram J. 1988. Taste–smell interactions are tastant and odorant dependent. *Chem Senses*. 13:445–455.
- Frank RA, Ducheny K, Mize SS. 1989. Strawberry odor, but not red color, enhances the sweetness of sucrose solutions. *Chem Senses*. 14: 371–377.
- Frank RA, van der Klaauw NJ, Schifferstein HN. 1993. Both perceptual and conceptual factors influence taste-odor and taste-taste interactions. *Percept Psychophys*. 54:343–354.
- Grabenhorst F, Rolls ET, Bilderbeck A. 2008. How cognition modulates affective responses to taste and flavor: top-down influences on the orbitofrontal and pregenual cingulate cortices. *Cereb Cortex*. 18: 1549–1559.
- Green BG, Dalton P, Cowart B, Shaffer G, Rankin K, Higgins J. 1996. Evaluating the 'Labeled Magnitude Scale' for measuring sensations of taste and smell. *Chem Senses*. 21:323–334.
- Herz RS. 2003. The effect of verbal context on olfactory perception. *J Exp Psychol Gen*. 132:595–606.
- Herz RS, von Clef J. 2001. The influence of verbal labeling on the perception of odors: evidence for olfactory illusions? *Perception*. 30:381–391.

- Indow T. 1966. A general equi-distance scale of the four qualities of taste. *Jpn Psychol Res.* 8:136–150.
- Ishii R, O'Mahony M. 1987. Taste sorting and naming: can taste concepts be misrepresented by traditional psychophysical labeling systems? *Chem Senses.* 12:37–51.
- Johnson J, Clydesdale FM. 1982. Perceived sweetness and redness in colored sucrose solutions. *J Food Sci.* 47:747–752.
- Johnson JL, Dzendolet E, Damon R, Sawyer M, Clydesdale FM. 1982. Psychophysical relationships between perceived sweetness and color in cherry-flavored beverages. *J Food Prot.* 45:601–606.
- Maga JA. 1974. Influence of color on taste thresholds. *Chem Senses.* 1: 115–119.
- Makens JC. 1965. Effect of brand preference upon consumers' perceived taste of turkey meat. *J Appl Psychol.* 49:261–263.
- Moskowitz H. 1979. Mind, body and pleasure: an analysis of factors which influence sensory hedonics. In: Krooze JHA, editor. *Preference behaviour and chemoreception.* Information Retrieval Ltd. p. 131–144.
- Mozell MM, Smith BP, Smith PE, Sullivan RL Jr, Swender P. 1969. Nasal chemoreception in flavor identification. *Arch Otolaryngol.* 90:367–373.
- O'Mahony M, Ishii R. 1986. A comparison of English and Japanese taste languages: taste descriptive methodology, codability and the umami taste. *Br J Psychol.* 77(Pt 2):161–174.
- Pfeiffer JC, Hollowood TA, Hort J, Taylor AJ. 2005. Temporal synchrony and integration of sub-threshold taste and smell signals. *Chem Senses.* 30: 539–545.
- Rozin P, Tuorila H. 1993. Simultaneous and temporal contextual influences on food acceptance. *Food Qual Prefer.* 4:11–20.
- Rozin P, Vollmecke TA. 1986. Food likes and dislikes. *Annu Rev Nutr.* 6: 433–456.
- Sakai N, Kobayakawa T, Gotow N, Saito S, Imada S. 2001. Enhancement of sweetness ratings of aspartame by a vanilla odor presented either by orthonasal or retronasal routes. *Percept Mot Skills.* 92:1002–1008.
- Schiffstein HN, Verlegh PW. 1996. The role of congruency and pleasantness in odor-induced taste enhancement. *Acta Psychol (Amst).* 94:87–105.
- Stein LJ, Nagai H, Nakagawa M, Beauchamp GK. 2003. Effects of repeated exposure and health-related information on hedonic evaluation and acceptance of a bitter beverage. *Appetite.* 40: 119–129.
- Stevenson RJ, Prescott J, Boakes RA. 1995. The acquisition of taste properties by odors. *Learn Motiv.* 26:433–455.
- Stevenson RJ, Prescott J, Boakes RA. 1999. Confusing tastes and smells: how odours can influence the perception of sweet and sour tastes. *Chem Senses.* 24:627–635.
- Tuorila H, Meiselman HL, Bell R, Cardello AV, Johnson W. 1994. Role of sensory and cognitive information in the enhancement of certainty and liking for novel and familiar foods. *Appetite.* 23:231–246.
- Wansink B, Park SB, Sonka S, Morganosky M. 2000. How soy labeling influences preference and taste. *Intern Food Agribus Manage Rev.* 3: 85–94.
- Wilson TD, Klaaren KJ. 1992. "Expectation whirls me around": the role of affective expectations in affective experience. In: Clark MS, editor. *Emotion and social behavior: review of personality and social psychology.* Newbury Park (CA): Sage. p. 1–31.
- Zellner DA. 1991. How foods get to be liked: some general mechanisms and some special cases. In: Bolles RC, editor. *The hedonics of taste.* Hillsdale (NJ): Lawrence Erlbaum Associates. p. 199–217.
- Zellner DA, Bartoli AM, Eckard R. 1991. Influence of color on odor identification and liking ratings. *Am J Psychol.* 104:547–561.
- Zellner DA, Stewart WF, Rozin P, Brown JM. 1988. Effect of temperature and expectations on liking for beverages. *Physiol Behav.* 44:61–68.
- Zellner DA, Strickhouser D, Tornow CE. 2004. Disconfirmed hedonic expectations produce perceptual contrast, not assimilation. *Am J Psychol.* 117:363–387.

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