Patterns of sweet liking in sucrose solutions and beverages

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A B S T R A C T

While preferred levels of sweetness are known to differ across individuals, investigations of hedonic responses to sweetness across multiple concentrations in both model system and beverage are limited. The objective of this study was to classify people according to their preferred sweetness in sucrose solutions and beverages. The stimuli were water and flavored beverages, each containing five levels of sucrose. A total of 200 female subjects rated liking and intensity of sweetness for sucrose solutions, and they conducted paired preference tests using the Monell forced-choice, paired-comparison, tracking procedure. These tests were replicated for the beverage. These evaluations were conducted on two separate occasions, once while the subjects were hungry and once relatively sated. Hierarchical cluster analysis revealed three distinct clusters based on the hedonic ratings. Cluster 1 showed positive hedonic ratings with increased sucrose concentration in both systems. Cluster 2 showed positive ratings to sucrose increases in the beverage, but not in the sucrose solution. Cluster 3 showed an inverted-U shaped pattern. These patterns were confirmed by the result of the Monell test. Similar trends were observed when the subjects were asked to rate liking of chocolates and in ratings of preferences for commonly consumed sweet and savory food items.

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Introduction

A universal preference for sweet tastes is evident in the stereotypical and unambiguously positive facial responses of humans and some other mammals even shortly after birth (Desor, Maller, & Turner, 1973; Steiner, Glaser, Hawilo, & Berridge, 2001). Throughout life, sweetness remains an important influence on food acceptability and choice (Birch, 1999; Blundell, Rogers, & Hill, 1988; Mela & Sacchetti, 1991). However, simple sugars are associated with health problems such as obesity and diabetes (Malik, Schulze, & Hu, 2006; Palmer et al., 2008). Soft drinks are a major source of sugar energy in Western diets (Bray, Nielsen, & Popkin, 2004), and specifically, consumption of one or more sugar sweetened soft drinks per day is related to metabolic syndrome (Dhingra et al., 2007). For this reason, understanding factors that determine variations in hedonic responses to sweetness is of major importance.

As sweetness levels increase, a pattern of hedonic responses that follows an inverted-U has been reported across different cultures (Paffmann, 1980; Prescott, 1998; Prescott et al., 1992, 1997). Thus, liking for sweetness is thought to increase with sucrose concentration up to approximately 10–12% w/v and then gradually decrease from this point (Yeomans, Tepper, Rietzschel, & Prescott, 2007). However, despite the apparently universal acceptance of sweet tastes overall, individual variations in response to increasing levels of sweetness have been reported. Pangborn (1970) measured liking for seven concentrations of sucrose solutions and described three distinct groups showing different hedonic response patterns. Similarly, Moskowitz (1971) reported that the pleasantness of sugars was not constant over concentration and he later (Moskowitz, Jacobs, & Lazar, 1985) segmented subjects into different clusters by hedonic ratings of sweetness. Subsequent studies have classified hedonic responses to sweetness into sweet likers and dislikers, based of broad groupings of such variations. Sweet likers are generally those who show monotonic increases in liking across the range of sweetener concentrations studied, while sweet dislikers are those who either show monotonic decreases or reach a hedonic asymptote at low – moderate concentrations, followed by decreases in liking.

