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Sour Taste Preferences of Children Relate to Preference for Novel and Intense Stimuli

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Abstract

Previous research has suggested that some children have a preference for sour tastes. The origin of this preference remains unclear. We investigated whether preference for sour tastes is related to a difference in rated sour intensity due to physiological properties of saliva, or to an overall preference for intense and new stimuli. Eighty-nine children 7–12 years old carried out a rank-order procedure for preference and category scale for perceived intensity for four gelatins (i.e. 0.0 M, 0.02 M, 0.08 M, 0.25 M added citric acid) and four yellow cards that differed in brightness. In addition, we measured their willingness to try a novel candy and their flow and buffering capacity of their saliva. Fifty-eight percent of the children tested preferred one of the two most sour gelatins. These children had a higher preference for the brightest color ($P < 0.05$) and were more likely to try the candy with the unknown flavor ($P < 0.001$) than children who did not prefer the most sour gelatins. Preference for sour taste was not related with differences in rated sour intensity, however those who preferred sour taste had a higher salivary flow ($P < 0.05$). These findings show that a substantial proportion of young children have a preference for extreme sour taste. This appears to be related to the willingness to try unknown foods and preference for intense visual stimuli. Further research is needed to investigate how these findings can be implemented in the promotion of sour-tasting food such as fruit.

Key words: citric acid, color, hedonics, intensity, saliva, sensation seeking

Introduction

The food choices of children in industrialized countries are an important determinant of the development of obesity during childhood (Ricketts, 1997; Ludwig *et al.*, 2001). Children's food choices are for the most part determined by their taste preferences (Olson and Gemmill, 1981; Pangborn and Giovanni, 1984; Michela and Contento, 1986; Liem and Mennella, 2002, 2003; Perez-Rodrigo *et al.*, 2003).

Since the late 1960s researchers have been trying to understand the sensory-taste world of young children (Cowart, 1981). In the past four decades the investigations were mainly focused on sweet, salt and, more recently, bitter taste (for a review, see Birch, 1999). However, little research has focused on preference for sour taste. Darwin (1877) noted that his children had a preference for this taste quality. A systematic scientific investigation of sour taste preferences of children, however, has not been carried out until recently. To our knowledge, Liem and Mennella (2003) were the first to show that a substantial proportion of children (5–9 years old) they tested had a preference for high concentrations of citric acid in gelatin, which were perceived as extremely sour by their parents.

The basis of these sour taste preferences remains unknown. One hypothesis is that children who have a preference for high concentrations of citric acid in foods, rate this as less sour compared to those who do not prefer these concentrations of citric acid. In order to achieve a similar sensation, those who rate a lower intensity need more stimulation of sour taste. In adults it has been suggested that a high salivary flow (Spielman, 1990), high buffering capacity of saliva (Christensen *et al.*, 1987) and low salivary pH (Norris *et al.*, 1984) are related to a lowrated intensity of sour-tasting foods.

An alternative, but not mutually exclusive, hypothesis is that preference for sour taste is secondary to their desire for adventures, thrills and excesses (Frauenfelder, 1999; Urbick, 2000). In this view, preference for sour taste might be related to preference for unfamiliar foods and intense stimuli perceived by other senses such as vision (e.g. bright colors).

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More generally, preference for sour taste might be related to an overall thrill-seeking behavior. Research suggests that this behavior is reflected by the rise in cortisol after encountering a challenging or stressful situation. That is, the increase in cortisol concentration in saliva, shortly after encountering a challenging or stressful situation, is larger for thrill-seekers compared with non-thrill-seekers (Gunnar *et al.*, 1997; Davis *et al.*, 1999; Donzella *et al.*, 2000).

The present study had two main objectives. First, we investigated whether children who preferred sour taste rated sourness as less intense. This might be due to a high salivary flow, a high buffering capacity of saliva and/or a low salivary pH. Secondly, we investigated whether children who preferred sour taste are more likely to prefer intense colors, to try new foods and/or are more thrill-seeking in general, than those who do not prefer this taste.

