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Temporal Perception of Sweetness by Adults and Children Using Computerized Time–Intensity Measures

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Abstract

There is a general paucity of knowledge of the cognitive and perceptual abilities of children to successfully undertake chemosensory-related tasks. An example is that there are no reports of temporal perception by children in time–intensity tasks, or how their responses in these tasks compare with those of adults. The latter paradigm has the potential to reveal differences that may occur during a normal eating or drinking episode that cannot be detected with single response measures. To address this shortcoming, the present study uses a computerized time–intensity method to compare the responses of adults and 8- to 9-year-olds in several measures of sweetness with three different types of stimuli. The results show that the children gave higher estimates than adults of the maximum sweetness of sucrose in water, orange drink and custard and recorded shorter sweetness durations with orange drink and custard. Both age groups, however, responded similarly to changes in concentration and the volume of stimuli with all three sensory measures. Overall, the consistency of the data from the children and the variability, which was similar to that of the adults, indicate that the tasks involved in the time–intensity paradigm were within the cognitive ability of the children. Nevertheless, further studies are needed to determine the basis of the differences found.

Introduction

Measurement of the perceived intensity of chemosensory stimuli such as tastes, is most commonly achieved using a single response procedure where the judgment is completed within a second or two. However, in everyday life, tastes are encountered in foods that, in the case of solid or semi-solids, take a finite time to masticate. During the period of mastication tastants are released from the food and, due to sensory adaptation and decreasing concentrations in the food, can vary in their intensity (Davidson *et al.*, 1998) and affect acceptability. With the advent of computers, the mapping of the responses of individuals to the changing taste environment in the oral cavity using the time–intensity paradigm has become relatively popular. Clearly, the provision of a more complete description of the sensory properties of a product offers advantages for the development of products and for identifying differences between products.

To date, all reported time–intensity studies of chemosensory stimuli have been conducted with adults as the subjects. This is surprising given that children comprise one-third of the market for foods and are computer literate early in life. In addition, there is growing evidence that by 8–9 years of age the sense of taste in children is still developing both anatomically (Segovia *et al.*, 2002) and functionally (Stein *et al.*, 1994; James *et al.*, 1997; Zandstra and de Graff, 1998; Oram *et al.*, 2001). Furthermore, since children have weaker jaws and facial musculature than adults they are likely to exert less force when chewing, which may reduce the amounts of chemosensory stimuli released and the sensations perceived. Accordingly, the immaturity of the gustatory system by mid-childhood, together with possible limitations in their mastication abilities, suggests that the temporal perception of tastes may be different in adults and children, and affects the acceptability of a food.

To determine if differences between adults and children occur during an eating/drinking episode, the present study investigates the responses of adults and 8- to 9-year-olds to the sweetness of sucrose in different products using time–intensity measures. The measurements were the time taken to perceive maximum sweetness, maximum sweetness, and the duration of perceived sweetness. These are the most common measures used in the paradigm and were selected because it has been shown with adults that increasing the concentration has little effect on the time to reach maximum intensity (Lawless and Skinner, 1979; Overbosch *et al.*, 1986; Yoshida, 1986; Burke *et al.*, 1987), however, it increases maximum intensity and extends the perceived duration of the stimulus (Birch *et al.*, 1982; Portmann *et al.*, 1992; Bonnans and Noble, 1993). Furthermore, varying the context, namely the food in which the tastant is perceived, should allow the effects of eating/drinking on these measures to be determined. Accordingly, in Part 1 of the study the effects of varying the concentration of sucrose on the three measures in three types of stimuli, namely, an aqueous solution of sucrose, orange drink and custard are determined. In Part 2 another factor that may affect temporal perception, namely the volume of a stimulus, is investigated. Increasing the volume, for example, may increase the chance of stimulating more taste receptors throughout the oral cavity in a shorter time. This factor could be particularly relevant in adult–child comparisons since the volume of the mouth of an 8- to 9-year-old child (~44 ml) is substantially smaller than that of an adult (~74 ml) (Temple, 1999).

Part 1

Aim

To determine if adults and children differ in measures of the time taken to perceive maximum sweetness intensity, maximum intensity and duration of sweetness when the concentration of sucrose is varied in aqueous sucrose solution, orange drink and custard.

Methods

The subjects were 20 8- to 9-year-olds (10 females, 10 males) who were recruited through local sports and community organizations, and 20 adults ranging in age from 19 to 39 years (10 females, 10 males; mean age 22.7 years) who were staff or students from the University. All participants were compensated for their efforts with several movie tickets.