A number of correlates of the sweet liking dichotomy have been explored. The relationships between these different sweet liking patterns and 6-n-propylthiouracil taster status have been investigated (Drewnowski, Henderson, Shore, & Barratt-Fornell, 1997; Looy & Weingarten, 1992; Yeomans, Prescott, & Gould, 2009; Yeomans et al., 2007), with the conclusion that these two factors...
are generally independent. Yeomans et al. (2009) showed that a sweet liker/disliker classification was a predictor of the extent to which the sweet taste of saccharin would condition liking for a novel odor when both were presented repeatedly in solution. Only sweet likers reliably showed such conditioning, suggesting that this individual difference played a key role in flavor learning. Additionally, sweet liking patterns as a function of age, ethnicity, hormone changes, alcoholism and satiety have been described (Laeng, Berridge, & Butter, 1993; Liem & Mennella, 2002; Looy & Weingarten, 1991; Kampa-Polevoy, Garbutt, & Khatlaitov, 2003; Kampa-Polevoy, Eick, Boland, Khatlaitov, & Crews, 2004; Coldwell, Oswald, & Reed, 2009; Mennella, Lukasewycz, Griffith, & Beauchamp, 2011; Pepino & Mennella, 2005). Pepino and Mennella (2005) found that African–American children and their mothers preferred higher sweetness levels than did white children and white mothers, and they noted that the possible reason for this could be earlier experiences since African–American mothers often feed sucrose solutions to their babies. Kampa-Polevoy et al. (2003, 2004) showed evidence that sweet liking was related to alcoholism by family history. Hence, sweet likers were 2.5 times more common in those who had a parental history of alcoholism.

Mennella, Pepino, and Reed (2005) developed the Monell forced-choice, paired-comparison tracking procedure (referred to as the “Monell test” in this manuscript) for measuring sucrose preference and this protocol has been subsequently used in studies (Mennella, Pepino, Lehmann-Castor, & Yourshaw, 2010; Mennella et al., 2011; Pepino & Mennella, 2005) to measure sucrose preference according to factors such as age, ethnicity, family history of alcoholism or depression. In this paired preference procedure, participants are asked to taste a pair of sucrose concentrations and select the preferred one, with the subsequent pair determined by this choice. The most preferred sucrose concentration is determined when the participant chooses two identical stimuli consecutively. Mennella et al. (2011) suggested that this test controlled position bias and that the forced-choice procedure was easy to administer and comprehend, especially in the testing of children. One potential drawback of this procedure is that it provides on a single optimal preference point and thereby forgoes any additional information that may be contained in a pattern of responses over concentrations. One aim of the current study was to compare the Monell test with one based on intensity responses over a range of concentrations, and determine to what extent classification based on the differing approaches overlapped.

An obvious question is the extent to which sweet taste liking as a construct is a useful predictor of actual sweet (or other) food consumption. The relationships between sweet/bitter taste and liking/intake have been investigated (Dinehart, Hayes, Bartoshuk, Lainer, & Duffy, 2006; Laneir, Hayes, & Duffy, 2005), with the result that sweet and bitter taste predicted liking and/or intake. Dinehart et al. (2006) observed that relationships between sweet and bitter vegetable sensation and preference and overall intake for vegetables. However, little effort has been made to link sweet liker/disliker measures based on tasting solutions with actual food consumption or preference data. As a first step, we determined patterns of sweet liking using simple model beverages in addition to sucrose solutions. A similar classification in both contexts would, we argue, provide further evidence for the generalizability of sweet liker classifications. While, in adults, preference for sweetness in foods is context dependent (Drewnowski, Mennella, Johnson, & Bellisle, 2012; Holt, Cobiac, Beaumont-Smith, Easton, & Best, 2000). Mennella et al. (2011) recently reported an association between preferred concentrations of sugar solutions and the sugar content of preferred breakfast cereals. To expand on this finding, another aim of the study was to relate sweet liking based on both sucrose solutions and simple model beverages to ratings of liking for common consumed sweet foods and, as a control, to a similar range of primarily savory foods. We also approached this issue by asking for ratings of liking for samples of milk/dark chocolate that were consumed during the test session.

There is limited evidence that sweet liker/disliker classifications are influenced by context or other situational factors, except perhaps for hunger. Cabanac (1971, 1979) reported that the pleasantness of a taste decreases during satiation, and coined the concept of alliesthesia that is an enhancement of liking of sweet taste by hunger. In contrast, Moskowitz, Kumraiah, Sharma, Jacobs, and Charma (1976) noted that sweet preferences seemed to be robust irrespective of the degree of satiation. However, Rolls, Rolls, and Rowe (1983) measured both taste intensity and pleasantness and reported that hedonic ratings only increased when subjects were hungry. Looy and Weingarten (1991) reported that hunger status did not change the liking pattern of sweet likers. In contrast, however, sweet dislikers showed decreased dislike for sucrose solutions when they were hungry. Laeng et al. (1993) reported subjects having a ‘sweet tooth’ (presumably sweet likers) showed a significant enhancement of sweet liking by hunger. In order to help clarify the impact of hunger state on sweet liking, we tested participants in both hungry and sated states.

