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Reproducibility of the measurement of sweet taste preferences[☆]

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Abstract

Developing interventions to prevent and treat obesity are medical and public health imperatives. Taste is a major determinant of food intake and reliable methods to measure taste preferences need to be established. This study aimed to establish the short-term reproducibility of sweet taste preference measurements using 5-level sucrose concentrations in healthy adult volunteers. We defined sweet taste preference as the geometric mean of the preferred sucrose concentration determined from two series of two-alternative, forced-choice staircase procedures administered 10 min apart on a single day. We repeated the same procedures at a second visit 3–7 days later. Twenty-six adults (13 men and 13 women, age 33.2 ± 12.2 years) completed the measurements. The median number of pairs presented for each series was three (25th and 75th percentiles: 3, 4). The intraclass correlation coefficients between the measurements was 0.82 (95% confidence interval [CI]: 0.63–0.92) within a few days. This study showed high short-term reproducibility of a simple, 5-level procedure for measuring sweet taste preferences. This method may be useful for assessing sweet taste preferences and the risks resulting from those preferences.

Keywords

Taste; Sweet taste; Reproducibility; Measurement; Preferences

Introduction

Obesity is associated with increased morbidity and mortality. Developing interventions to prevent and treat obesity are medical and public health imperatives. Taste is a major determinant of food intake among individuals free to select foods (Birch, 1979). In general, humans prefer foods that combine sweet and fat (Drewnowski, 1997; Drewnowski & Greenwood, 1983). The intake of such foods may potentially lead to weight gain, but the association between sweet taste preference and obesity has not been consistently

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demonstrated (Lanfer, 2012; Mattes & Mela, 1986; Tepper, Hartfiel, & Schneider, 1996). In addition, data regarding taste perceptions at the population level are available from only one study (Cruickshanks et al., 2009). This may be in part because of a lack of measurement methods that are affordable and feasible.

To identify differences in taste preferences among groups, within-individual test reproducibility must be high relative to the difference between individuals. However, only limited data (Coulon, Miller, Reed, & Martin, 2012; Kampov-Polevoy, Tsoi, Zvartau, Neznanov, & Khalitov, 2001; Kampov-Polevoy et al., 2003; Mennella, Lukasewycz, Griffith, & Beauchamp, 2011) are available concerning the reproducibility of measurements of sweet taste preferences within individuals. Although those reports suggest that the measurement of sweet taste preferences is relatively reproducible in the short term, they studied only patients with substance abuse and psychiatric disorders (Kampov-Polevoy et al., 2001, 2003), within a single day (Mennella et al., 2011), or using dairy mixtures (Coulon et al., 2012).

The Monell two-alternative, forced-choice, staircase procedure was initially developed to measure salt taste preferences (Coward & Beauchamp, 1990) and was modified to assess sweet taste preferences (Mennella, Pepino, Lehmann-Castor, & Yourshaw, 2010). The procedure is easy to administer, especially among adults. The aim of the present study was to assess the short-term reproducibility of sweet taste preference measurements using a modification of this procedure. We modified the previously published protocol (Mennella et al., 2011) to present tastants in a random order within a pair to reduce potential bias. Previously, tastants were presented in the fixed order with the lower concentration within a pair presented first for the first series and the higher concentration within a pair presented first for the second series.

Subjects and methods

Study subjects

The study protocol was reviewed and approved by the Institutional Review Board at the University of Michigan and all study subjects provided written informed consent. Study subjects were recruited through public advertisements (flyers and a website ad). Potential study subjects were pre-screened by telephone for major eligibility criteria. Study subjects were 18 years of age or older and were able to provide informed consent and to communicate in English. Pregnant women and individuals who had used tobacco products within 1 year were excluded. Other exclusion criteria included medical history or evidence of conditions that could alter gustatory senses such as chemotherapy, radiation treatment to the head or neck, kidney or liver failure; a medical history or evidence of diabetes mellitus; use of medications in the past week that could alter gustatory senses; having had a febrile illness within the last 36 h; or having had any type of oral or nasal disease or dental procedure within the last 36 h. A total of 30 healthy women and men were recruited for the study.