The stimuli were four concentrations of sucrose in water, orange drink and custard. The concentration levels (Table 1) used were based on those reported by Lawless and Skinner and James *et al*. to provide similar levels of sweetness across the three test substances (Lawless and Skinner, 1979; James *et al*., 1997). Sucrose solutions were prepared with food grade sugar and deionized water from a Millipore Milli-Ro 6 plus system (conductivity 0.9 μS). The solutions were refrigerated overnight and served at room temperature (~25°C). During familiarization and testing, 6 ml samples of the solutions of sucrose and orange drink were presented to each subject in clear plastic cups (30 ml) which were coded with a three-digit number. The orange drink was prepared with food grade sucrose and deionized water to which was added 0.125% w/v of analytical grade citric acid (Ajax Chemicals, Sydney, Australia), 1 part per 1000 of orange flavor (Quest International 2A 24393, Sydney, Australia), and 12 drops each of red and yellow food coloring (McCormick Foods, Clayton South, Australia) per 1000 ml of solution. The solutions were refrigerated overnight and presented to subjects in the same manner as for the sucrose solutions. Custard samples were made with sugar-free custard powder (White Wings, Sydney, Australia), full cream milk and food grade sucrose. Thirty grams of custard powder was used with each 1000 ml of milk. The custard was cooked on high power in a microwave oven (650 W) for 5 min 30 s and allowed to cool before refrigerating overnight. Samples were assessed at room temperature using a teaspoon (~5 ml).

Table 1 Sucrose concentrations (molarity) used in Part 1

Stimulus	Sucrose solution	Orange drink	Custard
1	0.100	0.100	0.056
2	0.180	0.180	0.100
3	0.342	0.342	0.180
4	0.583	0.583	0.342

During training and testing, subjects were seated in one of six booths in the University Sensory laboratory facing a computer terminal with a ‘mouse’ within reach. The six computer terminals were part of the Compusense 5 sensory analysis system (Compusense, Guelph, Canada) that provided instructions and recorded the responses of subjects. Initially subjects were presented with three cups containing 0.100 and 0.583 M sucrose, and water, and asked to give a number to represent the sweetness of each sample. They were advised that ‘0’ was not sweet, as occurred with water. This procedure was to determine if the subjects could distinguish between the samples and could allocate appropriate values to them. Subjects were then given verbal instructions on the test procedure and taken through the on-screen instructions and procedures on a 1:1 experimenter/subject basis. During testing, the latter 1:1 ratio was maintained for children with 1:2 occurring occasionally, whilst adults generally needed no additional guidance and performed the tasks on their own. Both groups were initially instructed (i) to follow the on-screen instructions, which informed them to match the commencement of the tasting of a sample and clicking of the on-screen start button, i.e. ‘Click on the start button as you start to sip the sample’, (ii) to move the mouse to make a cursor move up or down on the on-screen vertical line scale (0–100 units), (iii) that the movements of the cursor should be in accordance with how sweet the sample was during the time it was in their mouth, and that they should rate the sweetness of the sample continuously using the mouse, (iv) that when the sweetness disappeared they were to click at the bottom (zero point) of the scale.

At each trial an on-screen instruction indicated to a subject to move the sample around their mouth for 10 s before swallowing once they had the sample in their mouth. Another instruction appeared at 10 s to remind subjects to swallow. Ten seconds was adopted as the time for swallowing because this was found to be sufficient by Lawless and Skinner (Lawless and Skinner, 1979) for the tastant to reach maximum sweetness. Data from the latter study and that of Birch *et al*. and Portmann *et al*. (Birch *et al*., 1982; Portmann *et al*., 1992) also suggested that a cut-off point of

90 s (indicated on-screen) was appropriate for the types of stimuli used. During a trial, the computer recorded ratings every 0.2 s until the subject ended the trial by clicking on the zero point of the scale, or 90 s had elapsed. Between each stimulus there was a 45 s interval during which a subject used water and bread to cleanse their mouth. Each subject completed three sessions over 3 days, one for each type of stimulus, and during a session subjects completed four replicates with the first being used for familiarization with the procedure and stimuli. Only data from replicates 2–4 were used for statistical analyses. The order of testing the three types of stimuli and order of presenting the four concentrations of each stimulus was randomized for each subject.

