Chem. Senses 36: 345–355, 2011
doi:10.1093/chemse/bjq134
Advance Access publication January 12, 2011

Evaluation of the Monell Forced-Choice, Paired-Comparison Tracking Procedure for Determining Sweet Taste Preferences across the Lifespan

Julie A. Mennella[1], Laura D. Lukasewycz[1], James W. Griffith[2] and Gary K. Beauchamp[1]

[1]Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA and [2]Department of Medical Social Sciences, Feinberg School of Medicine, Northwestern University, 625 N. Michigan Avenue, 27th Floor, Chicago, IL 60611, USA

Correspondence to be sent to: Julie A. Mennella, Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA. e-mail: mennella@monell.org

Accepted November 10, 2010

Abstract

Lack of methodology to assess taste in children limits its measurement in research studies that include pediatric populations. We used the Monell 2-series, forced-choice tracking method to measure sucrose preferences of a racially/ethnically diverse sample (n = 949) of children, adolescents, and adults. Reliability was assessed by comparing the results of the first series with the second series. Validity was assessed by relating participants' sucrose preferences to their preferences for foods varying in sweetness. The task required, on average, 7 presentations of aqueous sucrose solution pairs. Children and adolescents preferred more concentrated sweetness than adults ($P < 0.001$). Black children/adolescents preferred a more concentrated sucrose solution than did White children/adolescents even when gender, parental education level, and family income were used as covariates. Data from a single series were sufficient to detect age-related differences but insufficient to detect racial/ethnic differences in sweet preferences. Level of sweetness preferred significantly correlated with the sugar content of favorite cereals ($P < 0.001$) and beverages ($P < 0.02$). This method is brief and has evidence of reliability and external validity. Although a single series will yield useful information about age-related differences in taste preferences, the 2-series version should be considered when differences in race/ethnicity are of interest.

Key words: ethnicity, food preference, methodology, race, sugars, table salt

Introduction

The sense of taste controls one of the most important decisions animals make—whether to eat or reject a foreign substance. This sensory system is acutely attuned to the ''basic taste'' qualities, classes of perception that specify crucial nutrients and are detected by specialized receptors in the tongue and other parts of the oral cavity.

Hardwired from birth (Ganchrow and Mennella 2003), humans seek out sweet foods dense with energy, salty foods dense with minerals, and savory foods rich in proteins and reject bitter-tasting toxins and unripe sour foods. Intimately connected to ingestion or rejection of foods, taste contributes to weight loss or gain, other forms of nutritional deficits or surplus (Mattes and Cowart 1994), and a number of illnesses, including diabetes and hypertension (Hooper et al. 2004; McKeown et al. 2004). Although humans generally initially like or dislike the same taste qualities, individuals have striking differences in preferences and sensitivity to each quality. Taste varies with age and can be affected by early experiences, genetics, race/ethnicity, medication use, nutritional deficiencies, metabolic changes, otitis media, and addictions (Bacon et al. 1994; Levine et al. 2003; Mennella et al. 2005, 2010; Hayes et al. 2008).

Despite its importance in nutrition and quality of life, we lack appropriate and validated methodologies to measure taste sensitivity and liking in children (Chambers IV 2005; Laing et al. 2008; Mennella and Beauchamp 2008). To address this gap, the National Institutes of Health (NIH) sought an appropriate method for children for inclusion in the NIH Toolbox for Neurological and Behavioral Function (Gershon et al. 2010), which is a collection of brief assessment tools for clinicians and researchers, with emphasis on measurement in epidemiologic and longitudinal studies (Hoffman et al. 2009). The NIH Toolbox focuses on 4 domains, one of which relates to sensory functioning. The sensory domain includes developing a battery of tests to assess taste in diverse populations from 3 to 85 years. Hedonic responses to tastes are particularly important because many taste-related nutrition issues relate to acceptance (overconsumption) or rejection of foods and beverages (Hooper et al. 2004; McKeown et al. 2004; Duffy et al. 2009). Perhaps nowhere during the lifespan is this more salient than childhood (Cowart et al. 2004).

Although there is a need for epidemiological studies of taste preferences to include children, several methodological concerns that are specific to this age-group must be addressed. First, children are more prone to attention lapses and exhibit response bias, so the method should not rely on sustained attention and should control for position bias. Second, children sometimes answer questions in the affirmative, so forced-choice procedures are particularly effective (Schmidt and Beauchamp 1988). Third, the taste bud area of the tongue does not attain adult size until adolescence (Temple et al. 2002), so a whole-mouth tasting procedure is preferred. Each of these issues is addressed in the Monell 2-series, forced-choice, paired-comparison, tracking technique developed by Beauchamp and Cowart (1990) and Cowart and Beauchamp (1990) to measure salt preferences and later modified by Mennella et al. (2005, 2010) to measure sucrose preferences.

The primary focus of this study was to present some psychometric properties (i.e., reliability and validity) of this tracking method by analyzing data collected from a racially/ethnically diverse sample of children, adolescents, and adults. We determined whether participants differed by age in task performance. Also, because this study produced a large database on the intensity of sweetness most preferred, we attempted to resolve some important issues about the influence of age (Desor and Beauchamp 1987), race/ethnicity (Bacon et al. 1994; Mennella et al. 2005), body weight (McDaniel and Reed 2004), and gender (Greene et al. 1975) on the level of sucrose preferred. We examined socioeconomic factors because sugars constitute one of the most palatable and low-priced nutrients (Drewnowski 2003). Last, because many epidemiological studies require that testing be of short duration, we determined whether data obtained from only series 1 yielded similar findings as 2 series combined.