Materials and methods

Subjects

Parents of 116 children were invited to participate in the study. They received a brochure with information that explained the procedures of the research. Parents of 92 children signed the informed consent. All children attended one of the two primary schools where the study was carried out. Exclusion criteria for participation were diabetes, sugar restriction in the diet, presumed allergies for one of the test stimuli and color blindness. In addition, subjects with non-removable braces ($n = 3$) were excluded from participation, because of the use of chewing gum during the test procedure. The final sample of subjects who participated in the study consisted of 89 children (40 females and 49 males) ranging in age from 7 to 12 years (mean = 10.3 ± 1.0 years; see Table 1). The study protocol was approved by the Medical Ethical Committee of Human Nutrition of Wageningen University.

General overview

The present study involved a training session and 2 days of testing. During the training session, children were trained in recognizing sweet, sour, salt and bitter tastes. During the 2 days of testing, separated from the training session by 2 days, the children carried out a variety of sensory tests. These tests were conducted at the children's primary school in a room that was familiar to them. This room conisted of 10 low tables, each separated by a screen that prevented the children from seeing each other during testing. Children had personal guidance from a trained adult who sat in front of them.

The first day of testing aimed to determine children's preference (±5 min) and rated sourness (±5 min) for four gelatins that varied in the amount of added citric acid. After a 5 min break, during which we measured children's weight and height, we determined children's willingness to try a novel food. We subsequently took a salivary sample, in order to determine the pH and cortisol concentrations of children's saliva.

The second day of testing started with a second salivary sample. After this we tested children's preference and perceived brightness for four yellow-colored squares that varied in brightness. Furthermore, we measured the buffering capacity and flow rate of the children's saliva. The order of testing (i.e. preference–intensity versus intensity–preference) was balanced across subjects.

Stimuli

Gelatins

The gelatins were sweet lemon flavored (Rowntrees Wobbly Fruity Fun; Nestlé, UK) with different amounts of added citric acid (0.00, 0.02, 0.08 and 0.25 M; Sigma Chemical Co., St Louis, MO). Similar stimuli were previously used by Liem and Mennella (2003). Twenty milliliters of each gelatin were poured into a 30 ml clear medicine cup and refrigerated at 4°C for at least 4 h to obtain firmness. They were transported in boxes at a constant temperature of 4°C. Several minutes before the actual test began, the gelatins were removed from the boxes and presented to the subjects.

Colors

The four colors were printed on small (5 × 5 cm) squares and were placed on larger (7 × 7 cm) white colored squares. The squares were of different intensities of the color yellow (soft yellow (SOY), lemon yellow (LY), canary yellow (CY) and sulphur yellow (SY) (Modo van Gelderen, Amsterdam, The Netherlands) and were used to measure children's preference and perceived brightness of colors. The colors were all different in brightness according the judgements of six adults (30 ± 8.2 years, three female and three males). From least intense to most intense, all adults but one placed the colors in the following order: SOY, LY, CY, SY.

Training session

In order to ensure that children were able to recognize sweet, sour, salt and bitter tastes, they were presented with 10 ml of a sweet solution (20% w/v sucrose in water), a sour solution (30% w/v natural lemon juice in water), a salt solution (20% w/v NaCl in water) and a bitter solution (tonic water; Schweppes International Ltd, Amstelveen, The Netherlands). After tasting each solution, the researcher asked the children whether it was sweet, sour, salty or bitter. The majority of the children were able to correctly identify the different solutions.

Preference test

Preferences for the different gelatins and colors were measured with a rank-by-elimination procedure (Birch, 1999). Subjects tasted the four gelatins in a random order, after which the researcher asked: 'Which one do you like most?'

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The children could either tell or point at the gelatin that was most preferred. This was then removed and after this subjects were asked to taste the remaining three gelatins again. Subsequently, the researcher asked: 'Which one of these three do you like most?' This procedure continued until a rank-order of preference was established. In order to determine reliability, children were asked to rank the four gelatins again according to their preference. After tasting each gelatin, subjects drank a sip of water. The same procedure was followed for the four different colors, with the difference that subjects did not drink a sip of water after each stimulus.