Results

Time to maximum sweetness intensity

Repeated measures ANOVAs determined the effects of age, concentration and gender on the time to perceive maximum sweetness intensity with each of the products. These indicated that children had shorter times to maximum intensity than adults with the sucrose solution [$F(1,144) = 4.164$, $P < 0.05$] (Figure 1a) and orange drink [$F(1,144) = 4.126$, $P = 0.05$] (Figure 1b), but that the two groups did not differ with custard [$F(1,144) = 2.186$, $P > 0.05$] (Figure 1c). However, with sucrose there was a significant age × concentration × gender interaction [$F(3,144) = 3.291$, $P < 0.05$], and Tukey's test indicated the main differences were due to shorter times by female children at most concentrations. There were no differences between the two adult groups at any of the four concentrations with the three types of products. There were also significant age × gender interactions with orange drink [$F(1,144) = 7.008$, $P < 0.05$] and custard [$F(1,144) = 5.621$, $P < 0.05$], where in both cases the female children recorded shorter times than the adults and male children. Thus, the shorter times of the female children were the primary reason for children as a group having shorter times than adults. At most concentrations of sucrose in the three products, the male children had times that were similar to those of the adults. As reported by others for adults (Lawless and Skinner, 1979; Overbosch *et al.*, 1986; Yoshida, 1986; Burke *et al.*, 1987), there were no significant effects of sucrose concentration on times to reach maximum intensity.

A comparison of the times taken to perceive maximum sweetness intensity at each of the four concentrations using repeated measures ANOVAs with product, age and gender as the factors, indicated there was no significant product-related differences at the three lower concentrations, however, the mean time was significantly longer for the orange drink compared with that for the sucrose solution [$F(2,108) = 6.440$, $P < 0.01$] at the highest concentration (Figure 2). In general, however, it can be concluded that the time to reach maximum sweetness intensity did not vary across the products. There were no age or gender effects.

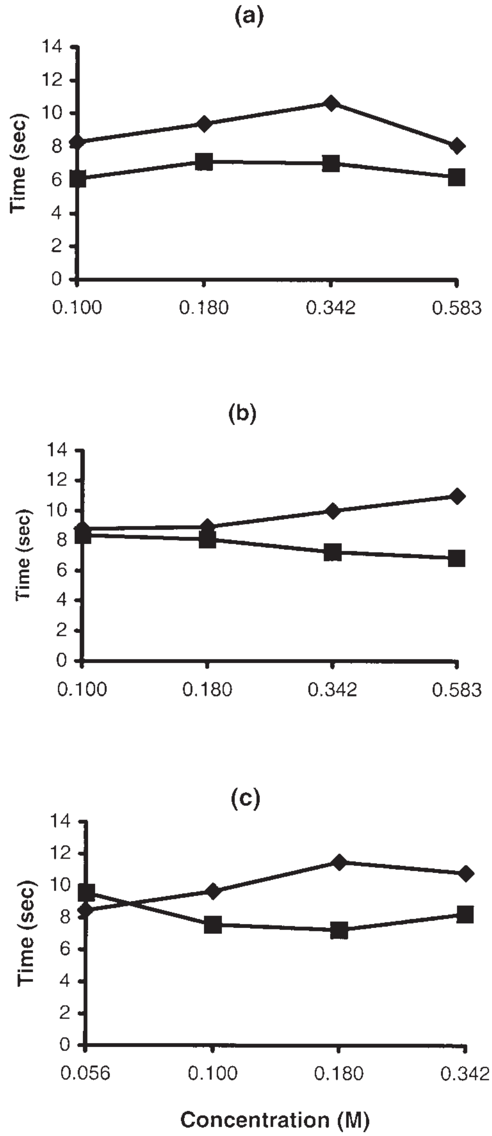

Figure 1 Time taken to perceive maximum sweetness intensity with **(a)** sucrose solution, **(b)** orange drink, and **(c)** custard containing different concentrations of sucrose. Filled diamonds and squares indicate the responses of adults and children, respectively.

Maximum sweetness intensity

Repeated measures ANOVAs with age, concentration and gender as factors, indicated that children recorded significantly higher maximum perceived intensities than adults with sucrose solution [$F(1,144) = 10.136$, $P < 0.01$] (Figure 3a), orange drink [$F(1,144) = 13.694$, $P = 0.001$] (Figure 3b) and custard [$F(1,144) = 10.979$, $P < 0.01$] (Figure 3c). Furthermore, there was a significant increase in intensity as the concentration of sucrose was increased with sucrose solution [$F(3,144) = 57.927$, $P < 0.001$], orange drink [$F(3,144) = 32.799$, $P < 0.001$] and custard [$F(3,144) =$

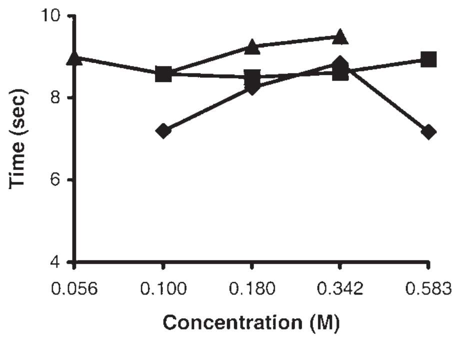

Figure 2 Comparison of the times taken to perceive maximum sweetness intensity of different products with different sucrose concentrations for sucrose solution (filled diamonds), orange drink (filled squares) and custard (filled triangles).

