Chem. Senses 24: 281–287, 1999

Perception of Sweetness in Simple and Complex Taste Stimuli by Adults and Children

C.E. James, D.G. Laing, N. Oram and I. Hutchinson

Children's Food Research and Education Unit, Centre For Advanced Food Research, University of Western Sydney, Bourke Street, Richmond, NSW 2753, Australia

Correspondence to be sent to: D.G. Laing, Children's Food Research and Education Unit, Centre For Advanced Food Research, University of Western Sydney, Bourke Street, Richmond, NSW 2753, Australia

Abstract

Currently, there is little information on the ability of children to analyse complex chemosensory stimuli in terms of the presence and magnitude of the components. The present study investigates this question by comparing the ability of 95 adults and 8- to 9-year-olds to estimate the sweetness of several concentrations of sucrose in water and in three foods, namely, orange drink, custard and shortbread biscuits, using a magnitude estimation procedure. The results indicated that similar response functions were produced by adults and children for the sweetness of aqueous solutions of sucrose, custard and biscuits, but not for orange juice, where the functions produced by both female and male children were significantly flatter than those of the adults. Stimulus context may have influenced the ratings of children in the no-sucrose and highest sucrose concentration conditions with two of the foods. The absence of differences between the response functions of the female and male children with all types of stimuli indicated that gender had no influence on their responses. It is concluded that, at mid-childhood, humans are capable of estimating the sweetness of sucrose in foods, but that they have a tendency to limit the range of numbers used in their estimates of sweetness at high concentrations of sucrose in some foods.

Introduction

The sensory analysis of foods by children has been restricted to measurements of their liking or acceptance of a product (e.g. Kroll, 1990; Kimmel *et al.*, 1994; Chen *et al.*, 1996; Hough *et al.*, 1997). Currently, therefore, there is no information that indicates whether (i) children can estimate the magnitude of a single attribute such as sweetness in a food or (ii) whether children and adults give similar ratings of magnitude for a food attribute.

Regarding the ability of children to estimate the perceived intensity of a taste, it has been reported that 5- to7-year-old children used a five-point category scale to estimate the sweetness of aqueous sucrose solutions (Anliker *et al.*, 1991), 10-year-old and older children produced a steeper slope than adults using magnitude estimation to assess the intensity of sucrose solutions (Enns *et al.*, 1979), and a group of 7- to 21-year-olds produced flatter slopes than adults when using a cross-modal procedure to indicate the intensity of sucrose and sodium choride (Shapera *et al.*, 1986). However, in each of these studies, the stimuli consisted of a single tastant in water. It remains to be seen, therefore, whether children can produce reliable estimates of the magnitude of single components in complex stimuli, namely, foods. For example, children are less able than adults to ignore irrelevant sensory information (Witkin *et al.*, 1967; Berman and Freidman, 1995) and may find it difficult to attend to a quality such as sweetness in the presence of different aromas, other tastants or variations in the texture of a food. Possible outcomes are that children may fail to detect the target attribute, or may give lower estimates of the magnitude of the attribute than adults.

The present study investigated the above questions by comparing the ratings of adults and 8- to 9-year-old children for the sweetness of sucrose in water, orange drink, custard and shortbread biscuit. These products provide a range of environments which vary in aroma, taste and texture, and it was proposed that the results should give a good indication of the capability of children in mid-childhood to assess the magnitude of a common food attribute. A set of aqueous sucrose solutions was included to provide an environment where the perception of sweetness was not influenced by other sensory attributes in the stimulus. Eight- to nine-year-olds were chosen because this study is part of a larger programme that is assessing the maturity of the sense of taste at mid-childhood, and this age group is capable of undertaking many of the psychophysical tasks used with adults. The ratings of adults and children were obtained using a magnitude estimation procedure which produced similar sucrose response functions for these groups in an earlier study (N. Oram *et al.*, submitted for publication).

Materials and methods

Subjects

The adults were 29 university students (19 females and 10 males, mean age 20.7 years) who had very little experience with sensory testing. The 66 children were from local public schools (34 females, mean age 9.1 years; 32 males, mean age 8.9 years) and participated with the consent of their parents, school principal and the NSW Department of School Education. Children and students participated voluntarily and were given no monetary reward, only the offer of a confectionary at the end of a session. To determine whether gender affects the maturity of the sense of taste at mid-childhood, the children were treated as female and male groups.