The results of the rank-order test gave insight into how the different gelatins were preferred relative to each other. In order to have a direct measurement of preference, subjects were presented with two pictures, a smiley face and sad face. The researcher told the children the following: 'I am going to give you one gelatin. If you like the taste I want you to give it to 'smiley face'. If you do not like the taste, I want you to give it to 'sad face'. Subsequently, the researcher gave the children the gelatin with no added citric acid. After tasting each gelatin, the subjects drank a sip of water

Rated sourness/brightness test

During a child-friendly game, children were presented with each of the four gelatins in a random order. Children rated each gelatin on perceived sourness using a five-point-category scale. The five categories were labeled 'not sour at all', 'a little bit sour', 'sour', 'very sour' and 'extremely sour'. Before the actual test began, the researcher explained the game by explaining each category of the five-point scale. After subjects rated the four gelatins on perceived sourness, the gelatin with 0.08 M added citric acid was presented again in order to determine consistency of the test. A similar procedure was followed for the four different colors, in which the five-point category scale was labeled, 'not bright at all', 'a little bit bright', 'bright', 'very bright' and 'extremely bright'. In order to test consistency, the color CY was presented twice.

Willingness to try a novel food

In order to test children's willingness to try a novel food, children were presented with three identical white opaque cups in a randomized order. The cups were labeled with 'z', 'y' and 'x' and placed up-side down. The researcher explained the test by saying: 'Under each cup a candy is hidden. Each candy had its own taste. Under cup 'z' a candy with a strawberry flavor is hidden, under cup 'y' a candy with a raspberry flavor is hidden and under cup 'x' a candy with a mysterious flavor is hidden.' The subjects could not see the actual candies that were hidden inside the different cups. After the researcher clarified the content of each cup, the subjects were told that they were allowed to pick one candy to try. They could either point to the cup or tell the research which one they wanted to try. A similar procedure was used by Raudenbush *et al.* (1998).

Collection of saliva

Salivary production was stimulated by having the child chew on sugarless gum (Freedent Menthol without sugar; Wrigley, France). Before the collection started, children were asked to rinse their mouth with water and to swallow the saliva left in their mouth. Subsequently, children were instructed to chew for 30 s on a piece of sugarless gum, without swallowing any saliva. After these 30 s, they expectorated their saliva directly in plastic tubes (Schwartz *et al.*, 1998). This procedure continued until at least 4 ml saliva was collected. If after 5 min the collected saliva did not reach a total of at least 4 ml, the collection was terminated. A similar procedure was previously used by Schwartz *et al.* (1998). Saliva was stored on dry ice and transported to the laboratory for the measurement of pH and cortisol concentration.

pH was measured by using non-bleeding pH indicator strips (pH 6.5–10.0; Merck, Darmstadt, Germany). Salivary cortisol concentrations were measured by the LDN Cortisol saliva test (DSL Diagnostic Laboratory Systems, Houston, TX)

Overall thrill-seeking behavior

In order to measure general thrill-seeking behavior in children, salivary cortisol was measured in a stress situation (hereafter referred to as stress-cortisol) and a non-stress situation (hereafter referred to as baseline-cortisol). We expected the children to be in a stress/challenge situation during the first day of testing due to the novelty of the sensory tests. The baseline-cortisol was measured at the beginning of the second day of testing. We expected the cortisol in saliva to be at baseline, because the measurement took place at the start of the stressor/challenge (sensory tests).

Salivary flow and buffering capacity

Before the measurement of salivary flow and buffering capacity, children were asked to rinse their mouth with water and to swallow the saliva left in their mouth. Salivary flow and buffering capacity was determined by having children rinse their mouth for 30 s with 10 ml citric acid solution (0.03 M citric acid, pH 2.5; Sigma Chemical Co., St Louis, MO), after which they expectorated the citric acid solution into a plastic cup. Subsequently, we measured the pH (Piccolo II; Hanna Instruments, Bedfordshire, UK) and weight (Sartorius GmbH, Göttingen, Germany) of the expectorated solution. A similar procedure was previously used by Dawes *et al.* (2000). The buffering capacity of saliva was defined as:

(pH after rinsing – pH before rinsing)/(volume of solution after rinsing – volume of solution beforre rinsing).