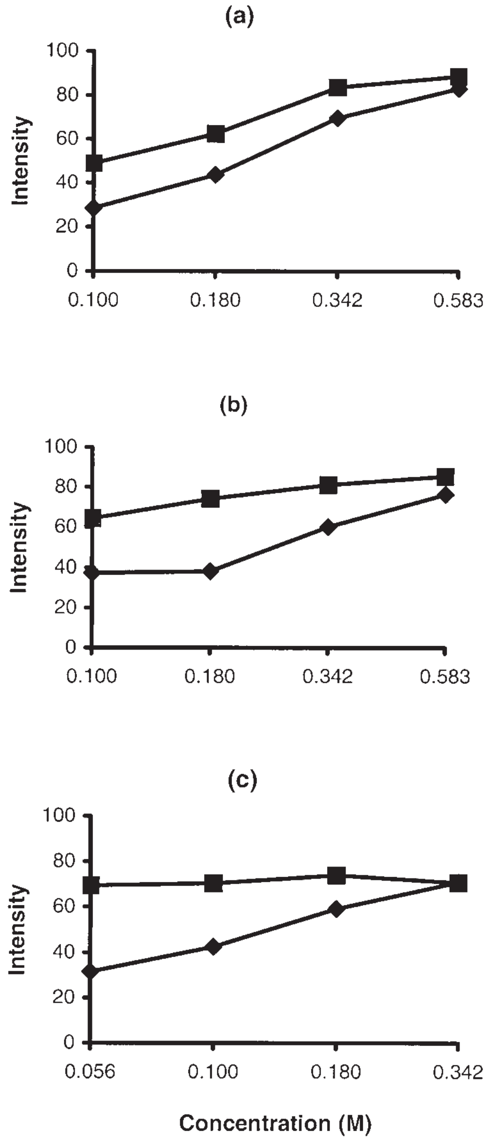

Figure 3 Maximum sweetness intensity of **(a)** sucrose solution, **(b)** orange drink and **(c)** custard with different concentrations of sucrose. Filled diamonds and squares indicate the responses of adults and children, respectively.

18.712, $P < 0.001$], although with custard the children did not discriminate between the concentrations. The finding of increases in maximum sweetness with increases in concentration in a time–intensity paradigm are similar to those reported by Birch *et al.*, Bonnans and Noble, and Portmann *et al.* (Birch *et al.*, 1982; Bonnans and Noble, 1993; Portmann *et al.*, 1992). Significant age × concentration interactions were found with orange drink [$F(3,144) = 5.670$, $P = 0.001$] and custard [$F(3,144) = 15.225$, $P < 0.001$] resulting from the intensities recorded for both groups being most different at the lower concentrations and becoming similar at the highest concentration. No significant effects for gender were found with any of the products for this measure.

Comparison of the maximum intensities at each of the four concentrations using repeated measures ANOVAs where product, age and gender were the factors, and *post hoc* Tukey's tests, indicated that custard was sweeter than sucrose at 0.1 M [$F(2,108) = 7.706$, $P = 0.001$] and 0.18 M [$F(2,108) = 5.200$, $P < 0.01$], there was no significant difference between the sweetness of the 0.342 M samples, and the 0.583 M sucrose solution was sweeter than the corresponding orange drink [$F(2,108) = 8.997$, $P < 0.001$]. The basis of age × concentration interactions recorded with the three lower concentrations has been described in the previous paragraph. Finally, in none of the analyses was there a gender effect.