Materials and methods

Participants

The study population consisted of 356 children, 169 adolescents, and 424 adults who participated in research studies at the Monell Center from 2002 to 2006. Parents and adult subjects were recruited for research studies on taste preferences from flyers and advertisements in local newspapers and parent magazines in Philadelphia, PA. The studies either consisted of children aged 5–9.9 years and their mothers, adolescents aged 10–19.9 years and their mothers, or adults only. The adult participants were the parents of the children and adolescents (337 mothers, 2 fathers) or unrelated men and women (n = 85). Among the children and adolescent participants were 102 pairs, 9 triads, and 6 quadrads of siblings. Race/ethnicity for children and adolescents was defined by the mother's report of herself and the child's father. We use the term "race/ethnicity" because it describes both the genetic and cultural components of the groups in the sample (Sankar and Cho 2002). Individuals of non-Hispanic African–American and non-Hispanic European descent are hereafter referred to as Black and White, respectively. All procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania. Informed consent was obtained from each adult, and assent was obtained from each child 7 or more years old.

Materials

Testing materials included 30 mL disposable medicine cups (Fisher Scientific, Inc.); sucrose solutions at concentrations of 3%, 6%, 12%, 24%, and 36% w/v; a stopwatch to monitor interpair and interseries intervals; and distilled water for rinsing. Data were recorded on a tracking grid (Figure 1).

Procedures

Following not having consumed food for at least 1 h, participants were tested individually in rooms specifically designed for sensory testing. Participants were presented with pairs of solutions (5 mL each) that differed in sucrose concentration. The first pair presented was from the middle range (6% and 24% w/v; see Figure 1). Participants tasted each solution for 5 s without swallowing and then pointed to which of the pair they liked better, without instruction on how the solutions differ. Each subsequent pair contained the participant's preceding preferred concentration paired with an adjacent stimulus concentration. This pattern continued until the participant chose 2 consecutive times either the same concentration of sucrose paired with both a higher and lower concentration or the highest (36% w/v) or lowest (3% w/v) concentration (i.e., participant reached criterion). Participants rinsed once with water after tasting each sample and twice between each pair of solutions; a timer was used to ensure a 1-min interval separated each pair presentation. The entire task was repeated after a 3-min break, with stimulus pairs presented in reverse order (i.e., weaker stimulus presented first in series 1; stronger stimulus first in series 2), thus preventing children from reaching criterion response based on bias toward first or second position. The geometric mean of the 2 sucrose concentrations chosen in series 1 and 2 estimated the participant's preferred level of sucrose.

To determine whether the concentration of preferred sucrose related to children's sweet preferences in everyday life, children and adolescents were asked to name their favorite cereals and beverages because these represent significant sources of added sweeteners in children's diets (Guthrie and Morton 2000; Harris et al. 2009). They were prompted with the questions, "What is your favorite cereal (or

Series 1

A 3% (0.09M)	B 6% (0.18M)	C 12% (0.35M)	D 24% (0.70M)	E 36% (1.05M)	Notes
	X̲		(X)		
		(X̲)	X		
	(X̲)	X			
X̲	(X)				"B" preference established

Series 2

A 3% (0.09M)	B 6% (0.18M)	C 12% (0.35M)	D 24% (0.70M)	E 36% (1.05M)	Notes
	X		(X̲)		
			(X)	X̲	
		(X)	X̲		
	(X)	X̲			
(X)	X̲				
(X)	X̲				"A" preference established

$$\text{Geometric Mean} = \sqrt{\left[(\text{series 1 preference}) \times (\text{series 2 preference})\right]}$$

Figure 1 Example of a tracking grid used to assess response patterns in a paired-comparison preference task using the "tracking" format for a single subject in the Monell Sweet Preference Study, Philadelphia, PA, 2002–2006. X denotes the 2 stimuli presented in each trial, and the circles indicate which stimulus the individual preferred. Underlining denotes the stimulus presented first (in series 1, the weaker sucrose solution; in series 2, the stronger solution). Response criteria for each series were reached when the subject either chose a given concentration of sucrose paired with both a higher and a lower concentration (top grid) or chose the highest (36% w/v) or lowest (3% w/v) concentration 2 consecutive times (bottom grid). The geometric mean of the 2 preferred concentrations estimates the participant's most preferred level of sucrose.

beverage) in the whole world? What cereal (or beverage) do you bug your mom to buy the most?'' A subset of adults (n = 326) were asked to name their favorite cereal. From the Nutrition Facts product labels, we recorded the total sugar content for each cereal (g/100 g) and beverage (g/100 mL).

Participants were weighed and measured for height and then classified into body mass index (BMI) categories following the Centers for Disease Control and Prevention pediatric growth charts if children or adolescents (Kuczmarski et al. 2002) or standard BMI categories if adults (NHLBI Obesity Initiative Task Force 1998).

Data analyses

Our analyses were framed around understanding variables, including age and race/ethnicity, associated with task performance and the intensity of sucrose most preferred (hereafter referred to as sucrose or sweet preference). We categorized participants into 3 age-groups: child (<10 years), adolescent (10–19.99 years), and adult (≥20 years) to examine age-related differences in task completion, sucrose preference, and test reliability. We assessed the relationship between sucrose preference and body weight. For these analyses, we collapsed underweight and normal-weight participants into a single category because there were too few underweight children (n = 12), adolescents (n = 2), adults (n = 11) to analyze as a separate category. Racial/ethnic differences were examined only in Black and White participants because other subgroups were too small. Analyses of variance (ANOVAs) were used to examine racial/ethnicity differences in sucrose preference, which were further probed by multiple regression analyses to examine independent effects of race/ethnicity, income, education, and gender on sucrose preference and on the sugar content of preferred foods. Centered leverage values were examined to see if some cases were substantially higher than others (Cohen 1988), but no problematic cases were identified. To determine whether a single series was sufficient, we compared regressions using the geometric mean of preferred concentration across series 1 and 2 with preferred concentration from series 1 only. Regression analyses of the preferred sucrose solution with the sugar content of the most preferred cereals and beverages were also conducted to establish criterion-related validity. All analyses were conducted using SPSS (version 17; SPSS Inc.) and SAS (version 9.2; SAS Institute Inc.) at $\alpha = 0.05$. Post hoc tests were used to follow-up significant omnibus tests.