Stimuli

The stimuli were orange drink, custard, shortbread biscuit and aqueous solutions of sucrose. For each type of stimulus there were five test samples. With each stimulus type, one sample had no sucrose, whilst the sucrose concentrations of the other four samples were set so that the sweetness level recommended by the manufacturer or the recipe was approximately at the centre of the range used (Table 1). The concentration difference between each level of sucrose was 50% to accommodate the minimum difference required by 8- to 9-year-old children to discriminate sucrose solutions (C.E. James *et al.*, submitted for publication). All products except shortbread biscuits were prepared the day before testing and discarded after 24 h. The biscuits were used within 48 h of baking.

Sucrose solutions

Sucrose solutions were prepared using food grade sugar (CSR caster sugar, a powdered sugar), and deionized water from a Milli-Ro-6 Plus System (conductivity 0.9 μS) was used as the diluent to produce each of the concentration levels (Table 1). The solutions were refrigerated overnight at 4°C and allowed to equilibrate to room temperature (21–22°C) before serving. During a test trial, 8–10 ml of each solution was presented in a 30 ml clear plastic cup that was coded with a three-digit number.

Orange drink

The appropriate amount of sucrose (Table 1) and 0.125% w/v of analytical grade citric acid (Ajax Chemicals) was dissolved in deionized water. The water-soluble orange flavour (Quest International-2A 24393) was added in the ratio of 1 part per 1000, and the solution dyed with red (carmoisine and tartrazine) and yellow (tartrazine and brilliant scarlet) commercial food colours (McCormick). The samples were refrigerated (4°C) and presented as described for the sucrose solutions.

Table 1 Composition of stimuli

Test stimulus	Sucrose solutions and orange drink (% w/v)	Custard (% w/v)	Shortbread biscuit (% w/v)
1	0	0	0
2	4.44	1.97	8.89
3	6.67	2.96	13.33
4	10.0	4.44	20.0
5	15.0	6.67	30.0

Custard

Custard was prepared using sugar-free White Wings custard powder. The appropriate amount of sucrose (Table 1) was dissolved in full cream milk to produce a volume of 1 l. This solution was used to dissolve the custard powder (41.6 g). The mixture was then cooked (8 min 20 s) in a 650 Watt microwave oven on high power, stirred and cooked on high power for a further 3 min 20 s. All custard samples were allowed to cool, and were refrigerated at 4°C overnight. Prior to testing, the custard was brought to room temperature (21–22°C) and 15 ml samples were presented in 30 ml clear plastic cups labelled with three-digit code numbers. A spoon was provided to taste each sample.

Shortbread biscuit

The recipe for the biscuit was adapted from that of Blacker (1987). The total mass of sugar used for each stimulus level (Table 1) was divided equally between caster sugar and icing sugar (CSR very finely powdered sugar). Butter (125 g) was melted and cooled, and vanilla essence (1.25 ml) added. The butter mixture was combined with the appropriate levels of caster sugar, icing sugar and cornflour (20.8 g), and beaten until thick and creamy. Plain flour (156.3 g) was added and the whole mixed. The shortbread mixture was pressed into a 27 × 18 cm tin, marked into 128 pieces with a sharp knife and baked in a conventional oven at 180°C for 30 min. Once removed from the oven, the shortbread was cut into 128 pieces and allowed to cool in the tin. Edges and excessively brown pieces were discarded, and the remaining pieces stored in an air-tight container until needed. For adults, one piece of shortbread was presented in a 30 ml plastic cup labelled with a three-digit code number, whilst for children samples were taken from bowls with tongs by the interviewer and presented one at a time on a plastic plate.

Two replicates for each of the stimuli were conducted, and each of the possible presentation orders of the five levels was balanced across subjects and replicates for each stimulus and subject group.