Duration of perceived sweetness

Repeated measures ANOVAs with age, gender and sucrose concentration as factors indicated that with all three products there were no significant main effects due to age or gender but there was a significant increase in duration of sweetness as the concentration of sucrose increased (Figure 4a–c): sucrose solution [$F(3,144) = 14.683$, $P < 0.001$], orange drink [$F(3,144) = 12.351$, $P < 0.001$], custard [$F(3,144) = 2.050$, $P < 0.001$]. The finding of longer durations with increased concentrations is in accord with previous reports in studies with adults (Lawless and Skinner, 1979; Birch *et al.*, 1982; Overbosch *et al.*, 1986; Yoshida, 1986; Burke *et al.*, 1987; Halpern, 1991; Portmann *et al.*, 1992; Bonnans and Noble, 1993). In addition, there were significant age × concentration interactions with orange drink [$F(3,144) = 3.213$, $P < 0.05$] and custard [$F(3,144) = 6.30$, $P < 0.001$]. In both cases Tukey's tests indicated that the main reason was that children recorded significantly shorter durations than adults ($P < 0.05$) (Figure 5a–c).

Comparison of the duration of sweetness times at each of the four concentrations using repeated measures ANOVAs with product, age and gender as the factors, indicated that the only significant difference occurred at the lowest concentration (0.1 M) [$F(2,108) = 4.503$, $P < 0.05$] where the duration of the sweetness of custard was longer than that for

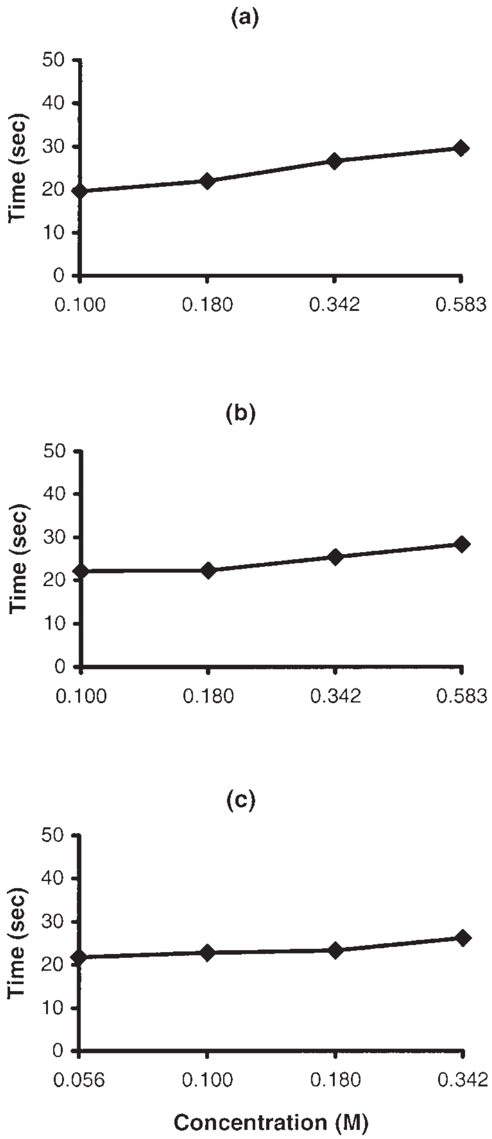

Figure 4 Duration of perceived sweetness for **(a)** sucrose solution, **(b)** orange drink, and **(c)** custard with varying concentrations of sucrose.

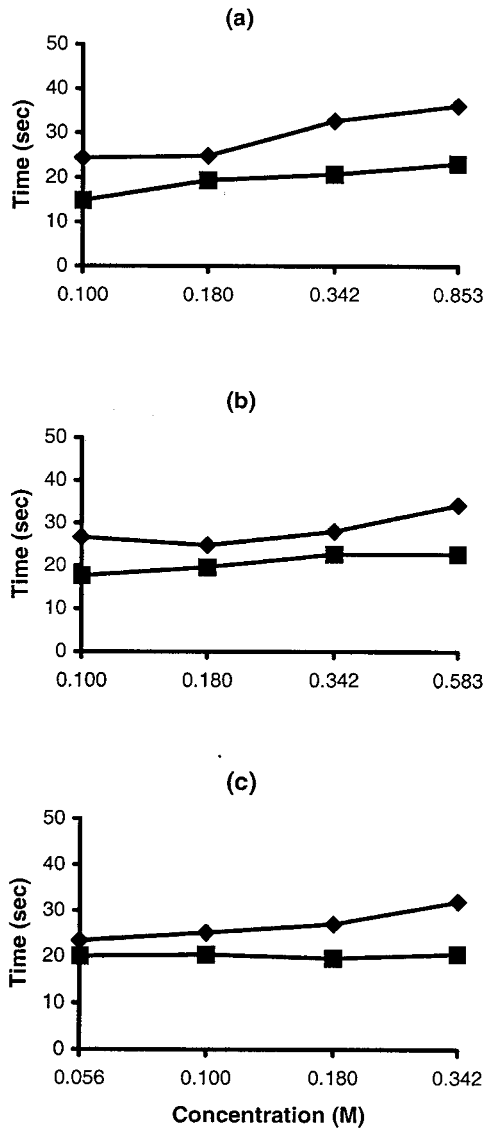

Figure 5 Duration of perceived sweetness for **(a)** sucrose solution, **(b)** orange drink, and **(c)** custard for adults (filled diamonds) and children (filled squares).

the sucrose solution (Tukey's test, $P < 0.05$) (Table 2). Stimulus context, therefore, had little effect on the duration of sweetness. A striking outcome of this measure was that children recorded much smaller standard deviations than the adults with each of the products.