Results

Population

Child and adolescent groups were approximately evenly divided by gender, but only 7 adult participants were male (Table 1). The participants were diverse regarding age, race/ethnicity, and body weight. Family yearly income and highest level of education for the adult participants reflected the socioeconomic diversity of the Philadelphia area (Bureau of the Census, USDoC 2006–2008).

Age-related differences in task completion and reliability

Only 4 children (1.1%) refused to participate; 14 children (3.9%) and 1 adolescent (0.6%) did not want to continue after completing the first series. Among participants who completed both series (n = 930), the task required, across all age-groups, 7.1 (standard deviation = 1.1) pairs to reach criterion for both series and required 13–17 min to complete both series 1 and 2 (Table 2). We found that age-group interacted with series in the number of pairs tasted before reaching criterion, $F_{2,927} = 4.23$, $P = 0.015$. In series 1, adults required fewer pairs to reach criterion than did children, $t_{927} = 3.53$, $P < 0.001$, Cohen's $d = 0.26$, but adolescents and adults did not differ nor did adolescents and children. Children and adolescents required fewer pairs to reach criterion in series 2 than in series 1, both t's > 2.22, both P's < 0.03, both d's > 0.16. The omnibus F test for series 2 was not significant.

Table 1 Demographic characteristics of participants by age-group, Monell Sweet Preference Study, Philadelphia, PA, 2002–2006

	Age-group		
	Children, (*n* = 356)	Adolescents, (*n* = 169)	Adults, (*n* = 424)
Sociodemographic data			
Age, years: mean (SD), range	7.8 (1.3), 5–9.9	12.8 (2.6), 10–19.9	34.1 (7.1), 20–55
Gender: *n* (female:male)	199:157	96:73	417:7
Race/ethnicity: *n* (% of age-group)			
White	127 (36)	25 (15)	135 (32)
Black	174 (49)	109 (64)	233 (55)
Hispanic/Latino/Latina	2 (0.6)	3 (2)	15 (3.5)
Asian	0	3 (2)	9 (2)
Other/unknown	53 (15)	29 (17)	32 (7.5)
BMI category[a]: *n* (% of age-group)			
Underweight	12 (3)	2 (1)	11 (3)
Healthy/normal	243 (68)	94 (56)	152 (36)
Overweight	45 (13)	41 (24)	107 (25)
Obese	56 (16)	30 (18)	152 (36)
Unknown	0	2 (1)	2 (0.5)
Socioeconomic data, adults only			
Highest education level: *n* (% of adults)			
Some High school			32 (8)
High school/technical school graduate			118 (28)
Some college			144 (34)
Graduated college or higher			120 (28)
Unknown			10 (2)
Income level: *n* (% of adults)			
<$20 000			118 (28)
$20 000–$49 999			169 (40)
>$50 000			122 (29)
Unknown			15 (3)

SD, standard deviation; BMI (kg/m^2).
[a]BMI categorization follows the Centers for Disease Control and Prevention pediatric growth charts for children and adolescents (Kuczmarski et al. 2002) and standard BMI categories for adults (NHLBI Obesity Initiative Task Force 1998): underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) and obese (30.0 kg/m^2).

Our first approach to examining reliability was to determine the degree of agreement between series 1 and 2 (same rating, difference of 1, 2, or >2 concentrations); we found a small association with age, Spearman's ρ (n = 930) = 0.15, $P < 0.001$; agreement in adults was greater than in children and adolescents. Most adults (86%), adolescents (77%), and children (77%) chose the same or the next closest concentration of sucrose in series 1 and 2 (Table 2). Sucrose preferences obtained in series 2 were higher than series 1 for 40% of children, 37% of adolescents, and 32% of adults and lower than series 1 for 24% of children, 26% of adolescents, and 19% of adults. As described below, further analyses revealed that preference for a more intense sucrose in series 2 was evident in only black children and adolescents.

As a second approach to examining reliability, we quantified internal consistency reliability (i.e., the degree to which the 2 series share common variance) using single-measure intraclass correlations (ICCs) with a mixed model to examine absolute agreement. Statistically significant correlations between the concentrations of sucrose chosen in the 2 series

Table 2 Task performance and sweet preferences by age-group, Monell Sweet Preference Study, Philadelphia, PA, 2002–2006

	Age-group		
	Children, (n = 338)	Adolescents, (n = 168)	Adults, (n = 424)
Task performance measures			
Number of pairs required to reach criterion, mean (SD), range			
Series 1	3.7* (1.0), 3–9	3.6 (0.8), 3–8	3.5 (0.8), 3–7
Series 2	3.5 (0.8), 3–9	3.4 (0.7), 3–7	3.5 (0.7), 3–8
Both series	7.2 (1.2), 6–13	7.0 (1.1), 6–12	7.0 (1.1), 6–14
Agreement between series 1 and 2, n (% of age-group)			
Preferred same concentration	122 (36)	62 (37)	209 (50)
Preferred 1 concentration higher/lower	137 (41)	67 (40)	157 (37)
Preferred 2 concentrations higher/lower	49 (14)	33 (19)	44 (10)
Preferred >2 concentrations higher/lower	30 (9)	6 (4)	14 (3)
Sweet preference measures, mean (SD)			
Intensity of sucrose most preferred, geometric mean (%w/v)	18.4* (10.5)	18.7* (9.9)	14.4 (10.4)
Sucrose content of most preferred cereal (g/100 g)[a]	36.4* (13.0)	36.4* (11.6)	26.8 (14.9)
Sucrose content of most preferred beverage (g/100 mL)[b]	9.9 (4.1)	10.4 (3.6)	

SD, standard deviation.
[a]Data from 343 children, 168 adolescents, and 326 adults.
[b]Data from 351 children and 158 adolescents.
*P < 0.001, compared with adults.

were observed for children (ICC = 0.42, n = 338), adolescents (ICC = 0.46, n = 168), and adults (ICC = 0.65, n = 424), which are medium-to-large ICCs (Cohen 1988).