Procedure

The children were tested in a hall at their school over two consecutive mornings. Two products were assessed each morning with a break of ~1 h between products. Each child was supervised by one experimenter, and six children were tested at a time. Six tables, one for each child and supervisor, were arranged to form a circle so that a child faced outwards towards their supervisor and could not easily make eye contact with other children. The children were trained in the use of the magnitude estimation procedure using six lengths of wood (2.8, 5.0, 13.0, 26.0, 52.0 and 132.5 cm long × 1 cm wide × 1 cm thick) (C.E. James *et al.*, submitted for publication). First, the children were asked several questions about their knowledge of large and small numbers, and of long and short lines. Secondly, they were shown the longest and shortest lengths of wood one at a time in random order, and asked whether they would describe each length with a large or small number. Finally, they were shown each of the wood lengths and asked to provide a number which described its length. This procedure was repeated, if necessary, until a set of satisfactory numbers was given. That is, they gave numbers of increasing value with increasing wood lengths that were non-ordinal and approximated the expected ratios.

Following this, testing with the aqueous sucrose solutions commenced. Before the first solution was given each child was told 'Now we are going to do the same thing you have been doing with the pieces of wood, but I want you to use a number to tell me how much sweetness is in a drink'. Their understanding of the word 'sweet' was checked by the supervisor who defined 'sweet' as being like a 'lolly'. This was followed by the presentation of the least and most sweet solutions one at a time to give each child an indication of the sweetness range they would receive shortly. Each child was then presented with five test stimuli, one at a time, with a different random order for each child. A child was asked to provide a number which described the sweetness of the solution. On completion of the first five samples, a second randomly ordered replicate was conducted. Water was sipped between each sample and there was an inter-trial interval of ~30s.

The order of presentation of the other three products was balanced across subjects The test procedure with the orange drink was the same as that for the sucrose solutions. However, with the custard and biscuit, subjects cleansed their mouth with water followed by a piece of bread and a second water sample between test trials. Before a session commenced with a new product, the children were reminded of the procedure, given the least and most sweet samples of the product to taste, and informed that these were the least and most sweet samples they would be given.

The adults were tested at the University Sensory Laboratory. All four products were assessed during one morning with a break of ~30 min between each session. Adults were given the same training procedures as the children. As with the children, the sweetness of sucrose was assessed first, and the test procedures and the order of assessing samples were similar. The only differences in the test procedures were that adults were given a tray with all 10 test samples of a product (two replicates) and they self-administered the test by following instructions given in a questionnaire.

Statistics

In the magnitude estimation procedure, subjects were free to use any numbers. To standardize the data across subjects, each rating by a subject was multiplied by a constant to make the sum of all the ratings equal to 500 (Lawless, 1979). This had the effect of bringing the ratings of all subjects into the same range without disturbing the response ratios between each stimulus level. A zero rating was given a value equal to one log step below the subject's lowest estimate (Enns *et al.*, 1979), including the zero values given for the no-sucrose condition. A mixed model repeated measures analysis of variance (ANOVA) was conducted on the logged data with subjects within groups as a random (not fixed) effect and two within-subject variables (sweetness, five levels; replicates, two levels). Since there were no systematic differences between the replicates in any of the analyses, the data were combined by averaging in further analyses. An overall group mean was calculated as the geometric mean of the group data. Regression analysis using an adjusted R^2 to accommodate the use of only four points on each function established the best linear fit of the estimates (logs) of sweetness and sucrose concentration. Systat for Windows Version 5.0 was used for all the analyses.

Results

Sucrose

The ANOVA indicated that all subject groups discriminated the different concentrations of sucrose [$F(4, 368) = 250.91$, $P < 0.001$]. The absence of a significant interaction between subject group and concentration [$F(8, 368) = 0.805$, $P = 0.599$] showed that similar sweetness ratings were given by adults and children at each of the concentrations of sucrose (Table 2), and that there were no differences between the response functions. Regression analysis showed that the data sets of each group provided a good linear fit (Figure 1a) and accounted for a substantial amount of the variance (Table 3).