In this study, sucrose solutions and beverages with various sucrose concentrations were used as stimuli to investigate the responses across stimulus contexts. Subjects rated liking and intensity of sweetness, and completed the Monell test to allow comparison of the classification results using the hedonic responses in the liking rating test. All tests were repeated over two sessions with alternating hunger conditions. The characteristics of classified groups by hedonic responses were discussed on the influences of contexts such as stimuli, hunger states, and compared the results across tests instructions.

**Methods**

**Experimental design**

This experiment was designed considering stimulus context, hunger status, and test type (Fig. 1). Subjects participated in two sessions, with 1–4 day intervals between sessions, in which the tests were repeated. Only the hunger status of the subjects changed between sessions. Those in a sated state had eaten within the previous hour while those in the hunger state had not eaten within the previous 4 h. There were four tasting tests per session, which were a combination of the Monell test and liking/intensity rating test and two stimuli contexts (sucrose solutions and beverages). The order of the tests was counterbalanced across subjects, but tests with sucrose solutions were always conducted first considering the bias from stimuli context that might affect the response of subjects. There was a 3-min break between tests, and a 5-min break was given when the stimulus system was changed.

**Subjects**

A total of 200 female participants (mean age, 22.0 years, range, 18–32 years; mean body mass index [BMI], 20.1, range, 15.6–27.9) were recruited from Ewha Womans University campus in Seoul, Korea using flyers in campus. All the subjects were naïve to the experiment, and they were told that the study would examine their liking for beverages. Before starting the first session, they were informed that the samples they would be evaluating were innocuous. They understood the test procedure and agreed to participate in the test. Subjects who completed the two sessions received a monetary compensation (approx. US$10).
Stimuli

The stimuli were a series of sucrose solutions and beverages, each containing five concentrations of sucrose (3%, 6%, 12%, 24%, and 36% w/v); the concentrations selected based on Mennella et al. (2011). The beverage consisted of a commercial pack (0.14 oz) of unsweetened strawberry flavored drink mix (Kool-Aid, Kraft Foods Global, Inc., Northfield, IL) dissolved in 2 L of distilled water as recommended by the manufacturer. The stimuli were prepared weekly by dissolving the corresponding amount of sucrose in water and beverage solutions. Aliquots of stimuli (10 ml) were served at room temperature (20 ± 2 °C) in 50-ml paper cups coded with three digit random numbers.

Rating scales

Visual analogue scales (VAS; 15 cm) were used to evaluate liking and intensity of sweetness. Three vertical lines at 0.5 cm, 7.5 cm and 14.5 cm were marked on the scale. Liking was rated on the scale with the labels ‘dislike extremely’ at 0.5 cm and ‘like extremely’ at 14.5 cm. The same scale was used to assess liking for 39 items of sweet or savory foods and liking for dark/milk chocolate. The intensity of sweetness was rated on the scale with the label ‘weak’ at 0.5 cm and ‘strong’ at 14.5 cm.

Procedure

Subjects were tested in a room using a one-to-one interview style. Prior to the test, a subject was asked to indicate when she had a last meal on the check list, and it was confirmed again verbally. A subject participated in the first session while hungry. She first performed the Monell test with the sucrose solutions. The participants sipped and expectorated a pair of stimuli (6% and 24% sucrose in solution) and selected the preferred one. She was always forced to taste the left stimulus first. Each subsequent pair was determined by the stimulus that the subject preferred and the test ended when the subject selected the same stimulus twice sequentially. The trial was repeated with the same procedure as the first trial, but the left stimulus in the first trial was the weaker stimulus, and that in the second trial was stronger. The additional procedures of this test are described in Mennella et al. (2011).