Part 2

Aim

To determine if adults and children differ in measures of the time taken to perceive maximum sweetness intensity, maximum intensity and duration of sweetness when the volume of the stimulus, namely, aqueous sucrose solution, orange drink and custard, is varied.

Methods

The 40 subjects were those who participated in Part 1. The stimuli were 0.1 M sucrose, 0.1 M sucrose in orange drink, and 0.056 M sucrose in custard. The latter two types of stimuli were prepared in the same manner as in Part 1. Each stimulus was presented to subjects as one of three volumes, namely, 2, 6 and 10 ml in 30 ml plastic cups. The test procedures were the same as in Part 1 using the Compusense 5 system. Subjects completed three test sessions, one for each product. During a test session, a subject assessed nine samples of a product which consisted of three samples of each of the three volumes in a randomized order. In addition, the order of sampling the three products was randomized across sessions for each subject. Since all the

Table 2 Mean durations (in seconds) and standard deviations (SD) of the sweetness of stimuli containing different concentrations (M) of sucrose

Stimulus	Adults		Children	
	Mean	SD	Mean	SD
Sucrose				
0.100	24.4	19.6	14.8	7.3
0.180	24.8	17.1	19.3	15.6
0.342	32.7	20.4	20.7	14.9
0.583	36.1	22.9	23.1	18.3
Orange				
0.100	26.7	21.7	17.6	8.5
0.180	24.8	18.9	19.6	7.9
0.342	28.0	17.7	22.8	8.5
0.583	34.2	21.1	22.7	7.1
Custard				
0.056	23.4	18.7	20.1	9.8
0.100	25.1	18.5	20.5	8.4
0.180	26.9	19.8	19.6	8.2
0.342	31.9	20.8	20.5	9.5

Table 3 Mean times (in seconds) and standard deviations (SD) to reach maximum sweetness intensity with different volumes of stimuli

Stimulus	Adults		Children	
	Mean	SD	Mean	SD
Sucrose (0.100 M)				
2 ml	9.2	3.8	7.2	3.7
6 ml	9.0	4.7	7.0	4.2
10 ml	9.1	3.9	7.3	4.0
Orange (0.100 M)				
2 ml	8.3	4.2	6.3	3.3
6 ml	9.8	6.6	6.3	3.3
10 ml	9.0	4.2	7.2	3.4
Custard (0.056 M)				
2 ml	8.7	3.8	8.9	3.9
6 ml	9.3	3.7	7.8	4.0
10 ml	10.5	4.3	8.5	4.4

Table 4 Maximum sweetness intensity with different volumes of stimuli

Stimulus	Adults		Children	
	Mean	SD	Mean	SD
Sucrose (0.100 M)				
2 ml	37.4	19.1	54.4	23.5
6 ml	37.6	20.4	50.7	24.3
10 ml	39.8	19.7	54.0	26.3
Orange (0.100 M)				
2 ml	29.4	17.8	69.3	23.6
6 ml	31.4	17.7	65.9	29.2
10 ml	32.3	19.9	65.5	24.7
Custard (0.056 M)				
2 ml	39.5	22.6	69.2	22.5
6 ml	41.8	21.7	68.1	28.2
10 ml	47.4	22.0	72.0	29.5

subjects were familiar with the test procedures, the first replicate was not treated as a familiarization, accordingly all three replicates were used for data analysis.

Results

Time to maximum sweetness intensity

Repeated measures ANOVAs with volume, age and gender as the factors indicated that there were no significant differences in the times recorded to reach maximum sweetness intensity for any of these factors with sucrose solution and custard. Only with orange drink was there a significant difference, with children recording shorter times than the adults regardless of the volume of the sample [$F(1,108) = 4.356$, $P < 0.05$] (Table 3).