Orange drink

All groups discriminated the sucrose concentrations [$F(4, 368) = 74.51$, $P < 0.001$] (Table 2). However, there was a significant group × concentration interaction [$F(8, 368) = 4.253$, $P < 0.001$], reflecting the finding that children gave lower sweetness ratings for the highest sucrose concentration than adults (Figure 1b). Two-way ANOVAs with concentrations as a within effect and the groups as a

Table 2 Group geometric means and their associated standard errors for each stimulus

Stimulus	Group		Level				
			None	1	2	3	4
Sucrose	Adult	Mean	7.17	27.92	47.36	70.08	89.12
		SE	1.18	1.07	1.06	1.03	1.02
	Female	Mean	5.25	23.41	45.38	71.73	85.74
		SE	1.22	1.12	1.09	1.05	1.04
	Male	Mean	6.90	29.80	44.33	60.74	84.65
		SE	1.25	1.13	1.09	1.07	1.05
Orange	Adult	Mean	9.29	26.09	45.63	63.95	85.75
		SE	1.25	1.12	1.07	1.07	1.06
	Female	Mean	22.95	33.96	42.74	62.11	63.93
		SE	1.17	1.11	1.08	1.05	1.06
	Male	Mean	19.05	30.42	44.97	57.39	61.51
		SE	1.25	1.12	1.10	1.08	1.09
Custard	Adult	Mean	8.23	27.65	45.43	67.70	91.47
		SE	1.20	1.07	1.05	1.02	1.04
	Female	Mean	10.55	31.84	48.65	60.61	73.19
		SE	1.23	1.10	1.09	1.06	1.06
	Male	Mean	11.79	38.11	46.33	62.95	66.73
		SE	1.26	1.09	1.09	1.06	1.06
Biscuit	Adult	Mean	7.10	26.21	41.80	72.52	88.78
		SE	1.24	1.12	1.07	1.03	1.04
	Female	Mean	9.89	33.37	32.44	59.50	87.35
		SE	1.22	1.09	1.11	1.05	1.09
	Male	Mean	11.79	34.20	34.41	62.44	76.59
		SE	1.26	1.12	1.13	1.07	1.07

between effect indicated that there were significant group × concentration interactions between adults and male [$F(4,236) = 4.71$, $P < 0.001$] and female children [$F(4,244) = 8.78$, $P < 0.001$], but not between the responses of the two groups of children [$F(4,256) = 0.27$, $P = 0.78$]. Regression analyses indicated that the best linear fit of the means accounted for most of the variance for each group (Table 3), and that the slope of the response function of the adults (0.96) was steeper than those of the children (0.56 and 0.58 for the female and males respectively).

Custard

Discrimination of the sweetness of the custard samples was achieved by each group [$F(4,352) = 143.45$, $P < 0.001$], but the group × concentration interaction was not significant [$F(8,352) = 1.515$, $P = 0.151$] (Figure 1c). Thus, although the children gave slightly higher sweetness ratings for the lowest sucrose condition and lower ratings for the highest concentrations than adults, in contrast to the result with orange drink, there was no significant difference between the three response functions. The best linear fit of the means accounted for most of the variance (Table 3), and the slope of the adult function, although steeper, was not significantly different from those of the female and male children.

Shortbread biscuit

All groups successfully discriminated between the sweetness levels of the shortbread biscuit [$F(4, 372) = 138.95$, $P < 0.001$], and there was no significant group × concentration interaction [$F(8, 372) = 1.821$, $P = 0.072$] (Figure 1d). Thus, although the regression analyses indicated that there was a significant linear fit of the data of the adults, and the fit of the data for the children was only marginally significant (Table 3), there was no significant difference between the slopes of the response functions of the three groups.

Discussion

The two most significant findings of the present study, were that (i) adults and children had similar sweetness response functions for three of the four types of stimuli, differing only in the response to the orange drink; and (ii) at mid-childhood humans can analyse complex foods and indicate the magnitude of a particular sensory attribute.