The subject took a 3-min break after the Monell test and then rated liking and intensity of sweetness in the five sucrose solutions. The order of stimuli was randomized, but the weakest stimulus never followed the strongest one and vice versa to prevent contrast effects. Subjects were instructed to swirl the entire amount of the stimulus in their mouth for a few seconds and then spit it out. The subject rinsed her mouth three times with filtered water and took a 1-min break between samples. A 5-min break was given to change the stimulus context after the evaluations of sucrose solution, and then the same tests were repeated with beverages.

When participants revisited the room a few days later, the second session used the same procedures as session 1 but the subject was in a sated state. At the end of session 2, participants rated their liking for 15 sweet and 24 savory food items on 15 cm VAS, and provided details of their age, weight and height. The selected foods items were commonly consumed by Koreans and hence very familiar. Finally, the subject were required to taste and then swallow whole pieces (about 4.6 g) of dark chocolate (Kisses Dark Chocolate, Hershey's, The Hershey Company, Hershey, PA) and milk chocolate (Kisses Milk Chocolate, Hershey's, The Hershey Company, Hershey, PA) and to rate their liking for these on the 15 cm VAS.

Data analysis

A hierarchical cluster analysis was performed on the data set, which were hedonic ratings of 20 variables (5 concentrations × 2 stimuli context × 2 dietary conditions) to classify subjects based on hedonic responses in the rating task. Three clusters were selected to best describe the sweet liking patterns. A three-way analysis of variance (ANOVA) was performed to check the effects of main factors (concentrations, hunger state, and clusters) for the liking and intensity of sweetness for both stimulus systems. Additionally, an ANOVA with Duncan’s multiple range test was conducted to discriminate the stimuli (x = 0.05). For the Monell test data, two kinds of analysis were conducted. According to the previous study (Mennella et al., 2011), a geometric mean was calculated to the two most preferred sucrose concentrations of the two trials by each subject. Frequency distributions over sucrose concentrations were obtained to see if there is any association between the two methods. A chi-square test was performed to check whether there was a significant difference in the response frequencies for five concentrations and three clusters. A standardized residual of each cell of the cross tabulation was calculated, and if the value was greater than ±1.96, p-value of 0.05, the cell was considered as a driving factor affecting a significant chi-square. A paired t-test was conducted to check whether the rated liking of dark chocolate and milk chocolate was significantly different. All the data were analyzed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY).

Results

Classification by hedonic ratings

The hierarchical cluster analysis revealed three distinct clusters based on the hedonic responses, with 99 participants in cluster 1, 63 in cluster 2 and 38 in cluster 3. There were no significant differences between clusters according to either BMI or age, and no significant main effects of hunger or interactions between hunger state and clusters (p > 0.05) in either solutions or beverages. Significant differences were observed between the clusters for the liking of sucrose solutions (F = 29.35, p < 0.001) and beverages (F = 40.13, p < 0.001), and the clusters showed interactions with sucrose concentration in both solutions (F = 54.64, p < 0.001) and beverages (F = 58.17, p < 0.001). There were no significant interactions.
between clusters, concentrations and hunger in either sucrose solutions or beverages.

Cluster 1 showed positive hedonic ratings with increased sucrose concentration for both the sucrose solutions and beverages. A significant effect of sucrose concentration was observed (p < 0.05). However, no significant differences were observed between the 24% and 36% under any of the testing conditions (Fig. 2). Cluster 2 showed positive hedonic responses to the increased sucrose concentration in the beverages, but an inverted-U shape was shown in the sucrose solutions (Fig. 2). The liking pattern for beverages in this cluster was similar to that of cluster 1, which showed positive hedonic ratings with increasing sucrose concentration. However, the increasing slope was not as steep as that in cluster 1, and the lowest score was higher than that in cluster 1 and the highest score was lower than that in cluster 1. In contrast, a somewhat broader inverted-U shape was shown for the sucrose solutions. The most liked solution was 24% sucrose, but the gap between the highest and lowest scores was only 2 points, suggesting no distinct sweet liking pattern for the sucrose solutions. Cluster 3 showed an inverted-U shape pattern for the increase in sucrose concentrations for both the sucrose solutions and beverages (Fig. 2). People who showed a similar pattern were classified as sweet dislikers in previous studies (Yeomans et al., 2007, 2009). The inverted U-shape pattern had a 12% sucrose maximum concentration. Moreover, the subjects mostly gave higher scores for lower concentrations (3% and 6%) than for higher concentrations (24% and 36%).