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Statistical procedure

Sour taste preference and rated intensity

Subjects were divided into two groups based on their sour preferences. Subjects who classified at least one of the two most sour gelatins as their most-preferred or second-most-preferred were grouped in the High-sour group. The remaining subjects were grouped in the Low-sour group. Reliability of the preference test for gelatins was defined as the percentage of subjects that were grouped in the High- or Low-sour group based on the first and the second preference ranking. Chi-square tests were conducted to determine differences between the two groups in terms of the distribution of boys and girls and differences in preference during the direct measurement of preference. Student's *t*-tests were used to determine differences in age, height, weight and body mass index (BMI). Wilcoxon analyses (Z) were conducted to determine differences between the first and the second intensity ratings for sour taste. Separate Friedman two-way analyses of ranks were performed to determine differences between the High- and Low-sour groups in intensity rank-order. When significant, multiple comparisons were carried out to determine which differences were significant (Siegel and Castellan, 1988). Student's *t*-tests determined differences in salivary pH, salivary flow rate and buffering capacity of saliva.

Sour taste preference, color preferences and thrill-seeking behavior

Reliability for the preference test for colors was defined as the percentage who preferred the brightest color during both the first and the second rankings. Wilcoxon analyses (Z) were conducted to determine differences between the first and the second intensity ratings for color. Mann–Whithney U-tests were performed to determine differences in preference for the four colors, between the High-and Low-sour groups. Chi-square tests were conducted to determine differences in children's willingness to try a novel food. Log transformations were applied to the cortisol concentrations in order to normalize the data. Student's *t*-tests were carried out to determine differences in cortisol concentrations. All summary statistics are expressed as means ± SD.

Results

Sour taste preferences and subject characteristics

Fifty-two children (58%) preferred one of the two most sour gelatins as either their most- or second-most-preferred gelatin (the High-sour group). The consistency between the first and the second rank-order was 91%. Subjects in the High-sour group showed an inverse U-shaped curve for preference with an increasing concentration of added citric acid. The most-preferred stimulus was the gelatin with 0.08 M added citric acid. Subjects in the Low-sour group showed a decrease in preference with an increase in concentration of added citric acid (see Figure 1, panel a). Ninety-five percent of the children in the Low-sour group and 65% of the children in the High-sour group gave the gelatin with no added citric acid to 'happy face'. This was significantly different [$\chi^2(1\ \text{df}) = 10.6$, $P < 0.01$]. Children in the High- and Low-sour groups were not significantly different in age [$t(84\ \text{df}) = 1.3$, $P = 0.18$], BMI [$t(87\ \text{df}) = 1.0$, $P = 0.30$] or proportion of boys to girls [$\chi^2(1\ \text{df}) = 1.1$, $P = 0.31$; see Table 1].

Rated sour intensity

Children did not rate the perceived sourness of the gelatin with 0.08 M added citric acid significantly differently during the two times this gelatin was presented ($Z = -3.0$, $P = 0.76$). No differences between the High- and Low-sour groups were observed in the rated sourness of any of the gelatins (no added citric acid, $U = 868.0$, $P = 0.32$; 0.02 M added citric acid, $U = 960.0$, $P = 0.99$; 0.08 M added citric acid, $U = 899.0$, $P = 0.59$; 0.25M added citric acid, $U = 918.5$, $P = 0.80$; see Figure 1, panel b). Children in both groups recognized differences in sourness across the four gelatins (Low-sour, $F_r = 128.0$, $P < 0.001$; High-sour: $F_r = 181.8$, $P < 0.001$). *Post hoc* analyses revealed that the gelatins with 0.08 M and 0.25 M added citric acid were rated as the most intense gelatins by children in the Low-sour group and High-sour groups (P-values < 0.05; see Figure 1, panel b).