The finding that very similar sweetness response functions were produced by all three groups to the aqueous sucrose solutions replicates recent work in this laboratory (C.E. James *et al.*, submitted for publication). The exponents are also similar to those reported with adults (Kroeze, 1976; Moskowitz, 1977; Green *et al.*, 1993). However, the result with children is in contrast to the reports of Enns *et al.*

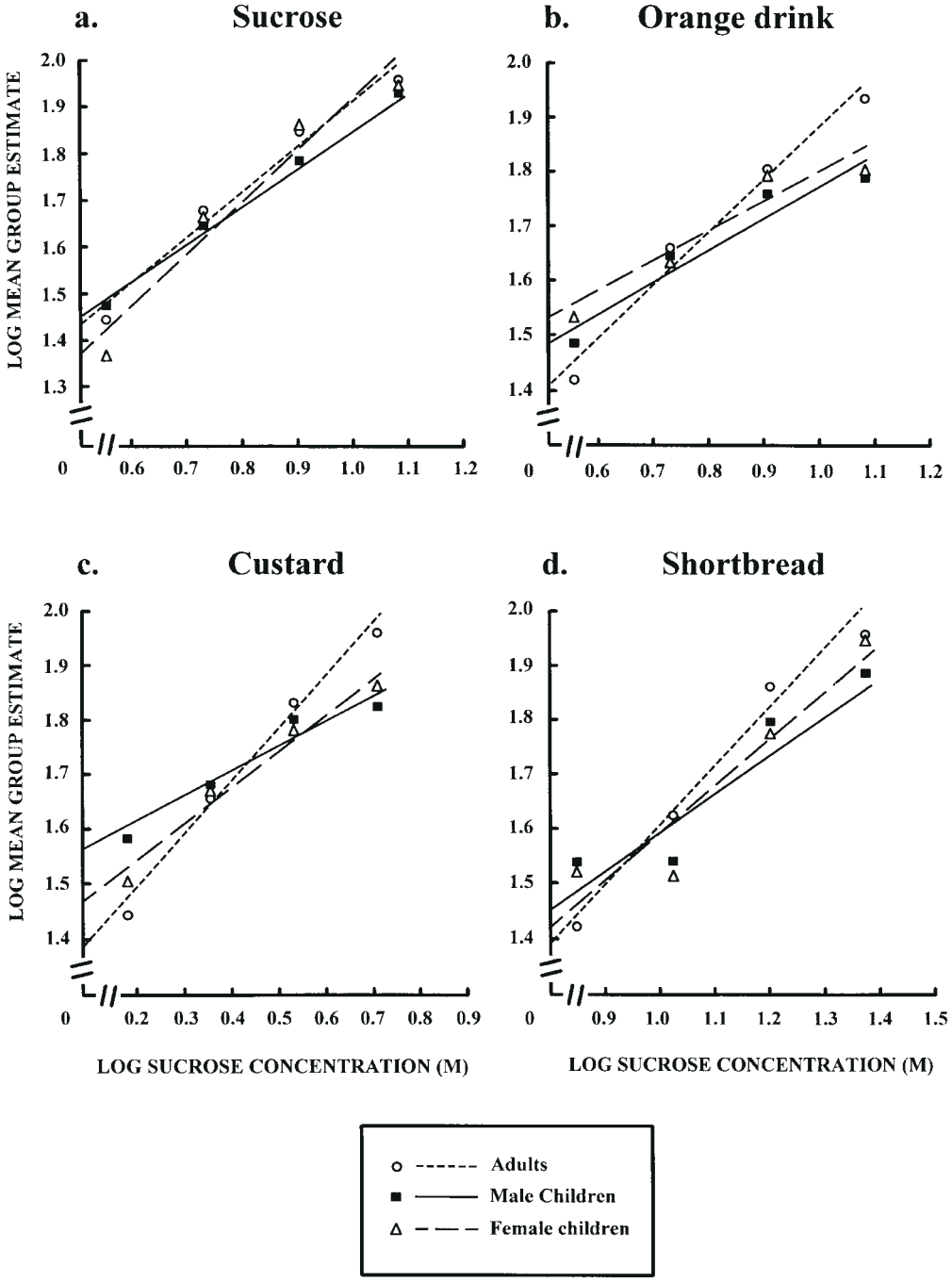

Figure 1 Relationship between the perceived sweetness and concentration of sucrose in different products for adults and children.

(1979), who found the slope of the sucrose response function of 10-year-olds to be steeper than that of adults (1.7 versus 1.12), and Shapera *et al.* (1986), who reported a low exponent (0.5) for a group ranging in age from 7 to 21 years. Since the latter two results are very different to those reported for adults, and are from older children, it is likely they may be due to methodological problems. For example, Enns *et al.* suggested that the use of 'extreme' numbers by the children may have caused the steeper slope.

