Published in final edited form as:
Chem Senses. 2003 February ; 28(2): 173–180.

Heightened Sour Preferences During Childhood

Djin Gie Liem and **Julie A. Mennella**
Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104-3308, USA

Abstract

Basic research has revealed that the chemical sensory world of children is different from that of adults, as evidenced by their heightened preferences for sweet and salty tastes. However, little is known about the ontogeny of sour taste preferences, despite the growing market of extreme sour candies. The present study investigated whether the level of sourness most preferred in a food matrix and the ability to discriminate differences in sour intensity differed between 5- to 9-year-old children and their mothers, by using a rank-by-elimination procedure embedded in the context of a game. Mothers also completed a variety of questionnaires and children were asked several questions to assess whether children's temperament and food preferences and habits related to sour preferences. The results indicated that, although every mother and all but two of the children (92%) were able to rank the gelatins from most to least sour, more than one-third (35%) of the children, but virtually none of the adults, preferred the high levels of sour taste (0.25 M citric acid) in gelatin. Those children who preferred the extreme sour tastes were significantly less food neophobic ($P < 0.05$) and tended to experience a greater variety of fruits when compared with the remaining children ($P = 0.11$). Moreover, the children's preference for sour tastes generalized to other foods, such as candies and lemons, as reported by both children and mothers. These findings are the first experimental evidence to demonstrate that sour taste preferences are heightened during childhood and that such preferences are related to children's food habits and preferences. Further research is needed to unfold the relationship between the level of sour taste preferred and the actual consumption of sour-tasting foods and flavors in children.

Keywords

children; taste preferences; sour taste; food neophobia; picky eating; nutrition

Introduction

> I will add that formerly it looked to me as if the sense of taste, at least with my own children when they were still very young, was different from the adult sense of taste; this shows itself by the fact that they did not refuse rhubarb with some sugar and milk which is for us an abominable disgusting mixture and by the fact that they strongly preferred the most sour and tart fruits, as for instance unripe gooseberries and Holz apples.
>
> (Darwin, 1877)

Charles Darwin (Darwin, 1877) keenly observed that children live in different chemical sensory worlds than adults, as evidenced by their heightened preference for sweet and sour tasting foods. Although basic research confirmed his observations on sweet preferences a

Correspondence to be sent to: Julie A. Mennella, 3500 Market Street, Philadelphia, PA 19104-3308, USA. mennella@monell.org.

century later (Peiper, 1963; Nisbett and Gurwitz, 1970; Maller and Desor, 1973; Desor *et al.*, 1975; Steiner, 1977; Enns *et al.*, 1979; Desor and Beauchamp, 1987), little scientific investigation has focused on the ontogeny of sour taste preferences (Desor *et al.*, 1975; Zandstra and De Graaf, 1998). In spite of this paucity of basic research, industry has clearly found a niche in children for extreme sour candies, which are reported to be quite aversive to adults (Frauenfelder, 1999).

Some contend that children's preference for extreme sour tastes is secondary to their desire for adventure, thrills and excesses (Frauenfelder, 1999; Urbick, 2000), of which these products supposedly provide. To our knowledge, there are no published reports on whether aspects of temperament or attitudes toward foods, in general, relate to children's preferences for sour tastes. However, a study on adults revealed that those who experienced greater dietary diversity preferred higher levels of sour intensity when compared with food neophobic adults (Frank and van der Klauw, 1994).

The present study aimed to test the hypotheses that children prefer higher levels of sourness in foods when compared with adults, and that such preferences are positively related to their willingness to try new foods and experience with dietary diversity. A rank-by-elimination and randomized order procedure, embedded in the context of a game, was used to assess sour preferences as well as the ability to discriminate differences in sour intensity in 5- to 9-year-old children. The mothers of these children were also tested using identical procedures in order to determine sour preferences in an adult population. Mothers also completed a variety of questionnaires and children were asked whether they had ever tried sour-flavored candies, to determine whether personality factors, such as temperament and attitudes towards or experience with foods in general, contribute to preferences for sour taste and flavors.