Salivary flow, pH and buffering capacity

Children in the High-sour group produced significantly more saliva after stimulation with water with added citric acid than children in the Low-sour group [High-sour, 1.8 ± 1.0 g; Low-sour, 2.3 ± 0.8 g; $t(79\ \text{df}) = -2.4$, $P < 0.05$]. No differences, between the Low-and High-sour groups were observed between the salivary pH [High-sour, 7.2 ± 0.12; Low-sour, 7.2 ± 0.12; $t(85\ \text{df}) = 0.01$, $P = 0.99$] and the pH of the sour solution after subjects rinsed their mouth with this solution [$t(79\ \text{df}) = -1.23$, $P = 0.22$]. Children in the High-sour group, however, had a significantly lower buffer capacity of their saliva than children in the Low-sour group [High-sour, 0.18 ± 0.07 (ΔpH/ml produced saliva); Low-

Table 1 Characteristics of children who preferred 0.08 and 0.25 M citric acid in gelatin (High-sour group) and those who did not (Low-sour group)

Children's characteristics	Preference group based on level of sourness preferred in gelatine	
	Low-sour group	High-sour group
Age (years)	10.2 ± 1[a]	10.5 ± 1
Sex (girls:boys)	19:18	21:31
Weight (kg)	41.0 ± 9.1	41.0 ± 2.9
Height (m)	1.5 ± 0.1	1.5 ± 0.1
BMI (kg/m^2)	18.5 ± 2.9	17.9 ± 2.9

[a]x ± SD.

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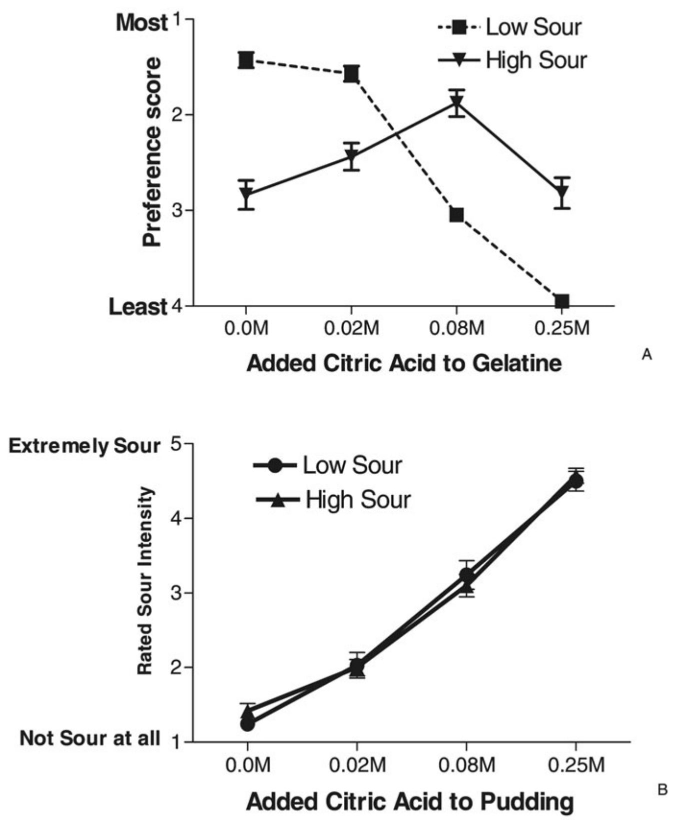

Figure 1 Mean (±SEM) preference ranking **(A)** and sour intensity score **(B)** for gelatin with 0.00, 0.03, 0.08 and 0.25 M added citric acid. Shown for children who preferred 0.08 and/or 0.25 M added citric acid in gelatin (triangles, $n = 52$) and those who did not (circles, $n = 37$).