The similar results found here for adults and children for the sucrose response function also strengthen the view that the different rating behaviour of the children compared with the adults with the complex stimulus orange drink was context dependent and not due to an underdeveloped sense of taste. It is clear that the flatter slopes of the sweetness functions obtained with orange drink for the children were due to the difficulty they had in giving ratings to the stimulus that had the highest sucrose concentration when other

Table 3 Slope of linear regression functions and the amount of variance accounted for by the line of best fit for estimates of the sweetness for each type of stimulus for each group

	Slope	Adjusted R^2	*P*
Sucrose			
Adults	0.96	0.96	0.01
Female	1.07	0.91	0.03
Male	0.85	0.99	0.001
Orange			
Adult	0.96	0.96	0.01
Female	0.56	0.88	0.04
Male	0.58	0.87	0.04
Custard			
Adult	0.98	0.98	0.006
Female	0.67	0.94	0.02
Male	0.49	0.92	0.03
Biscuit			
Adult	1.04	0.96	0.02
Female	0.86	0.83	0.06
Male	0.74	0.83	0.06

food components were present. Indications of the difficulty were also observed with the highest concentration of sucrose in custard.

Comparison of the slopes of the functions obtained with the four types of stimuli is only possible for the sucrose solutions and orange drink. Those for custard and shortbread cannot be used in an across-food comparison because different amounts and ranges of amounts of sucrose were used in their preparation. Comparison of the responses of adults to the sucrose and orange solutions (Table 2), however, showed that very similar responses were used at each of the five levels of sucrose for the two types of stimuli. In contrast, both groups of children gave substantially higher estimates for the sweetness of the orange drink that had no sucrose added than for water alone, and lower estimates for the highest concentration of sucrose in orange drink compared with the highest concentration of sucrose presented alone. Thus, the slopes of the sweetness functions produced by the adults for the two types of stimuli were the same (0.96), in contrast to the corresponding ones produced by the female (1.07 and 0.56) and male children (0.85 and 0.58). It is possible that with the no-sucrose orange drink the children were influenced by the colour of the drink and gave a higher than expected estimate. Such an interpretation is in keeping with the finding of Oram *et al.* (1995) that in beverages colour is a more salient feature than flavour for children under ~12 years of age. It is also possible that the inherent sweetness of the orange flavour of the drink, and to a lesser extent the vanilla flavour of custard and the biscuit, induced the children to give higher estimates than the adults for the no-sucrose conditions with these foods. The presence of irrelevant or distracting quality components, therefore, may have affected the judgements of sweetness by the children. Such distractions have also been reported for children in studies involving other modalities (Witkin *et al.*, 1967). Why children appeared to find little difference between the sweetness of the two highest concentrations of sucrose with orange drink is unknown. It is unlikely that this occurred because they could not discriminate between the two levels, since 8- to 9-year-olds can easily discriminate differences in sucrose levels that differ by ~35% (C.E. James *et al.*, submitted for publication), compared with the difference of 50% used here. One possibility, however, is that the children were influenced by their high familiarity with the three products. Accordingly, they may have tended to regress their rating of sweetness to that commonly found in each product, which for this study was at the middle of the concentration range used. Nevertheless, the possibility remains that the presence of other stimuli in the foods made it more difficult to detect differences in sweetness.

An unexpected aspect of the rating behaviour exhibited by the children was their avoidance of both very low and very high numbers. This was contrary to the finding by Moskowitz (1985) that children tend to use the extremes of scales more often than adults. However, in that study hedonic ratings were obtained, and it may be that for children hedonic aspects of foods are described by a love–hate relationship that is absent when estimating different levels of a food attribute.

An interesting outcome was that there was no difference between the response functions of the two groups of children for any of the foods or sucrose alone. Gender therefore had no influence on the ability of the children to perceive and rate the intensity of sweetness in simple or complex chemosensory stimuli. Since none of the other studies of taste magnitude compared the responses of female and male children, the present study is the first to report that gender has no influence on this measure at mid-childhood.