Age-related differences in sweet preferences

Using the geometric mean across the 2 series as the dependent variable, a one-way ANOVA showed an effect of age on sucrose preferences, $F_{2,927} = 17.81$, $P < 0.001$ (Table 2). By pairwise comparisons, adults preferred a less concentrated sucrose solution than did adolescents, $t_{927} = 4.56$, Cohen's $d = 0.42$, and children, $t_{927} = 5.22$, Cohen's $d = 0.38$, both P's < 0.001; the latter 2 groups did not differ from each other. Similar age-related differences were found for sugar content of favorite cereals, $F_{2,834} = 49.94$, $P < 0.001$. Adults preferred cereals with lower sugar content than did children, t_{834} = 9.18, Cohen's $d = 0.69$, and adolescents, $t_{834} = 7.42$, Cohen's $d = 0.69$, both P's < 0.001 (Table 2). Children and adolescents did not differ in the sugar content of their most preferred beverages, $t_{507} = 1.30$, Cohen's $d = 0.13$, $P = 0.19$, or cereals, $t < 1$, ns, $d = 0.01$. Small, but significant, correlations were found between the participants' sucrose preference and sugar content of their favorite cereals, r (n = 818) = 0.13, $P < 0.001$, and beverages, r (n = 490) = 0.11, $P < 0.02$. Similar correlations were obtained when data from only one series were used, r (n = 818) = 0.10, $P = 0.005$ for cereals, r (n = 490) = 0.12, $P = 0.010$ for beverages.

Body weight relationship with sucrose preferences

Across all participants, Black participants tended to be in higher body weight categories than did White participants: for children and adolescents, $P = 0.002$; for adults, $P < 0.001$ (Table 3). Body weight category was also assessed with 1-way analyses of covariance with race/ethnicity as a covariate. There were no statistically significant effects of body weight category on intensity of sucrose preferred for children, adolescents, or adults. Because body weight category did not have an independent effect on sucrose preferences when race/ethnicity was covaried, we did not examine it further.

Race/ethnicity and sucrose preferences

Black participants preferred a more concentrated sucrose solution than did White participants, $t_{784} = 2.55$, $d = 0.19$, P = 0.011. Because White adults had higher levels of income and education (Table 3), we used multiple regression analyses to examine the independent effects of race/ethnicity, family income, education, and gender. Adults were analyzed separately from children and adolescents.

For the adult analyses, we only included female participants because there were so few males. We used 3 dichotomous variables to represent education level (<high school education was reference) and 2 dichotomous variables to represent family income (<$20 000 was reference). Education did

Table 3 Demographic characteristics of White and Black participants, Monell Sweet Preference Study, Philadelphia, PA, 2002–2006

	Race/ethnicity		r_s[a]	*P*
	White	Black		
Adults, *n* (%)	135 (37)	233 (63)		
Age, years: mean (SD)	34.2 (7.7)	34.5 (6.6)		0.71
Education: *n* (% of race/ethnic group)			−0.31	<0.001
Some High school	3 (2)	23 (10)		
High school/technical school graduate	28 (21)	82 (35)		
Some college	40 (30)	87 (37)		
College/advanced degree	60 (44)	37 (16)		
Unknown	4 (3)	4 (2)		
Income: *n* (% of race/ethnic group)			−0.37	<0.001
<$20 000	15 (11)	87 (37)		
$20 000–$49 999	46 (34)	107 (46)		
$50 000+	68 (50)	32 (14)		
Unknown	6 (5)	7 (3)		
BMI: mean (SD)	26.5 (6.4)	30.8 (8.0)		<0.001
BMI Category[b]: *n* (% of race/ethnic group)			0.31	<0.001
Underweight/normal weight	75 (56)	58 (25)		
Overweight	29 (21)	66 (28)		
Obese	30 (22)	108 (46)		
Unknown	1 (1)	1 (0)		
Children/adolescents, *n* (%)	152 (35)	283 (65)		
BMI *Z*-score[c]	0.31	0.67		0.001
BMI category: *n* (% of race/ethnic group)			0.15	0.002
Underweight/healthy weight	114 (75)	174 (62)		
Overweight	24 (16)	46 (16)		
Obese	14 (9)	62 (22)		
Unknown	0 (0)	1 (0)		

SD, standard deviation; BMI (kg/m^2).
[a]For Spearman rho (r_s) calculations, race/ethnicity was coded White = 0, Black = 1 so that positive correlations indicate a positive association with Black race/ethnicity. Unknown data were not included in analysis.
[b]BMI categorization follows the Centers for Disease Control and Prevention pediatric growth charts for children and adolescents (Kuczmarski et al. 2002) and standard BMI categories for adults (NHLBI Obesity Initiative Task Force 1998): underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (30.0 kg/m^2).
[c]BMI *Z*-scores for children and adolescents calculated using Epi-Info software version 3.4.3 based on the 2000 Centers for Disease Control and Prevention (CDC) growth references.

not account for variation in sucrose preference, but income accounted for a significant increase in variance in sucrose preference (Table 4). Income of ≥$50 000 was associated with lower sucrose preference. Covarying income and education showed no significant effect of race/ethnicity on sucrose preferences in adults.