Materials and methods

Subjects

Mothers were recruited from advertisements in local newspapers. The mothers (31 Caucasian, 26 African American, 1 Asian and 3 from other ethnic groups) were, on average, 37.8 ± 0.7 years of age, and their children (29 girls, 32 boys) ranged in age from 5 to 9 years (mean = 7.4 ± 0.2 years). During a telephone interview, the mother, who was not informed of the hypothesis of the study, was told that she and her child would participate in a 'taste study' in which they would be asked to taste different flavored gelatins. Seven additional children began, but did not complete, testing because they could not understand the task. All children were reported by their mothers to be healthy at the time of testing. The testing procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania. Informed consent was obtained from each parent and assent was obtained from each child who was eight years of age or older.

General procedures and stimuli

Children and their mothers were individually tested at the Monell Center in a closed room specifically designed for sensory testing, with a high air-turnover ventilation system. After subjects acclimated to the room and personnel, we assessed their preferences for sourness. To this end, four lemon-flavored gelatins were made by either adding no citric acid (0.00 M) or different concentrations of citric acid (0.02, 0.08 and 0.25 M; Sigma Chemical Co., St Louis, MO) to 22 g of a stock gelatin dissolved in 473.2 g of water (JELL-O™, Kraft Foods, Inc., Rye Brook, NY). It should be noted that the stock gelatin has a sweet taste because it contains ~0.24 M sucrose and 0.30 M glucose (First Data Bank, Inc, San Bruno, CA). Twenty milliliters of each gelatin was poured into a 30 ml clear medicine cups (Delaware Valley Surgical Supply,

Boothwyn, PA) and refrigerated for at least 4 h to obtain firmness. During testing, the gelatins were stored on a tray containing crushed ice.

Preference rankings methods

An age appropriate, game-like task that was fun for children and minimized the impact of language development was used to examine sour preferences. Using a rank-by-elimination and randomized ordered procedure (Birch, 1979), subjects tasted each of the four gelatins and were asked to point to the one that they liked best. This gelatin was then removed after which subjects were asked to taste the remaining three gelatins again and then indicate which of the three was most preferred. This procedure continued until a rank order preference was established. To determine reliability, subjects were presented, in counterbalanced order, the gelatins ranked as their two most preferred and were asked to point to which of the pair they liked best. Subjects rinsed their mouth twice with bottled water after tasting each gelatin.

Intensity rankings methods

A second test session was conducted ~7.0 ± 0.5 weeks later to determine whether subjects could distinguish the different intensities of sour taste in the gelatins. We randomly selected 24 children (10 boys, 14 girls) and their mothers from those who participated in the first session. Before testing, each subject was trained to distinguish three of the basic tastes: sweet (0.30 M glucose; Sigma), salty (0.30 M Na gluconate; Sigma) and sour (0.01 M citric acid; Sigma). Subjects were then given three pairs of solutions that differed in sour intensity and were asked to focus only on sour taste and to point to which of the pair tasted more sour, rinsing their mouths twice after tasting each sample. All subjects were able to perform this task.

After a five-minute break during which subjects were offered an unsalted cracker and a cup of water to cleanse their palate, they were asked to rank the four gelatins used during the first session (0.00, 0.02, 0.08 and 0.25 M added citric acid) from most to least sour. The rank-by-elimination procedure was identical to that described above for the preference test, except here subjects indicated which one tasted most sour. At the end of the test session, subjects were asked to taste, in counterbalanced order, the least (0.00 M added citric acid) and the most sour (0.25 M added citric acid; hereafter referred to as ‘extreme sour’) gelatin. Immediately after tasting each gelatin, subjects were asked to respond in the affirmative or negative to the questions: Does this gelatin taste sweet? Does it taste sour? Subjects rinsed their mouths with water twice between tastings. One child did not understand the task and therefore was excluded.