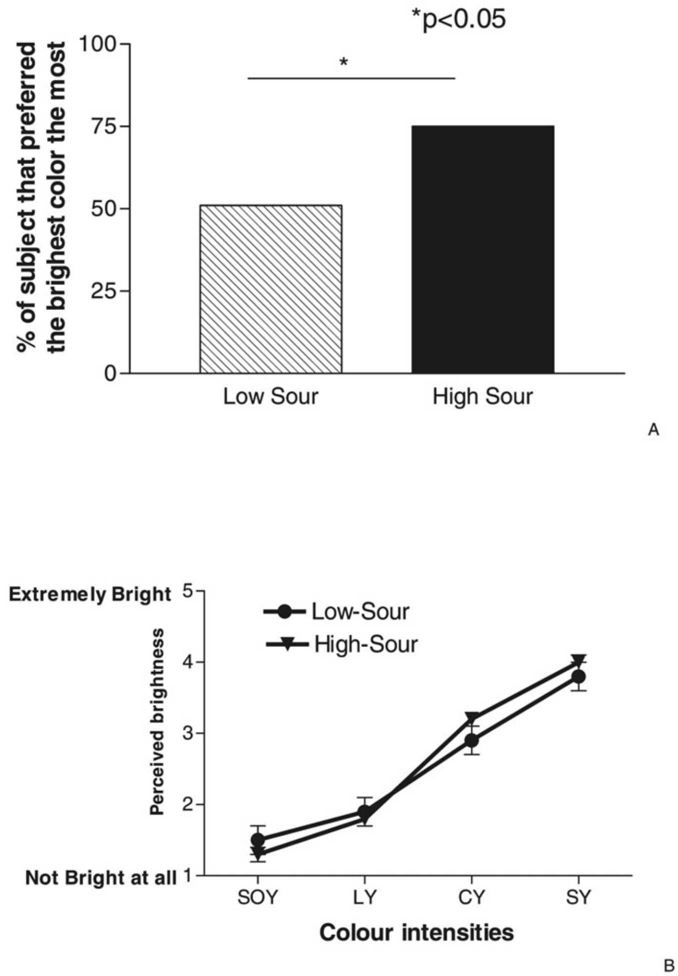

Figure 2 Percentage of subjects who preferred the brightest color the most **(A)**, and intensity scores for brightness of the soft yellow (SOY), lemon yellow (LY), canary yellow (CY) and sulphur yellow (CY) **(B)**. Shown for children who preferred 0.08 and/or 0.25 M added citric acid in gelatin (triangles, $n = 52$) and those who did not (circles, $n = 37$)

sour, 0.33 ± 0.44 (ΔpH/ml produced saliva); t(79 df) = 2.3, $P < 0.05$].

Color preferences and rated brightness

Children in the High-sour group were more likely to judge the SY color as their most favorite than children in the Low-sour group [High-sour, 75%; Low-sour, 51%, χ^2(1 df) = 5.1, $P < 0.05$; see Figure 2, panel a]. Children in both the Low- and High-sour groups recognized differences in brightness across the four colors (Low-sour, $F_r = 103.1$, $P < 0.001$; High-sour, $F_r = 56.8$, $P < 0.001$). *Post hoc* analyses revealed that the CY and SY colors were rated as the most intense by children in the Low-sour group and High-sour group (P-values < 0.05; see Figure 2, panel b). A significant difference was found between the first (3.1 ± 0.9) and the second time (3.4 ± 1.1) children rated the CY color on perceived brightness ($Z = 2.8$, $P < 0.01$).

Willingness to try a novel food and overall thrill-seeking behavior

The candy with the unknown flavor was chosen significantly more often by children in the High-sour group (67%) than by children in the Low-sour group [36% (χ^2(1 df) = 7.6, $P < 0.001$].

Children aged 7–10 years did not show a significant difference between their stress-cortisol and baseline-cortisol concentrations [Low-sour, t(27 df) = –0.80, $P = 0.43$; High-sour, t(39 df) = –1.4, $P = 0.16$]. Children aged 11–12 years, however, did show a significant lower baseline-cortisol concentration than stress-cortisol concentration [Low-sour, baseline 0.52 ± 0.04 ng/ml, stress 0.73 ± 0.06 ng/ml, t(13 df) = 3.2, $P < 0.01$; High-sour, baseline 0.67 ± 0.06 ng/ml, stress 0.94 ± 0.09 ng/ml, t(22 df) = 2.9, $P < 0.01$].