For the children and adolescent analyses, the groups were combined because they showed similar preferences for sucrose, cereals, and beverages. Here, the education level was that of the parent who was tested and income was of the family. Race/ethnicity with gender, parental education level, and family income as covariates had significant effects: Black children and adolescents preferred a more concentrated sucrose solution than did White children and adolescents (Table 5). Because some participants were nested within their family, we reran the regressions in Table 5 using

Table 4 Outcomes from multiple regression analyses of effects of education, income, and race/ethnicity on preferred sucrose concentration in 351 adult female participants from the Monell Sweet Preference Study, Philadelphia, PA, 2002–2006[a]

	Sucrose preference[b], series 1 and 2						Sucrose preference[b], series 1 only					
	ΔR^2	*F*	df	*B*	SE (*B*)	β	ΔR^2	*F*	df	*B*	SE (*B*)	β
Intercept				12.61*	2.38					11.71*	2.59	
Education	0.00	<1	3				0.01	<1	3			
High school/technical school graduate				1.88	2.40	0.08				2.29	2.61	0.09
Some college				2.93	2.44	0.14				4.39	2.65	0.19
College graduate or advanced degree				3.08	2.63	0.13				3.90	2.85	0.15
Family income	0.03*	4.41	2				0.03*	4.62	2			
\$20 000–49 999				−0.55	1.44	−0.03				−0.69	1.56	−0.03
≥\$50 000				−4.00*	1.76	−17*				−4.47*	1.92	−0.18*
Race/ethnicity												
(1 = Black; 0 = White)	0.00	<1	1	0.75	1.29	0.04	0.00	<1	1	0.90	1.40	0.04

df, degrees of freedom; SE, standard error; *B*, unstandardized regression coefficient; β, standardized regression coefficient; R^2, proportion of the variance in the dependent variable accounted for by the covariance; ΔR^2, the increment in R^2.
[a]These regression coefficients are from the final model that contained all the covariates. Dichotomous variables for income and education were coded "1" if the person fell in that category and "0" otherwise. Participants with missing data were listwise excluded.
[b]The unit of measure for the dependent variable is % w/v.
*$P < 0.05$.

Table 5 Outcomes from multiple regression analyses of effects of parental education, family income, and race/ethnicity on preferred sucrose concentration in 399 child and adolescent participants from the Monell Sweet Preference Study, Philadelphia, PA, 2002–2006[a]

	Sucrose preference[b], series 1 and 2						Sucrose preference[b], series 1 only					
	ΔR^2	*F*	df	*B*	SE (*B*)	β	ΔR^2	*F*	df	*B*	SE (*B*)	β
Intercept				16.52*	2.38					17.19*	2.71	
Gender												
(1 = male; 0 = female)	0.00	<1	1	−0.16	1.06	−0.01	0.00	<1	1	−0.14	1.21	−0.01
Parental education[c]	0.00	<1	3				0.01	1.23	3			
High school/technical school graduate				−1.42	2.34	−0.06				−1.53	2.66	−0.06
Some college				−0.88	2.38	−0.04				−1.32	2.71	−0.05
College graduate or advanced degree				0.61	2.58	0.03				0.93	2.94	0.03
Family income	0.00	<1	2				0.01	1.68	2			
\$20 000–49 999				0.97	1.93	0.05				2.94	1.60	0.12
≥\$50 000				0.64	2.21	0.03				2.11	1.97	0.08
Race/ethnicity												
(1 = Black; 0 = White)	0.01*	4.26	1	2.75*	1.33	0.13*	0.00	<1	1	0.35	1.52	0.01

df, degrees of freedom; SE, standard error; *B*, unstandardized regression coefficient; β, standardized regression coefficient; R^2, proportion of the variance in the dependent variable accounted for by the covariance, ΔR^2, the increment in R^2.
[a]These regression coefficients are from the final model that contained all the covariates. Dichotomous variables for income and education were coded "1" if the person fell in that category and "0" otherwise. Participants with missing data were listwise excluded.
[b]The unit of measure for the dependent variable is % w/v.
[c]All but 2 of the parents are the mothers of the children.
*$P < 0.05$.

mixed modeling. Family was entered as a random-effect variable, and the variance components covariance structure option of SAS was used. With the nested structure of the data taken into account, we obtained similar, unstandardized parameter estimates and gender was the only significant covariate when the geometric mean was used as the dependent variable. For the data obtained from series 1 only as the dependent variable, no covariate was statistically significant and the unstandardized parameters were similar to those presented in Table 5.

To explore whether sucrose preferences differed across series, we conducted a 3-way mixed ANOVA with race/ethnicity, age category, and series with repeated measures on series. There was a significant 3-way interaction, $F_{1,782}$ = 13.32, $P < 0.001$, and a significant 2-way interaction between series and race/ethnicity, $F_{1,782}$ = 12.01, $P < 0.001$. A 2 × 2 mixed ANOVA with race/ethnicity and series for each age-group revealed that only for children/adolescents was the 2-way interaction between race/ethnicity and series significant, $F_{1,416}$ = 21.47, $P < 0.001$. Black children and adolescents preferred a more concentrated sucrose solution during series 2 than during series 1, t_{272} = 6.08, d = 0.37, $P < 0.001$; whereas the intensity of sucrose preferred in series 1 did not differ from series 2 among White children and adolescents, t_{144} = –1.33, d = 0.11, ns. Boys preferred beverages with a higher sugar content than girls, even with maternal education, income, and race/ethnicity as covariates (Table 6, right).

For adults, sugar content of preferred breakfast cereals was predicted by race/ethnicity, with Black participants preferring cereals with higher sugar content, even with income and education covaried (ΔR^2 = 0.05, $F_{1,262}$ = 14.58, $P < 0.05$). However, higher education was associated with preferences for lower sugar cereals in the women themselves (ΔR^2 = 0.03, $F_{3,265}$ = 2.97, P = 0.03) and their children (Table 6, left).

Is 1 series sufficient?

Age-related differences in concentration of sucrose preferred were also evident with data from only series 1 as the dependent variable ($F_{2,927}$ = 15.24, $P < 0.001$). Regression analyses using the preferred sucrose concentration from only series 1 were compared with geometric mean of the 2 series (Tables 4 and 5, right). For adults, results with 1 series yielded a pattern similar to that with the geometric mean; income accounted for a significant proportion of variance in sucrose preference even when only 1 series was used. Using only 1 series, the effect of race/ethnicity for children and adolescents was no longer significant (Table 5, right).