Food habits, food neophobia and child temperament measures

Without communicating to the child, mothers completed a series of questionnaires which included a 10-item scale that measured food neophobia (Pliner and Loewen, 1997) and a eight-item scale that measured general neophobia in adults (Pliner and Loewen, 1997), and a 25-item scale that measured five temperament dimensions (i.e. emotionality, shyness, activity, sociability and negative reaction to foods in general) in their children (Pliner and Hobden, 1992). In a few cases, mothers did not answer all questions and therefore some measures could not be calculated (see Table 1). Because we were also interested in assessing the children’s reaction to new foods, mothers were asked to indicate on a 5-point scale (1 = not at all characteristic of the child; 5 = very characteristic of the child) their agreement with the statements ‘My child is afraid to try new foods’ and ‘My child does not trust new foods’ (Pliner and Loewen, 1997), as well as to indicate whether they regarded their child as a picky eater and whether they were picky eaters as children themselves. We also asked each mother whether she thought her child went ‘through a sour phase’ exhibiting strong preferences for sour candies or raw lemons. As a first step in investigating whether experience with a variety of sour foods (e.g. fruits) impacts upon children’s sour preferences, all but six of the mothers indicated which of the following fruits their child had experienced at home during the past week (i.e. grapes,

bananas, oranges, pineapple, melon, apples, apple sauce, pears, apricots, raisins and berries). Children were asked directly whether they had ever eaten and whether they liked extreme sour candies such as Warheads™ (Foreign Candy Company, Hull, IA); all but three of the children responded to these questions. In addition, all but one of the children were weighed and measured for height.

Statistical analyses

Sour taste preference and intensity rankings—The null hypothesis tested was that there were no systematic differences in children's or mothers' preference ranking of the four gelatins that differed in citric acid content (i.e. 0.0, 0.02, 0.08 and 0.25 M added citric acid). To test this, each of the four gelatins was ranked according to subject's preferences (1 = most preferred; 4 = least preferred). Data obtained from mothers were analyzed separately from children. Separate Friedman two-way analyses of ranks were then conducted on these preference ranking scores. Similar analyses were conducted on the sour intensity ranking scores. When significant, multiple comparisons were performed to determine which differences among the gelatins were significant (Siegel and Castellan, 1988). To test the reliability, identical responses between test and retest were defined as reflecting guessing if the proportion was below the upper limit of the 95% confidence interval for 50% correct responses, the latter being the predicted proportion if subjects were guessing (Snedecor and Cochran, 1989). All summary statistics are expressed as means ± SEM and levels of significance were $P < 0.05$.

To investigate whether there were differences in sour taste preferences between children and mothers, the frequencies of subjects who classified the extreme sour tasting gelatin (0.25 M added citric acid) as either their most preferred (ranked 1 or 2; hereafter referred to as high-sour group) or least preferred (ranked 3 or 4; hereafter referred to as low-sour group) were also determined. Chi-square statistics were then performed to determine whether children's preferences differed from adults; the Yates correction for continuity was applied to all chi-square analyses. To determine whether the children's sour preferences were related to their mothers' sour preferences, Kendall tau correlations were calculated for each child–mother pair.

Subject demographics, child temperament and food habits—One-way analyses of variance (ANOVA) were conducted to determine whether there were significant differences between the groups (High-Sour versus Low-Sour) on a variety of measures such as the ages, body mass index (BMI, in kg/m^2) and temperament scores of the children, and the age, and food and general neophobia scores of the mother. Chi-square analyses with Yates correction for continuity were performed to determine whether there were group differences in sex ratio, ethnicity and the proportion of children who were perceived as picky eaters.

Results

Sour taste preferences

A striking difference emerged between children and their mothers in their preferences for the extreme sour gelatin. That is, more than one-third (35%) of the children (High-Sour group), but virtually none of the mothers, ranked the highest concentration of citric acid (0.25 M added citric acid in gelatin) as one of their most preferred gelatins [$\chi^2(1) = 24.46$; $P < 0.0001$]. Friedman analyses indicated significant differences in preference ranking of the four gelatins in both groups of children [Low-Sour group: $F_r(3) = 81.73$; $P < 0.0001$; High-Sour group: $F_r(3) = 23.07$; $P < 0.001$] as well as the mothers [$F_r(3) = 127.20$; $P < 0.00001$]. Post-hoc analyses revealed that children in the High-Sour group ranked the extreme sour gelatin as their most preferred and the least sour gelatin as their least preferred whereas the exact opposite was true for the remaining children (Low-Sour group) and mothers (all $P < 0.05$) (see Figure 1).