Children in the Low- and High-sour groups were not statistically different with respect to baseline-cortisol [0.69 ± 0.38 ng/ml versus 0.74 ± 0.46 ng/ml; t(85 df) = -1.5, $P = 0.60$] or stress-cortisol [0.69 ± 0.35 ng/ml versus 0.81 ± 0.39 ng/ml; t(87 df) = -1.5, $P = 0.14$]. The difference between baseline-cortisol and stress-cortisol concentration was also not different between the Low-sour group and the High-sour group [t(35 df) = 0.15, $P = 0.88$].

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Discussion

The results of the present study suggest that young children's preference for sour taste is more likely to be related to behavioral determinants than differences in rated sourness as measured with a five-point category scale. Salivary flow may play a role in the preference for sour taste, but a high salivary flow is not related to large differences in rated sourness in children who prefer this taste.

In the present study preferences for sour taste were measured by a rank-by-elimination procedure. Previous research showed that this is a reliable method to measure taste preferences of young children (Guinard, 2001; Liem *et al.*, 2004). Moreover, children in the present study showed a high consistency between the two times they rank-ordered the gelatins according to their preference. The finding that a substantial part of the children tested (58%) had a preference for high concentrations of citric acid in gelatin, is in line with a previous study (Liem and Mennella, 2003). In the present study sour taste was defined as gelatins with added citric acid concentrations of 0.08 or 0.25 M. In general children rated these gelatins between sour and extremely sour. It is likely that those who preferred sour taste during our sensory tests also preferred this taste outside the testing environment, as suggested by previous research (Moskowitz *et al.*, 1975; Liem and Mennella, 2003). This could be beneficial for the consumption of citrus fruit, which are in general high in vitamin C content. In the present study children, who preferred sourness in gelatins, appeared not to prefer the gelatins with no added citric acid. Supposedly, these gelatins were too bland in taste for those who preferred sour taste.

As shown in the present study, preference for sour taste was not related to a difference in rated sour intensity as measured with a five-point category scale. The consistency between the first and second time subjects rated the gelatin with 0.08 M added citric acid on perceived sourness, suggests the consistency of the testing procedure. Moreover, in general children rated the gelatins as more sour as citric acid content increased. We hypothesize that children in the High- and Low-sour groups not only rated the sour intensity similarly, but also perceived the sour intensity similarly. This is supported by the similarity of the pH of children's expectorated sour solutions. However, due to the methodology used in the present study to measure sour intensity such hypothesis can not be confirmed. We can not be sure that the adjectives used in our five-point scale meant the same to all the children. Children in the High-sour group (preference for extreme sour taste) may judge a stimulus as extremely sour at lower perceived intensities than children in the Low-sour group. Children in the High-sour group may have been limited in their responses by the scale and anchors that were used. Differences might have occurred when we used the label magnitude estimation scale with the anchors 'not sour at all' and 'most extreme sour ever tasted', but it needs to be determined whether such a procedure is reliable when testing young children. Future research is needed to determine whether children who prefer sour taste perceived it as less intense compared with children who do not prefer this taste.

Despite the similarity in rated sourness, as measured with a five-point category scale, children in the High-sour group had a higher salivary flow than children in the Low-sour group. Initially, we hypothesized that high salivary flow would be related to a lower rated sourness, due to the dilution of the citric acid and the large amount of buffering agents (Spielman, 1990). However, as shown by the present study, the high salivary flow of children who preferred sour taste was not related to large differences in rated sourness. Previous investigations on the relationship between salivary flow rate and perceived taste intensity gave conflicting results. Some suggest that high salivary flow rates are related to a lower perceived intensity (Spielman, 1990), whereas Norris *et al.* (1984) suggested the opposite. Others, however, did not observe any relationship (Christensen *et al.*, 1983, 1987; Bonnans and Noble, 1995; Sowalsky and Noble, 1998). Hypothetically, the saliva of children in the High-sour group had a lower buffering capacity per milliliter of saliva compared with saliva of children in the Low-sour group. This could explain why no differences were found in the rated sourness between the High- and Low-sour groups, despite the differences in salivary flow. This hypothesis can, however, not be fully confirmed by the present study, because buffering capacity was not measured by means of titration.