The study subjects' characteristics are shown in Table 1. Four of 30 study subjects were identified as ineligible (two for medication use that potentially alters taste perception; one

for smoking and one for a medical condition that potentially alters taste perception): Thus, a total of 26 study subjects (13 males and 13 females) were included in this analysis. The mean age of the study subjects was 33.2 (standard deviation [SD] 12.2) years. The study subjects were racially and ethnically diverse. About half had graduate degrees. The mean BMI was 26.6 (SD 5.1) kg/m². Ninety-two percent had their visit one and visit two procedures performed by the same examiner.

Research clinic visits

Each subject made two 60-min research clinic visits in the morning within a 3–7-day period. They were asked to fast overnight and not to brush their teeth within 1 h of the appointment time. At the clinic visits, we asked study subjects to fill out a brief questionnaire to obtain demographic information and to ensure their eligibility. During the second visit, we measured height and weight with light clothes and without shoes using standardized procedures.

Sweet taste preference procedures

Sucrose solutions

Sweet taste preference was measured using 0.09, 0.17, 0.33, 0.61, and 0.86 M equivalent sucrose (prepared as 3%, 6%, 12%, 24%, and 36% weight-to-solvent-volume) (Anonymous, 2012). The molarity of the solutions we used was different from those used in previous publication (0.09, 0.18, 0.35, 0.70, and 1.05M) (Mennella et al., 2011). The sucrose solutions were prepared daily using food-grade sucrose (American Sugar Refining, Inc., Baltimore, MD) and distilled drinking water (Absopure, Plymouth, MI).

Taste preference testing procedure

Each study subject's preferred sucrose concentration was determined using a two-alternative, forced-choice staircase procedures (Mennella et al., 2011). First, a pair of 5 mL solutions in the middle range of the concentrations (0.17 M and 0.61 M) was presented to each study subject. The study subject was asked to hold the entire solution in his or her whole mouth for approximately 5 s, to spit it out, and then to rinse his or her mouth with distilled water. Then he or she was asked which one he or she liked better. He or she was told that there is no right or wrong answer to the question. If the study subject liked the higher concentration, the next trial was conducted using the selected concentration and the concentration that was one step higher. If he or she liked the lower concentration, the next trial was conducted using the selected concentration and the concentration that was one step lower. The inter-pair intervals were timed for 30–60 s. The series was terminated when the study subject chose one concentration as both the higher and lower preferred concentration or if he or she chose the highest or lowest concentration two consecutive times. The maximum number of pairs was set to 10. One-half of the study subjects underwent an additional brief taste preference test after each series of the procedures (data not shown). The series was repeated after a 10 min break.

We modified the published procedure (Mennella et al., 2011) to present the sucrose solutions in a random order within each pair. To implement this randomization, we

generated a data-collection form with the pre-assigned letter sequences of “A” or “B” for each possible solution concentration in each trial of pairs. This was done by a computer program (SAS 9.2., 2002) so that for any given pair of adjacent concentrations, “A” and “B” were randomly assigned to either of the concentrations with a 50% probability (Fig. 1). Within the pair, the concentration assigned to “A” was presented first, and the one assigned to “B” was presented second. The data-collection forms with the new letter sequences were generated for each series, each visit day, and each study subject.

Two examiners were trained to carry out the procedures. For all study subjects, the two series that took place within a day were conducted by the same examiner. For the majority of study subjects, the same examiner was assigned to test a given study subject during visit one and visit two 3–7 days later.

Statistical analyses

We calculated summary statistics and frequencies to describe the characteristics of the study subjects. The distribution of the preferred sucrose concentrations was examined using a stacked histogram. A Shapiro–Wilk test was used to test normality of the distribution. The correlation between the preferred sucrose concentrations within the day was assessed using weighted kappa statistics (Cohen, 1968; Crewson, 2001). The effect of the presentation order within the pair was tested using Fisher’s exact test, assuming the independency of the trials of each pair. The geometric mean between the two series within the day was calculated as the preferred concentration for each study subject. The between-day intraclass correlation coefficients were calculated using ANOVA models (Lu, 2004). To assess the between-day variation and bias, Bland–Altman plots were drawn (Bland & Altman, 1986). Statistical analyses were performed using SAS 9.2 (SAS 9.2, 2002). A type I error of less than 0.05 was defined as statistically significant.