Furthermore, children in the Low-Sour group, as well as adults, preferred the gelatin containing 0.02 M citric acid more than gelatins containing 0.08 and 0.25 M citric acid, although there were no significant differences in preference between the gelatin with no added citric acid and that with 0.02 M citric acid.

That both groups of children and mothers understood the task is suggested by the strong agreements between their first and second preference rank ordering of the gelatins [High-Sour group: 80% (95% confidence limits = 50 ± 23%); Low-Sour group: 92% (95% confidence limits = 50 ± 17%); mothers: 98% (95% confidence limits = 50 ± 13]. No significant difference in sour preference was observed between children in the Low-Sour group and mothers [$\chi^2(1) = 0.04$; $P = 0.84$]. Nor was a significant relationship observed between mother-child pairs in their preferences for sour flavors in gelatin (Kendall tau correlation, all $P > 0.30$).

Sour intensity rankings—There were significant differences in the intensity ranking scores of the four gelatins in both groups of children [Low-Sour group: $F_r(3) = 45.00$; $P < 0.0001$; High-Sour group: $F_r(3) = 24.87$; $P < 0.0001$] as well as in mothers [$F_r(3) = 72.00$; $P < 0.00001$]. That is, every mother and all but two of the children (92%) were able to rank the gelatins from most to least sour in an errorless fashion thus suggesting that they perceived the different sour intensities in the gelatins. Furthermore, every child and adult reported that the 0.25 M citric acid gelatin tasted sour but the 0.0 M citric acid gelatin did not. Likewise, the majority of subjects (High-Sour group: 66.7%, $n = 6$, Low-Sour group: 80%, $n = 12$, Adults: 95.8%, $n = 23$) reported that the 0.0 M citric acid gelatin tasted sweet. There were no significant differences between the groups [High-Sour versus Low-Sour group, $\chi^2(1) = 0.06$; $P = 0.81$; High-Sour group versus adults, $\chi^2(1) = 2.85$; $P = 0.10$; Low-Sour group versus adults, $\chi^2(1) = 1.09$; $P = 0.30$].

Subject characteristics, child temperament and food experience—Further analyses were then conducted to determine whether there were significant differences on any of the measures studied between these High-Sour and Low-Sour groups of children. Salient characteristics of these two groups of children and their mothers are listed in the Table. No significant differences between the groups were observed for the children's ages [$F(1,59) = 0.99$; $P = 0.32$], BMI [$F(1,58) = 1.28$; $P = 0.26$], proportion of girls to boys [$\chi^2(1) = 0.31$; $P = 0.58$] and ethnicity [$\chi^2(3) = 6.61$; $P = 0.09$]; nor was there any difference between the groups in the mothers' age [$F(1,58) = 0.89$; $P = 0.35$], or the mothers' food neophobia [$F(1,59) = 0.74$; $P = 0.39$] and general neophobia [$F(1,59) = 1.94$; $P = 0.17$] scores.

In addition, there were no significant differences in the children's temperament dimensions of shyness [$F(1,59) = 0.25$; $P = 0.162$], emotionality [$F(1,58) = 0.10$; $P = 0.75$], sociability [$F(1,59) = 0.53$; $P = 0.38$], activity [$F(1,59) = 1.14$; $P = 0.29$] or overall negative reactions to foods [$F(1,58) = 0.32$; $P = 0.57$]. However, mothers of children in the Low-Sour group were significantly more likely to perceive their child as a picky eater [$\chi^2(1) = 4.47$; $P < 0.05$], and were more likely to agree with the statements 'My child is afraid to try new foods' [$F(1,56) = 5.11$; $P < 0.05$] and 'My child does not trust new foods' [$F(1,56) = 6.02$; $P < 0.05$] when compared with those in the High-Sour group. In addition, mothers who reported that their child was a picky eater tended to be more likely to report that they themselves were considered picky eaters when they were children [$\chi^2(1) = 3.41$; $P < 0.06$]. Furthermore, mothers who were considered picky eaters when they were children were more likely to be food neophobic as adults [$F(1, 57) = 10.68$; $P < 0.001$] when compared with mothers who were not considered picky eaters as children.