Table 6 Outcomes from multiple regression analyses of effects of parental education, family income, and race/ethnicity on sucrose content of preferred breakfast cereal and beverage in 404 child and adolescent participants from the Monell Sweet Preference Study, Philadelphia, PA, 2002–2006[a]

	Sucrose content of preferred breakfast cereal[b]						Sucrose content of preferred beverage[c]					
	ΔR^2	*F*	df	*B*	*SE* (*B*)	β	ΔR^2	*F*	df	*B*	SE (*B*)	β
Intercept				34.86*	2.79					9.90*	0.91	
Gender												
(1 = male; 0 = female)	0.01	2.61	1	1.97	1.22	0.08	0.01*	5.17*	1	0.88*	0.398	0.11*
Parental education[d]	0.02*	2.63*	3				0.01	<1	3			
High school/technical school graduate				−0.72	2.75	−0.03				−0.25	0.89	−0.03
Some college				2.34	2.80	−0.09				−0.83	0.91	−0.10
College graduate or advanced degree				−1.44	3.04	−0.05				−0.04	0.99	−0.01
Family income	0.00	<1	2				0.01	1.33	2			
$20 000–49 999				−1.65	1.63	−0.07				0.44	0.53	0.05
≥$50 000				0.08	2.01	0.00				−0.34	0.65	−0.04
Race/ethnicity												
(1 = Black; 0 = White)	0.00	1.67	1	2.00	1.55	0.08	0.00	<1	1	0.07	0.50	0.01

df, degrees of freedom; SE, standard error; *B*, unstandardized regression coefficient; β, standardized regression coefficient; R^2, proportion of the variance in the dependent variable accounted for by the covariance, ΔR^2, the increment in R^2.

[a]These regression coefficients are from the final model that contained all the covariates. Dichotomous variables for income and education were coded "1" if the person fell in that category and "0" otherwise. Participants with missing data were listwise excluded.

[b]The sugar content of the cereals was measured in units of g/100 g.

[c]The sugar content of beverages was measured in units of g/100 mL.

[d]All but 2 of the parents are the mothers of the children.

*$P < 0.05$.

Discussion

Here, we demonstrate several desirable aspects of the forced-choice, paired-comparison tracking technique. First, the test can be used successfully in a racially and ethnically diverse sample of participants and across a large age range; the majority of children completed both series, and younger children were not statistically different from adolescents in the number of presentation pairs required to reach preference criteria. Second, the task was of short duration, requiring about 15 min. Third, using this method, we were able to replicate a well-known relationship between age and sweet preferences (Desor and Beauchamp 1987; Mennella et al. 2005; Coldwell et al. 2009): children and adolescents preferred higher concentrations of sucrose than did adults. Fourth, the intensity of sucrose most preferred in the laboratory was significantly related to preferences for sugars in beverages and cereals, which provides evidence of criterion-related validity. Thus, this technique is well suited to studies that examine age-related changes in taste preference and has real-world relevance.

In adult women, family income ≥$50 000 per annum was associated with lower sucrose preferences. Lower income individuals may consume more readily available, low-cost foods, which are often high in added sugars (Drewnowski 2009). Perhaps like sodium (Bertino et al. 1986), excess intake of sweet-tasting foods or beverages shifts preferences. This effect of income was not seen in children and adolescents, possibly due to the innately driven heightened sweet preference or perhaps because these children consume similar amounts of sweets in their diets.

The present study found no difference in the intensity of sucrose preferred based on body weight category of the participants. Although there is the assumption that increases in sugar consumption led to the increased rates of obesity, there are conflicting reports on the existence of a positive association between body weight and sweet preferences (for review, see McDaniel and Reed 2004; Bartoshuk et al. 2006). We caution that more research is needed to determine the real-world significance of what we are measuring in the laboratory and how it relates to food habits and the emotional (e.g., analgesic; Mennella et al. 2010) consequences of eating something sweet.

The present study also found that Black children and adolescents preferred a more concentrated sweet taste sensation than did White children, and this difference persisted even when gender and socioeconomic variables such as family income and parental education were covaried. Several hypotheses, not mutually exclusive, are presented. First, that these differences appear early in life suggests genetic variation in taste receptor genes as an underlying factor (Fushan et al. 2009, 2010). Second, Black children and adolescents preferred more concentrated sweetness in series 2 than series 1, which may reflect differences in short-term taste adaptation after exposure to sweets (Schiffman et al. 2000). That is, there may be a gradual decline in the magnitude of the perceived taste intensity following repeated samplings of the sweet-tasting solutions during the tracking procedure, leading to preferences for more concentrated sweetness over time (Lawless 1982; Schiffman et al. 1994, 2000). Whether the race/ethnic differences in allelic polymorphisms in the TAS1R3 promotor (Fushan et al. 2009, 2010) contribute to these differences is unknown. Third, the practice of feeding sugar water during infancy, which is prevalent among urban Black mothers (Parraga et al. 1988), has been associated with heightened sweet preferences during later childhood (Pepino and Mennella 2005). Although the race/ethnic differences in sucrose preference did not persist into adulthood, Black women preferred sweeter cereals than did White women (even with income and education used as covariates) perhaps reflecting established cultural food habits in older participants.

We acknowledge several limitations in the present study. First, although agreement between preferences measured in each of the series was high, and the regression analyses showed similar patterns of results using 1 versus 2 series, this wasn't the case for the effects of race/ethnicity on sucrose preferences in children and adolescents. Thus, for analyses of relationships between sucrose preference and race/ethnicity, 2 series are necessary for these age-groups. However, we caution that using only one series does not allow investigators to control for position bias, which is an important consideration for testing of children. Second, although we found associations between body weight, race/ethnicity, and income, the multicollinearity makes it difficult to separate these variables as they relate to sucrose preference. Furthermore, even if future studies use targeted recruitment procedures (e.g., recruiting various ethnic groups that are stratified on income, education, and body weight), there is still the possibility that some other unknown covariates could underlie racial/ethnic differences in sweet preferences among children and adolescents. Third, we acknowledge that other factors (e.g., marketing to children and adults) could contribute to the heightened sweet preferences in children and adolescents. Research is needed to determine whether the age-related differences in intensity of sweet taste most preferred in solutions, cereals, and beverages reflects a common biological drive among children for sweet tastes or whether the marketing of sweetened foods affects food choice (see Robinson et al. 2007) and, in turn, sweet preferences.