Sweetness ratings

The rated sweetness of the five sucrose concentrations in sucrose solutions and beverages according to the clusters is shown in Fig. 3. Intensity ratings increased with sucrose level for all testing conditions of all clusters, as expected. Significant differences were observed for the sweetness intensity of both sucrose solutions (F = 47.15, p < 0.001) and beverages (F = 66.47, p < 0.001). There were no significant interactions with clusters, concentrations or hunger in either sucrose solutions or beverages.

Optimal sweetness by Monell test

The most preferred sucrose concentration determined by the Monell test is listed according to the clusters in Table 1. Significant differences were observed among the clusters for the most preferred sucrose concentration under the four testing conditions (p < 0.001). The most preferred concentration was highest in cluster 1 under all four conditions, while cluster 3 preferred the lowest sucrose concentration under all testing conditions.

The number of subjects who selected the corresponding concentration to their most preferred sweetness in each trial was represented as percentage over sucrose concentrations (Fig. 4). The chi-square analysis indicated significant differences among clusters and concentrations under the four testing conditions (p < 0.001). Cluster 1 showed lower observed counts than expected in 6% sucrose and higher observed counts than expected in 24% sucrose. More than half of all subjects in cluster 1 preferred 24% sucrose most under all testing conditions. Cluster 2 also showed the largest percentages of subjects preferring 24% sucrose, but this differed depending on the stimulus context. Over half of the subjects selected 24% sucrose as their most preferred sucrose level in the beverages, while a lower percentage of subjects selected 24% sucrose and the percentage in 6% of sucrose increased. This trend was also shown in rating (Fig. 2). Cluster 3 showed higher observed counts than expected for 6% sucrose while less than 4% of subjects selected the 36% of sucrose as their most preferred concentration.

Liking for sweet and savory food items

The liking ratings for the 15 sweet and 24 savory foods according to the clusters are shown in Fig. 5 and Fig. 6. There were significant differences (p < 0.05) among clusters in three sweet foods (chocolate flavored milk, donut, and coffee with artificial sweetener) and five savory foods (cream sauce pasta, sweet and sour pork, cream cheese on bagel, fried rice and Chinese noodle). The three clusters showed similar trends for liking of the 15 sweet food items, but cluster 1 had higher scores to most sweet items than the other clusters, especially cluster 3. Cluster 1 gave higher scores to 9 items than the other clusters, including ice cream, cake, shake, chocolate flavored milk, donut, fruit juice, fruit jelly on toast, soda and candy, but significant difference among clusters were observed in only two foods, chocolate flavored milk and donut. In contrast, cluster 3 gave the highest scores to rice cake only, which is less sweet than cake, but it was non-significant. Of the 24 savory food items, cluster 1 gave high scores to the majority of meaty and fatty foods, but significantly higher ratings were observed in five items including cream sauce pasta, sweet and sour pork, cream cheese, and five savory foods (cream sauce pasta, sweet and sour pork, cream cheese on bagel, fried rice and Chinese noodle).

Fig. 2. Mean liking ratings for each of the three clusters as a function of sucrose concentration under the four test conditions.
on bagel, fried rice, and Chinese noodle. Cluster 2 showed a similar pattern to cluster 1, but they tended to give lower scores to most items than cluster 1. Cluster 3 gave higher scores for salad, miso soup, chicken soup, kimchi (fermented vegetables with a variety of seasonings), french-fries, and beef soup than cluster 1 and 2.