A comparison of the times taken to perceive maximum sweetness intensity at each of the three volumes using repeated measures ANOVAs with product, age and gender as the factors and *post hoc* Tukey's tests, indicated there was no significant product-related differences with the 2 and 10 ml samples, however, the mean time was significantly longer with the custard than for the sucrose solution [$F(2,108) = 3.618$, $P < 0.05$] with the 6 ml sample (Table 3). Age and gender had no effects on the data.

Maximum sweetness intensity

Repeated measures ANOVAs with stimulus volume, age and gender as factors indicated that children recorded higher maximum sweetness intensities than adults for sucrose solution [$F(1,108) = 5.458$, $P < 0.05$], orange drink [$F(1,108) = 28.936$, $P < 0.001$] and custard [$F(1,108) = 13.343$, $P < 0.001$] (Table 4), and there was a significant increase in the sweetness of custard as the volume of the sample increased [$F(2,108) = 3.283$, $P < 0.05$]. Gender had no effect on the data.

A comparison of the maximum sweetness intensities at each of the three volumes using repeated measures ANOVAs with product, age and gender as the factors and *post hoc* Tukey's tests ($P < 0.05$) indicated that with the 2, 6 and 10 ml samples that custard was sweeter than the sucrose solution: 2 ml [$F(2,108) = 21.564$, $P < 0.001$], 6 ml [$F(2,108)$

= 14.604, $P < 0.001$] and 10 ml [$F(2,108) = 15.793$, $P < 0.001$] (Table 4). Age and gender had no effects on the data recorded.

Duration of perceived sweetness

Repeated measures ANOVAs with stimulus volume, age and gender as factors, indicated that children recorded significantly shorter durations of sweetness than adults with the sucrose solution [$F(1,108) = 7.764$, $P < 0.01$] (Table 5), but not with the other products. There were no other effects due to age or gender. The analyses also showed that the duration of sweetness increased as the volume of the sample increased with orange drink [$F(1,108) = 3.281$, $P < 0.05$] and custard [$F(1,108) = 3.800$, $P < 0.05$] (Table 5). Tukey's tests indicated that durations were longer with the 10 ml sample than the 2 and 6 ml samples for orange drink ($P < 0.05$), and longer for the 10 ml sample than the 2 ml sample for custard ($P < 0.05$).

A comparison of the durations of sweetness at each of the three volumes using repeated measures ANOVAs with product, age and gender as the factors indicated that there were no significant differences arising from these factors at each of the three sample volumes used. In brief, the results indicated that for both age groups the type of product had no effect on the duration of sweetness.

Table 5 Mean duration of sweetness (in seconds) and standard deviations (SD) with different volumes of stimuli

Stimulus	Adults		Children	
	Mean	SD	Mean	SD
Sucrose (0.100 M)				
2 ml	19.7	7.7	13.0	6.6
6 ml	20.0	7.3	13.4	6.8
10 ml	20.1	7.3	14.7	7.4
Orange (0.100 M)				
2 ml	18.6	12.2	14.8	9.5
6 ml	20.7	13.1	15.0	7.1
10 ml	20.2	12.4	15.5	6.4
Custard (0.056 M)				
2 ml	19.7	6.7	16.6	6.9
6 ml	20.6	8.4	17.7	9.4
10 ml	22.2	8.8	18.2	9.3

Discussion

The present study is the first to report the responses of children in a time–intensity paradigm with tastants as stimuli, and the first to report a comparative study of this paradigm with adults and children. The study demonstrated (Part 1) that adults and children exhibit a number of differences and similarities in their responses when undertaking this paradigm. Children, particularly females, perceived the maximum sweetness of the products faster than adults, the maximum sweetness was higher for children, whilst the duration of sweetness was shorter for children with orange drink and custard. As regards similarities, both age groups indicated that increasing the concentration of sucrose had no significant effect on the time taken to perceive the maximum sweetness. This result is similar to those reported by several other workers (Lawless and Skinner, 1979; Overbosch *et al*., 1986; Yoshida, 1986; Burke *et al*., 1987), but is contrary to the findings of Bonnans and Noble (Bonnans and Noble, 1993) and Halpern (Halpern, 1991). Increasing the sucrose concentration also increased the maximum perceived sweetness with all products for adults and for sucrose solution and orange drink with children. Similar findings have been reported with adults by other workers (Lawless and Skinner, 1979; Birch *et al*., 1982; Overbosch *et al*., 1986; Yoshida, 1986; Burke *et al*., 1987; Halpern, 1991; Portmann *et al*., 1992; Bonnans and Noble, 1993). Another similarity was that both age groups indicated that the duration of sweetness for all products increased with increases in sucrose concentration, paralleling the results of all of the latter authors.