Summary and future directions

The forced-choice paired-comparison tracking procedure is a reliable and quick method for assessing taste preferences from childhood to adulthood in an ethnically/racially diverse population. The test is reasonably stable across trials and shows externally validity with respect to multiple criteria. We anticipate that a single series will yield useful information about taste preferences in future studies, but use of the longer (but still brief) 2-series version should be considered where differences in race/ethnicity and short-term adaptation are of interest. Additional research is needed to determine its usefulness in other race/ethnicity groups, the elderly and populations with language and cognitive impairments and by examining other outcomes of interest, such as measures of dietary habits.

Much like excess sugar consumption has been implicated in metabolic syndrome and diabetes (Ferder et al. 2010), excess salt consumption has been implicated in serious health problems, particularly hypertension and cardiovascular disease (Hooper et al. 2004). In light of evidence that adult salt preferences are strongly influenced by early experiences (Stein et al. 2006), this tracking method takes on particular significance because it was originally developed to measure salt preferences (Beauchamp and Cowart 1990; Cowart and Beauchamp 1990). The United States Department of Agriculture Dietary Guidelines (United States Department of Health & Human Services and United States Department of Agriculture 2005) stress the importance of substantially reducing the intake of foods high in added salt, and the Institute of Medicine (Henney et al. 2010) has more recently recommended that the food and drug administration set mandatory standards to gradually reduce the amount of salt added to prepared foods and that more research on salt taste preference, particularly in children, is a priority. Thus, the present method should be used to study salt preferences in a manner similar to that done here for sweet preferences to determine its usefulness in examinations of population-wide reductions in preferences that are expected to occur as a result of a lowered salt environment.

Funding

This work was supported by grants from the Pennsylvania Department of Health, the National Institute of Alcohol Abuse and Alcoholism [R01AA09523], and the Eunice Kennedy Shriver National Institute of Child Health and Human Development [R01HD37119] and by Monell Institutional Funds. This study was also funded in part with Federal funds from the Blueprint for Neuroscience Research and the Basic Behavioral and Social Science Opportunity Network (OppNet), NIH under Contract No. HHS-N-260-2006-00007-C.

Acknowledgements

We acknowledge the expert technical assistance of Ms Allison Steinmeyer, Janice Kennedy, and Aleida Silva-Garcia and the valuable discussions with and advice from Dr Beverly Cowart and Dr Susan Coldwell, domain leader of the NIH Toolbox Taste Team. We also gratefully acknowledge Dr Kwang-Youn Kim and Mrs Jennifer Beaumont for their consultation about statistical analyses. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute of Child Health and Human Development or the NIH. The Pennsylvania Department of Health specifically disclaims responsibility for any analyses, interpretations, or conclusions. Conflict of interest: None of the authors had a personal or financial conflict of interest.

References

Bacon AW, Miles JS, Schiffman SS. 1994. Effect of race on perception of fat alone and in combination with sugar. Physiol Behav. 55:603–606.

Bartoshuk LM, Duffy VB, Hayes JE, Moskowitz HR, Snyder DJ. 2006. Psychophysics of sweet and fat perception in obesity: problems, solutions and new perspectives. Philos Trans R Soc Lond B Biol Sci. 361: 1137–1148.

Beauchamp GK, Cowart BJ. 1990. Preference for high salt concentrations among children. Dev Psychol. 26:539–545.

Bertino M, Beauchamp GK, Engelman K. 1986. Increasing dietary salt alters salt taste preference. Physiol Behav. 38:203–213.

Bureau of the Census, USDoC. 2006–2008. American Community Survey, Philadelphia City, PA. Bureau of the Census, Washington, DC. Available from http://factfinder.census.gov.

Chambers E IV. 2005. Commentary: conducting sensory research in children. J Sens Stud. 20:90–92.

Cohen J. 1988. Statistical power analysis for the behavioral sciences. Hillsdale (NJ): Lawrence Erlbaum Associates.

Coldwell SE, Oswald TK, Reed DR. 2009. A marker of growth differs between adolescents with high vs. low sugar preference. Physiol Behav. 96:574–580.

Cowart BJ, Beauchamp GK. 1990. Early development of taste perception. In: McBride RL, MacFie HJH, editors. Psychological basis of sensory evaluation. London: Elsevier. p. 1–7.

Cowart BJ, Beauchamp GK, Mennella JA. 2004. Development of taste and smell in the neonate. Fetal and neonatal physiology. Vol. 2. 3rd ed. Philadelphia: Saunders. p. 1819–1827.

Desor JA, Beauchamp GK. 1987. Longitudinal changes in sweet preferences in humans. Physiol Behav. 39:639–641.

Drewnowski A. 2003. Fat and sugar: an economic analysis. J Nutr. 133: 838S–840S.

Drewnowski A. 2009. Obesity, diets, and social inequalities. Nutr Rev. 67(Suppl 1):S36–S39.

Duffy VB, Hayes JE, Sullivan BS, Faghri P. 2009. Surveying food and beverage liking: a tool for epidemiological studies to connect chemosensation with health outcomes. Ann N Y Acad Sci. 1170:558–568.

Ferder L, Ferder MD, Inserra F. 2010. The role of high-fructose corn syrup in metabolic syndrome and hypertension. Curr Hypertens Rep. 12: 105–112.

