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Patterns of sweet liking in sucrose solutions and beverages

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ABSTRACT

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.

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 (Pfaffmann, 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, Rietschel, & 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 responses 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

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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; Kampov-Polevoy, Garbutt, & Khalitov, 2003; Kampov-Polevoy, Eick, Boland, Khalitov, & 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. Kampov–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 choses 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 vegetable. 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).