The differences and similarities found in Part 1 were generally replicated in Part 2. Children tended to perceive the maximum sweetness faster than the adults, they recorded higher sweetness levels with all products, and children generally had shorter durations of sweetness than adults. Varying the volume of the products had little effect on the responses of both groups in measures of time to perceive maximum sweetness. However, both groups showed increases in maximum sweetness as the volume increased with custard and longer durations for the sweetness of orange drink and custard. Accordingly, it appears that at least over the range of stimulus volumes investigated here, the differences in the volumes of the oral cavity of adults and children had little effect on the three types of sweetness measures. Interestingly, the finding that both groups reported increases in maximum intensity and longer durations with larger volumes in some of the conditions, is contrary to the finding of Birch *et al*. (Birch *et al*., 1982), who found no changes in perceived intensity of sucrose solutions with volumes ranging from 1 to 10 ml with adults. However, the absence of differences due to volume with sucrose solutions here is in agreement with the latter study.

Another similarity between the age groups was that the type of product had little effect in most conditions on the time taken to perceive maximum sweetness and little effect on the duration of sweetness. Both groups also found that all levels of sucrose in custard were perceived to be sweeter than in the aqueous solutions in Parts 1 and 2. This latter finding may indicate that the sweetness of the custard flavor may have contributed to the overall sweetness of the product.

The differences in the responses of the two age groups cannot be accounted for on the basis of inconsistency or variability in the behaviors of the children. For example, the magnitude of the standard deviations for all measures was similar for both groups and there were no significant differences between the replications of the various measures in Part 2. Only in Part 1 was there some evidence that task learning was in progress across replicates in the time to perceive maximum sweetness and duration of sweetness measures, with responses in replicate 3 being different to replicate 1 but not to replicate 2 for the children. However, no replication effects were found in any measure of the maximum sweetness where children had higher estimates than adults in every condition in Parts 1 and 2. In addition, there were no replicate effects with adults.

As indicated above, the most consistent difference between the adults and children was the higher maximum sweetness reported by the children with each of the products. It is unlikely that the differences were due to differences in sensitivity to suprathreshold concentrations since children of the same age as studied here have been shown to have similar sweetness response functions to adults for sucrose in water, custard and biscuits (James *et al.*, 1999). Furthermore, the effect did not appear to result from inexperience with the computer-based scale since there was minimal evidence of replicate differences. Whether children used the scale differently to adults, however, remains to be determined. Another possible influence could be a halo effect of the hedonic impact of the sweetness of the products. It has been reported, for example, that 6–12 (Zandstra and de Graaf, 1998) and 9–10-year-old children (de Graaf and Zandstra, 1999) prefer higher sweetness levels than adults in water and soft drink, and this may have resulted in them giving higher estimates for sweetness in the context of this particular paradigm. As regards the shorter durations of sweetness recorded by the children, there are no studies that would suggest such an outcome. Whether children experienced greater gustatory adaptation, had a shorter attention span, or generated more saliva to dilute the stimulus and reduce sweetness more rapidly, are all possibilities that require investigation. However, the absence of differences between the two age groups with orange drink and custard later in the study in Part 2, albeit with a reduced number of concentrations, suggests that experience with the task may have been a factor.

Gender had little effect on almost all of the measures for both adults and children. Only with the time taken to perceive maximum sweetness of orange drink and custard in Part 1, where female children recorded shorter times than male children and both adult groups, was there a gender effect. In other comparative studies, James *et al.* (James *et al.*, 1999) also found that gender does not affect the sweetness response functions of 8- to 9-year-old children and Leon *et al.* (Leon *et al.*, 1999) reported that gender did not affect preferences of 4- to 10-year-olds for sweet-tasting jams.

In conclusion, adults and children exhibited substantial similarities and some differences during the time–intensity paradigm that involved measuring the time to maximum sweetness, maximum sweetness and the duration of sweetness. The main differences were that children recorded higher maximum sweetness ratings with all the products at different concentrations and volumes and shorter sweetness durations with different concentrations of orange drink and custard than adults. The main similarities were that for both groups increasing the concentration of the stimulus had no effect on the time taken to perceive the maximum sweetness, maximum sweetness increased, and the duration of sweetness increased. When the volume of the stimulus was increased, for both groups it had no effect on the time taken to perceive maximum sweetness, maximum sweetness was unchanged with sucrose and orange drink but increased with custard, and the duration of the sweetness of orange drink and custard increased. Accordingly, although the study has shown that adults and 8- to 9-year-old children exhibit many similarities in their responses in the time–intensity paradigm, there are no clear reasons that account for the differences found.

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