Fushan AA, Simons CT, Slack JP, Drayna D. 2010. Association between common variation in genes encoding sweet taste signaling components and human sucrose perception. Chem Senses. 35:579–592.

Fushan AA, Simons CT, Slack JP, Manichaikul A, Drayna D. 2009. Allelic polymorphism within the TAS1R3 promoter is associated with human taste sensitivity to sucrose. Curr Biol. 19:1288–1293.

Ganchrow JR, Mennella JA. 2003. The ontogeny of human flavor perception. In: Doty RL, editor. Handbook of olfaction and gustation. 2nd ed. New York: Marcel Dekker, Inc. p. 823–846.

Gershon RC, Cella D, Fox NA, Havlik RJ, Hendrie HC, Wagster MV. 2010. Assessment of neurological and behavioural function: the NIH Toolbox. Lancet Neurol. 9:138–139.

Greene LS, Desor JA, Maller O. 1975. Heredity and experience: their relative importance in the development of taste preference in man. J Comp Physiol Psychol. 89:279–284.

Guthrie JF, Morton JF. 2000. Food sources of added sweeteners in the diets of Americans. J Am Diet Assoc. 100:43–51.

Harris JL, Schwartz MB, Brownell KD, Sarda V, Weinberg ME, Speers S, Thompson J, Ustjanauskas A, Cheyne A, Bukofzer E, et al. 2009. Cereal FACTS: evaluating the nutrition quality and marketing of children's cereals. Rudd Center for Food Policy and Obesity. Available from http://www.cerealfacts.org.

Hayes JE, Bartoshuk LM, Kidd JR, Duffy VB. 2008. Supertasting and PROP bitterness depends on more than the TAS2R38 gene. Chem Senses. 33: 255–265.

Henney JE, Taylor CE, Boon CS. 2010. Strategies to reduce sodium intake in the United States. Washington (DC): Committee on Strategies to Reduce Sodium Intake; Institute of Medicine.

Hoffman HJ, Cruickshanks KJ, Davis B. 2009. Perspectives on population-based epidemiological studies of olfactory and taste impairment. Ann N Y Acad Sci. 1170:514–530.

Hooper L, Bartlett C, Davey SG, Ebrahim S. 2004. Advice to reduce dietary salt for prevention of cardiovascular disease. Cochrane Database Syst Rev. 1: CD003656.

Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL. 2002. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat. 11: 1–190.

Laing DG, Segovia C, Fark T, Laing ON, Jinks AL, Nikolaus J, Hummel T. 2008. Tests for screening olfactory and gustatory function in school-age children. Otolaryngol Head Neck Surg. 139:74–82.

Lawless H. 1982. Paradoxical adaptation to taste mixtures. Physiol Behav. 29:149–152.

Levine MD, Marcus MD, Perkins KA. 2003. A history of depression and smoking cessation outcomes among women concerned about post-cessation weight gain. Nicotine Tob Res. 5:69–76.

Mattes RD, Cowart BJ. 1994. Dietary assessment of patients with chemosensory disorders. J Am Diet Assoc. 94:50–56.

McDaniel AH, Reed DR. 2004. The human sweet tooth and its relationship to obesity. In: Moustaid-Moussa N, Berdanier C, editors. Genomics and proteomics in nutrition. New York: Marcel Dekker, Inc. p. 49–67.

McKeown NM, Meigs JB, Liu S, Saltzman E, Wilson PW, Jacques PF. 2004. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care. 27:538–546.

Mennella JA, Beauchamp GK. 2008. Optimizing oral medications for children. Clin Ther. 30:2120–2132.

Mennella JA, Pepino MY, Lehmann-Castor SM, Yourshaw LM. 2010. Sweet preferences and analgesia during childhood: effects of family history of alcoholism and depression. Addiction. 105:666–675.

Mennella JA, Pepino MY, Reed DR. 2005. Genetic and environmental determinants of bitter perception and sweet preferences. Pediatrics. 115: e216–e222.

NHLBI Obesity Initiative Task Force. 1998. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults—the evidence report. National Institutes of Health. Obes Res. 6(Suppl 2):51S–209S.

Parraga IM, Weber MA, Engel A, Reeb KG, Lerner E. 1988. Feeding patterns of urban black infants. J Am Diet Assoc. 88:796–800.

Pepino MY, Mennella JA. 2005. Factors contributing to individual differences in sucrose preference. Chem Senses. 30(Suppl 1):i319–i320.

Robinson TN, Borzekowski DLG, Matheson DM, Kraemer HC. 2007. Effects of fast food branding on young children's taste preferences. Arch Pediatr Adolesc Med. 161:792–797.

Sankar P, Cho MK. 2002. Genetics. Toward a new vocabulary of human genetic variation. Science. 298:1337–1338.

Schiffman SS, Graham BG, Sanly-Miller EA, Peterson-Dancy M. 2000. Elevated and sustained desire for sweet taste in African-Americans: a potential factor in the development of obesity. Nutrition. 16:886–893.

Schiffman SS, Pecore SD, Booth BJ, Losee ML, Carr BT, Sattely-Miller E, Graham BG, Warwick ZS. 1994. Adaptation of sweeteners in water and in tannic acid solutions. Physiol Behav. 55:547–559.

Schmidt HJ, Beauchamp GK. 1988. Adult-like odor preferences and aversions in three-year-old children. Child Dev. 59:1136–1143.

Stein LJ, Cowart BJ, Beauchamp GK. 2006. Salty taste acceptance by infants and young children is related to birth weight: longitudinal analysis of infants within the normal birth weight range. Eur J Clin Nutr. 60: 272–279.

Temple EC, Hutchinson I, Laing DG, Jinks AL. 2002. Taste development: differential growth rates of tongue regions in humans. Brain Res Dev Brain Res. 135:65–70.

United States Department of Health & Human Services and United States Department of Agriculture. 2005. Dietary guidelines for Americans, 2005. Washington (DC): US Government Printing Office.