Results

Distribution of sweet taste preferences

The median number of pairs presented for each series of tests was three (25th and 75th percentiles: 3, 4). The distribution of the preferred sucrose concentrations is displayed in Fig. 2 for the study subjects with complete data during visit one and visit two. Three subjects were not included because of errors in implementing the test algorithms for at least one series (92 series for 23 study subjects). The stacked histogram suggested a bimodal distribution of sweet taste preferences. A Shapiro–Wilk test for normality failed (P -value < 0.0001).

Order of presentation and preferences

The randomized order of presentation of the concentrations within the 479 pairs resulted in the higher concentration being presented first 53.7% of the time. The concentration that was first presented was selected 51.4% of the time as being preferred. There was no association between the order of presentation and the choice of the preferred concentration (Table 2).

Within-day reproducibility of sweet taste preferences

The correlation between within-day preferred sucrose concentrations are displayed in Fig. 3. The weighted kappa statistics between the within-day series were 0.64 (95% confidence interval [CI]: 0.42–0.86) and 0.71 (95% CI: 0.54–0.87) at visit one and at visit two, respectively.

Reproducibility of between-day sweet taste preferences

The between-day correlation of the preferred sucrose concentrations is displayed as a scatter plot (Fig. 4). The between-day intraclass correlation coefficient for the preferred sucrose concentration was 0.82 (95% CI: 0.63–0.92).

The intraclass correlation coefficients were calculated among subgroups of study subjects (Bursac, 2010). Intraclass correlation coefficients were lower (less than 0.7) for the following subgroups: 0.53 (95% CI: –0.18–0.88) for African Americans and 0.67 (0.23–0.88) for study subjects with undergraduate degrees or less.

Bland–Altman plots (Fig. 5) showed no apparent bias in the between-day agreement. All of the between-day differences fell into the range within 1.96 times the standard deviation above or below the mean differences except for two subjects. This indicates that the between-day agreement is acceptable.

Discussion

If we are to measure a trait in a population that is a risk factor for a health condition, it is important that the measurement has high reproducibility, particularly relative to the variation between subjects. As shown in this study, sweet taste preferences as measured in this study satisfy this important requirement. Among healthy adults, a two-alternative, forced-choice staircase procedure provides good short-term reproducibility in assessing sweet taste preference. The between-day intraclass correlation coefficient between measurements was 0.82 (95% CI: 0.63–0.92). This high reproducibility is consistent with previous reports (Kampov-Polevoy et al., 2001, 2003; Mennella et al., 2011). Kampov-Polevoy et al. reported a weighted kappa of 0.65 (0.43–0.87) among alcoholic patients with a 9-day interval (Kampov-Polevoy et al., 2001) and 0.68 (0.60–0.76) among patients with substance abuse and psychiatric disorders with a 15-day interval between procedures (Kampov-Polevoy et al., 2003). Both used a visual analog scale rather than a two-alternative, forced-choice staircase procedure. Another study (Mennella et al., 2011), which used methods similar to ours, showed an intraclass correlation coefficient of 0.65 among healthy adults when measured twice with 3-min intervals on the same day.

We modified the previously published protocol (Mennella et al., 2011) to present tastants in a random order within a pair. Although we found that, in adults, the order of presentation within a pair did not significantly influence the study subjects' hedonic responses, random order of presentation within a pair would provide an unbiased estimate for the population level when only one series is administered.

There is a possibility that the response to the sweet taste preference procedure was influenced by social pressure to prefer a taste that is less sweet. This is a rather common problem for measurements related to nutrition. Obesity, dieting and dietary restraint, female gender, socioeconomic factors, and financial constraints have all been associated with under-reporting dietary energy intake (Hill, 2001). A similar bias might occur during sweet taste preference testing, even though our study subjects were advised that we would make no value judgment based on their responses.