Liking for dark chocolate and milk chocolate

Ratings of liking for dark and milk chocolate are shown in Table 2. All clusters gave higher scores to milk chocolate than dark chocolate, but this was only significant for cluster 1 ($p < 0.05$). No significant differences in liking were observed among clusters for either dark ($F = 0.797, p > 0.05$) or milk ($F = 0.368, p > 0.05$) chocolate.

Discussion

As in previous studies that have measured sweetness hedonics, we found substantial variation in the pattern of hedonic responses to increasing sweetness in the absence of any consistent variation in sweetness intensity ratings. This hedonic variation has most often been framed as a distinction between sweet likers and...
Yeomans et al. (2009) classified sweet likers/dislikers using an average hedonic score for all sweet stimuli. If the average score was higher than the mid-point of the hedonic scale, the subject was considered as a sweet liker, while if the score was lower than the mid-point, a sweet disliker. Other studies (Coldwell et al., 2009; Looy, Callaghan, & Weingarten, 1992) divided subjects into sweet liker/disliker categories visually, with subjects who showed increasing liking with increasing sucrose concentration were defined as sweet likers, while those showing decreasing liking or inverted U-shape liking with increasing sucrose concentration defined as sweet dislikers.

Here we found three distinct clusters that varied according to optimal sweetness as well as rate of rise of hedonic function. Cluster 1 showed a steep increase in sweet liking to asymptotic sweetness liking at 24–36% sucrose concentration. When considered in the context of typical sucrose levels (12–14%) for beverages in Korea, this group clearly represents the sweet likers seen in previous studies. Cluster 3 rated optimal sweetness at 12% and showed a sharp decline thereafter, more typical of prior definitions of sweet dislikers. Cluster 2 had relatively shallow increasing function in sucrose solutions but a steeper function in the model beverages. Previously, Holt et al. (2000) suggested hedonic

### Table 2

Mean (±SE) liking for dark and milk chocolates for the three clusters.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Dark chocolate</th>
<th>Milk chocolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster1</td>
<td>9.20 ± 0.31</td>
<td>10.12 ± 0.30</td>
</tr>
<tr>
<td>Cluster2</td>
<td>9.73 ± 0.26</td>
<td>9.75 ± 0.35</td>
</tr>
<tr>
<td>Cluster3</td>
<td>9.66 ± 0.46</td>
<td>10.14 ± 0.49</td>
</tr>
</tbody>
</table>

* Indicates a significant difference between dark chocolate and milk chocolate (*p* < 0.05).
response pattern to the sucrose solution was not a good predictor because the preferred level of sweetness seemed to be food-specific. We found one cluster showing two different hedonic patterns across stimuli contexts. This was the only finding in which responses to sweetness in the solution and beverages differed, and point to at least a limited generalizability of the sweet liking dimension to real foods/beverages. Depending on whether sweet likers are defined as cluster 1 only or a combination of cluster 1 and 2, the proportion of sweet likers in this population is estimated at approximately 50% or 80%, respectively.

We asked three other questions of these data. The first was the extent to which the rating of an ascending series of solutions, as was done here, produces a similar outcome in terms of classification as the Monell test. This latter approach provides a simple way of operationalizing sweet liking by providing a measure of the optimum sweetness concentration. This means, potentially, that there could be as many classifications as concentrations. In practice, however, there tends to be a low value and a high value. In the present study, these different values were consistent with a division into clusters 1 and 3. With the exception of the sucrose solutions in the sated condition, the Monell test did not discriminate between clusters 1 and 2. Moreover, the Monell test is unable to discriminate these different clusters on the basis of their different slopes. It therefore becomes an empirical question as to whether or not discriminating clusters 1 and 2 has some practical consequences.