It can be concluded that by mid-childhood humans can analyse complex chemosensory stimuli and provide estimates of the magnitude of a specific sensory attribute, in this instance, sweetness. The resultant estimates showed that similar sweetness response functions for adults and children exist over a wide range of sucrose concentrations in very different food products. However, the different response functions obtained for the adults and children with orange drink, arising primarily from the children rating the sweetness of the highest concentration of sucrose very differently from adults, suggests that children's responses may be influenced by other food components in some products.

Acknowledgements

The authors extend special thanks to the children and adults who participated, to the teachers for their cooperation, and to G. Rose and A. Jinks for assisting with the statistical analysis. We also wish to thank the anonymous reviewers for their helpful comments and suggestions. C.E.J. was supported by a University of Western

Sydney, Hawkesbury Postgraduate Scholarship, and N.O. by a Meat Research Corporation grant to D.G.L.

References

Anliker, J.A., Bartoshuk,. Ferris, A.M. and **Hooks, L.D.** (1991) *Children's food preferences and genetic sensitivity to the bitter taste*. Am. J. Clin. Nutr., 54, 316–320.

Berman, S. and **Friedman, D.** (1995) *The development of selective attention as reflected by event-related brain potentials*. J. Exp. Child Psychol., 59, 1–31.

Blacker, M. (ed.) (1987) Australian Women's Weekly Big Book of Beautiful Biscuits. Australian Consolidated Press, Sydney.

Chen, A.W., Resurreccion, A.V. and **Paguio, L.P.** (1996) *Age appropriate hedonic scales to measure food preferences of young children*. J. Sens. Stud., 11, 141–163.

Enns, M.P., Van Itallie, T.B. and **Grinker, J.A.** (1979) *Contributions of age, sex and degree of fatness on preferences and magnitude estimations of sucrose in humans*. Physiol. Behav., 22, 999–1003.

Green, B.G., Schaffer, G.S. and **Gilmore, M.M.** (1993) *Derivation and evaluation of a semantic scale of oral sensation magnitude with apparent ratio properties*. Chem. Senses, 18, 683–702.

Hough, G., Sancez, R., Barbieri, T. and **Martinez, E.** (1997) *Sensory optimization of a powdered chocolate milk formula*. Food Qual. Pref., 8, 213–221.

James, C.E., Laing, D.G. and **Oram, N.** (1997) *A comparison of the ability of 8–9-year-old children and adults to detect taste stimuli*. Physiol. Behav., 62, 193–197.

Kimmel, S.A., Sigman-Grant, M. and **Guinard, J.** (1994) *Sensory testing with young children*. Food Technol., 48, 92–99.

Kroeze, J.H.A. (1976) *Exponential values of the psychophysical power function for sucrose obtained by two different estimation methods*. Chem. Senses, 2, 39–43.

Kroll, B.J. (1990) *Evaluating rating scales for sensory testing with young children*. Food Technol., 44, 78–86.

Lawless, H. (1979) *Evidence for neural inhibition in bittersweet taste mixtures*. J. Comp. Physiol. Psychol., 93, 538–547.

Moskowitz, H.R. (1977) *Intensity and hedonic functions for chemosensory stimuli*. In Kare, M.R. and Maller, O. (eds), Chemical Senses and Nutrition. Academic Press, New York.

Moskowitz, H.R. (1985) New Directions for Product Testing and Sensory Analysis of Foods. Food and Nutritions Press, Westport, CT, pp. 147–164.

Oram, N., Laing., D.G., Hutchinson, I. and **Rose, G.** (1995) *The influence of flavour and colour on drink identification by children and adults*. Devl Psychobiol., 28, 239–246.

Shapera, M.R., Moel, D.I., Kamateh, D.K., Olsen, R. and **Beauchamp, G.K.** (1986) *Taste perception of children with chronic renal failure*. J. Am. Dietit. Assoc., 86, 1359–1365.

Witkin, H. A., Goodenough., G. H. and **Karp, S.E.** (1967) *Stability of cognitive style from childhood to young adulthood*. J. Personal. Social Psychol., 7, 291–300.

Accepted January 4, 1999