The high reproducibility of sweet taste preference observed in this study and others (Coulon et al., 2012; Kampov-Polevoy et al., 2001, 2003; Mennella et al., 2011) indicates stability of sweet taste preference as well as reproducibility of the measurement. The stability of sweet taste preference might indicate that the trait has a genetic component. This hypothesis is supported by previous studies on genetic variation of the genes coding taste receptors. Associations have been observed between variation in the TAS1R2 gene and sugar consumption (Eny, Wolever, Corey, & El-Sohemy, 2010) and the TAS2R38 gene and sweet taste preference (Mennella, Pepino, & Reed, 2005). Another study found that both genes are associated with the risk of dental caries (Wendell et al., 2010), a marker for sweet-food intake (Heller, Burt, & Eklund, 2001). Within individuals, however, sweet taste preference has been shown to decrease from adolescence to adulthood (Desor & Beauchamp, 1987). During infancy, the exposure to sweetened water has also been associated with greater sweet taste preferences (Beauchamp & Moran, 1982). The full range of modifying factors for sweet taste preferences are yet to be determined.

In conclusion, this study showed high between-day reproducibility of sweet taste preferences in healthy volunteers using two-alternative, randomly-presented, forced-choice, staircase procedures. Research concerning the association between sweet taste preferences and other nutrition-related covariates is warranted. This method may be a useful tool for assessing the risks of life-style related health issues.

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	3%	6%	12%	24%	36%	Note
I		(A) X		B X		
II	A X	(B) X	A	B	A	
III	B	(A) X	B X	A	B	6% preferred
IV	B	A	B	A	B	
V	A	B	A	B	A	
VI	B	A	B	A	B	
VII	B	A	B	A	B	
VIII	B	A	B	A	B	
IX	A	B	A	B	A	
X	A	B	A	B	A	

Fig. 1.

Example of a completed data collection form for sweet taste preferences used in this study. A pair of solutions in the middle range of the concentrations (6% and 24% wt:vol of solvent, equivalent to 5.5% and 18% wt:vol of solution) was presented to each study subject. Depending on his or her response, another pair was presented (see text for details of the algorithm). The Greek numerals in the left column indicate the first to the tenth trials of pairs. "X" markings in the cells indicate the solutions that were presented to study subjects. The letter "A" or "B" was pre-assigned, and the concentration with the letter "A" was presented first within the pair. The circle indicates the concentration that the study subject preferred.

Fig. 2.

Cumulative distribution of preferred sucrose concentrations from visit one and visit two.

Fig. 3.

Within-day correlation of preferred sucrose concentrations. Note that small horizontal shifting was added to the plots to visualize overlapping points.

Fig. 4.
Between-day correlation of the preferred sucrose concentrations (wt%:vol%).

Fig. 5.

Bland–Altman plots for the repeated measurements of preferred sucrose concentrations (wt%:vol%) procedures performed 3–7 days apart. The horizontal axis shows the mean of the measurement at the two visits. The vertical axis shows the difference between the measurements for the two visits (the preferred sucrose concentration at visit two minus the preferred sucrose concentration at visit one). The horizontal reference lines indicate the mean (solid line) as well as the values 1.96 times the standard deviation of the difference between the measurements at the two visits (dotted lines).

Table 1

Characteristics of study subjects.

<i>N</i>	26
<i>Age (years)</i>	
18–24	8
25–39	11
40 or older	7
Mean $\pm$ SD	33.2 $\pm$ 12.2
<i>Sex</i>	
Male	13
Female	13
<i>Race/ethnicity</i>	
Non-hispanic white	13
African American	8
Other	5
<i>Education</i>	
College degree or less	14
Graduate degree	12
<i>Body mass index (kg/m²)</i>	
24.9 or lower	11
25.0–29.9	8
30.0 or above	7
Mean $\pm$ SD	26.6 $\pm$ 5.1
<i>Days between visit one and visit two</i>	
Mean $\pm$ SD	5.3 $\pm$ 1.4

Figures are the number of subjects who fall in the category, unless specified otherwise.

Table 2

The order of presentation and preference choices.

	Total number of pairs	Preference for the higher concentration (%)			
		Overall	According to presentation order		<i>P</i> -value
			When higher concentration was presented first	When lower concentration was presented first	
Overall	479	53.7%	54.7%	52.5%	0.14
Pairs					
0.17 vs. 0.61M	101	60.4%	67.3%	52.2%	0.15
0.09 vs. 0.17M	64	48.4%	54.8%	42.4%	0.45
0.17 vs. 0.33M	41	36.6%	52.6%	22.7%	0.06
0.33 vs. 0.61M	49	61.2%	61.9%	60.7%	1.00
0.61 vs. 0.86M	94	52.1%	46.4%	60.5%	0.21