The second question we posed was whether hunger state would be an influence on sweet liking. The rationale for asking this lies in the work of Cabanac and others (Cabanac 1971, 1979; Laeng et al., 1993), showing that the pleasantness of sweet tastes reduces under conditions of satiety because of decreased physiological need. Here, though, the subjects in our study presented very similar sweet liking patterns over the two hunger states. This lack of effect of hunger may reflect the relatively low degree of physiological need experienced by our participants who had been food-deprived for only four hours. Those tested in the sated state had eaten a normal meal approximately four hours prior to the testing session. In contrast, Cabanac (1979) used pre-loads of glucose, which may have a much greater impact on alliesthesia due to more rapid absorption. The other possibility is that when we feel hungry near meal time, we take a meal which is quite savory, not sweet, especially in the Korean context. It is possible that this might not produce an increase in the pleasantness of sweetness. The fact that individual patterns of sweet liking appear to persist irrespective of normal variations in hunger state suggests strongly that such patterns represent a trait hedonic response for that individual.

Finally, we attempted to link the hedonic patterns found in the different clusters to liking ratings for sweet foods. A number of common sweet foods were provided as a list and rated for liking. As a control, this was done also for a similar list of savory foods. Cluster 1 gave higher mean scores to a majority of the sweet foods than did the other two clusters, and this pattern was repeated with the savory foods as well. The only one item cluster 3 gave higher score than the other clusters was Korean rice cake which is less sweet item in the category. Sweet liking pattern seems to be food specific, but generally people have their basic criteria with sweet liking. On the one hand, cluster 3 tended to give high scores to the low-fat savory items, such as salads, miso soup, Kimchi. In the one test in which real foods – milk and dark chocolate – were tasted and rated, cluster 1 had a significantly greater preference for the sweeter milk chocolate. This raises the possibility that testing with actual foods, especially perhaps in contrasting versions varying is sweetness, might reveal associations between sweet liking as defined by solutions and dietary preferences.

A variation in sweet liking has been consistently demonstrated in an increasing number of studies over recent decades. The present study was aimed at addressing some of the issues that are important in characterizing the phenomenon. We argue that the appropriate method to define the different sweet liking groups should be based on a pattern across multiple concentrations, rather than being defined by a single, optimal concentration. Clearly, as shown by the distinction between clusters 1 and 2, the rate of increase in liking provides an additional defining feature.

Given that very many of the most liked, and indeed energy-dense, foods are characterized by high levels of sweetness (often in combination with fat), there is a need to explore further the relationship between sweet liking based on solutions and actual food preferences or choices. A number of relationships between the bitterness of PROP and/or fungiform papillae densities and preferences for, and intake of, various foods have been described (Duffy, Peterson, Dinehart, & Bartoshuk, 2003; Duffy et al., 2010; Hayes & Duffy, 2008). Sweetness liking may also prove to be an important taste phenotype, variations in which help explain sweet food intake. It has already been shown that variations in sweet liking act to influence the degree with which we develop liking for foods. For sweet likers, the pairing of a flavor with a sweet taste will result in a liking for that flavor; for sweet dislikers, the result may be no increased liking or even a learned dislike for the flavor (Yeomans et al., 2009).

There is obviously a need, too, for research into the etiology of this phenotype. How such differences arise out of the newborn’s universal acceptance of sweet tastes is not known. There is evidence that greater liking for sweetness is linked to higher consumption of both added sugars and sweet foods (Duffy et al., 2003; Holt et al., 2000) suggesting the importance of experience/learning. Thus, among African-Americans, higher rates of sweet liking have been reported, and one interesting habit in such populations is for mothers to feed their infants sweetened water. In both adults and children, the experience of a highly sweet version of a product produces an increased preference for that version (Holt et al., 2000). At the same time, the pleasantness of very sweet solutions of sugar has been found to be partly heritable as has the pleasantness and frequency of consumption of selected sweet foods. Craving for sweet foods such as chocolates, while apparently not related to bodily needs, similarly also seems to be partly heritable (Keskitalo et al., 2007). These findings are consistent with the fact that the sweet liker/disliker distinction is not associated with different degrees of sensitivity to sweetness, but rather seems to be confined to how much we liked increasing sweetness.

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References

the metabolic syndrome in middle-aged adults in the community. Circulation, 716, 480–488.