It is more likely that preference for sour taste is related to children's general preference for intense and new stimuli. In the present study, children who preferred sour taste were more willing to try a novel food than children who did not prefer this taste. A previous study suggests that parents of children who preferred sour taste were less likely to report that their child was afraid to try new foods (Liem and Mennella, 2003). Pliner and Hobden (1992) showed that children who were willing to try a novel food were less shy and emotional compared with those who were reluctant to try a novel food.

Children in the High-sour group were also more likely to prefer a bright color as shown in the present study. Previous studies demonstrated that bright colors are more preferred by people with an extrovert temperament than by people with an introvert temperament (Birren, 1973). It needs to be noted that a significant difference was observed between the first time and the second time children rated the CY color on perceived brightness. It is unlikely that children were not able to carry out the test. Recall that children rated the colors in the same order of intensity as adults did. The difference between the first and the second rating of the color CY, could be a result of an order effect. The duplo was always presented last.

We suggest that children in the High-sour group were more likely to be sensation seekers than children in the Low-sour group. But children in the High-sour group and the Low-sour group did not differ in overall sensation-seeking

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behavior as measured by salivary cortisol. Studies by Gunnar and colleagues suggest that surgent temperament (e.g. extrovert, sensation seeking) in children was related to a high reactivity of cortisol in reaction to a stressor (Gunnar *et al.*, 1997; Davis *et al.*, 1999; Donzella *et al.*, 2000). The lack of difference between the High- and Low-sour groups in the reactivity of cortisol in the present study can be explained by at least three hypotheses.

First, especially in young children, stress may have been experienced at the baseline measurement. Children were aware when testing was supposed to take place and this could have resulted in a stress response even before the actual testing began. This could explain why no differences in the reactivity of cortisol were measured in the young children. However, previous research indicated that baseline salivary cortisol concentrations of young children are most likely between 0.7 and 3.7 ng/ml (Gunnar *et al.*, 1997; de Haan *et al.*, 1998; Davis *et al.*, 1999; Donzella *et al.*, 2000). In the present study, salivary cortisol concentrations in response to our 'stress' situation were on average between 0.73 ng/ml and 0.9 ng/ml. A second hypothesis is therefore that the 'stress' situation in our study did not initiate real stress. In order for the 'cortisol' system to respond, the situation must be perceived as potentially threatening (Gunnar *et al.*, 1997). A third hypothesis is that the cortisol concentration was not correctly measured. Cortisol, as well as other hormones in the body, follow a circadian rhythm. In general, cortisol levels peak during the early morning and decreases during the afternoon (Schmidt, 1998; Davis *et al.*, 1999). In the present study, stress-cortisol was measured during the late afternoon, whereas baseline-cortisol was measured during the early afternoon. The circadian rhythm of cortisol concentration could potentially have diminished the difference between stress- and baseline-cortisol levels.

Although the results of the present study are in favor of the behavioral determinants in the development of sour taste preferences, it cannot be excluded that the biological development of the sense of taste may also play a role. Previous research has suggested that the development of preferences for sweet-and salt taste are influenced by biological determinants such as energy requirement (sweet taste; Beauchamp and Cowart, 1987) and postnatal maturation of central and/or peripheral mechanisms (salt taste; Mistretta, 1981). It remains unknown whether similar mechanisms are important in the development of preference for sour taste.

It has been suggested that children who prefer sour taste have experienced the tastes of a large variety of fruit (Liem and Mennella, 2003). Preference for sour taste could therefore play an important role in the consumption of sour-tasting fruits. Increasing preference for sour taste in children who initially do not like sour taste is most likely to succeed if the sour food is not presented as novel and exciting. Children who do not prefer sour taste should carefully be introduced to this taste quality. Subsequent repeated exposure could then slowly increase the preference for sour taste and, hypothetically, increase the consumption of sour fruits. This, however, needs to be investigated.

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