Those children who preferred the extreme sour flavor in gelatins, as assessed in the laboratory, were significantly more likely to report not only that they had tried sour candies [$\chi^2(1) = 4.65$; $P = 0.03$], but they liked their taste as well [$\chi^2(1) = 7.02$; $P < 0.008$]. That such sour preferences

generalized to other foods is suggested by the findings that mothers of children in the High-Sour group were significantly more likely to report that their child had gone, or was going through, a phase of preferring sour foods such as lemons or candies [$\chi^2(1) = 3.76$; $P < 0.05$], and tended to report that, at least in the home, their child experienced a larger variety of fruits during the last week when compared with the Low-Sour group [$F(1,53) = 2.59$; $P < 0.11$].

Discussion

The present study demonstrated, as Darwin (Darwin, 1877) observed 125 years ago, that some children have heightened sour preferences when compared with adults. One-third of the 5- to 9-year-old children, but virtually none of the mothers, preferred extremely sour tastes in a novel context, that is, sour-flavored gelatin. Their preferences increased with increasing levels of citric acid. The remaining children exhibited the adult pattern such that preferences decreased with increasing levels of citric acid, a finding that is consistent with previous research on both young adults (Moskowitz *et al.*, 1975, 1976; Chauhan and Hawrysh, 1988) and the elderly (Murphy and Withee, 1986; Chauhan and Hawrysh, 1988). Those children who preferred the extreme sour tastes were less food neophobic and tended to experience a greater variety of fruits, as reported by their mothers, when compared with the remaining children. Moreover, the children's preferences for sour tastes generalized to other foods, such as candies and lemons, as reported by both children and mothers, and were not related to their mothers' sour taste preferences.

Three hypotheses, not mutually exclusive, could account for the differences in sour preferences within children and between children and adults. First, perhaps children who preferred the extreme sour taste could not discriminate between the different sour gelatins when compared with the other children and adults (Oram *et al.*, 2001). However, this seems highly unlikely for several reasons. First, the vast majority of the children were able to rank the gelatins from most to least sour in an errorless fashion. Secondly, children's ranking of the gelatins from most to least preferred was found to be a reliable measure, regardless of the level of sour most preferred. Thirdly, children, like adults, recognized the sour taste components in a complex food matrix such as gelatin. Nevertheless, additional research is needed to determine whether the two groups of children perceived sour tastes differently (Enns *et al.*, 1979; James *et al.*, 1997).

A second hypothesis, and one that is popular in the marketing field, is that children's preferences for sour tastes are secondary to their generalized preferences for adventure and thrills (Frauenfelder, 1999; Urbick, 2000). To our knowledge, there is no scientific basis for such claims. It is unknown whether children who have heightened preferences for sour tastes generalize this preference to other senses, such as vision (e.g. bright colors) and hearing (e.g. loud noises), or other tastes (e.g. sweet). However, previous research in our laboratory revealed that preference for extreme sour taste in children was not related to heightened sweet preferences (Liem and Mennella, 2002). Although the present study did not measure thrill-seeking behavior or sensory reactivity *per se*, children who preferred extreme sour tastes did not differ significantly from the other children in a variety of temperament dimensions, such as shyness, emotionality or sociability. What appears to be significant is the degree of adventure as it relates to new foods, however. That is, like adults (Frank and van der Klauw, 1994), children who preferred extreme sour tastes were less food neophobic and less likely to be perceived as picky eaters by their mothers.

Perhaps individuals who are less food neophobic were more likely to experience extremely sour foods and, after repeated exposure, developed preferences for such flavors (Birch and Marlin, 1982; Birch *et al.*, 1998; Pliner and Stallberg-White, 2000). Consistent with this suggestion is the finding that children who preferred the extreme sour tastes in the gelatin (High-Sour group) were significantly more likely to try extreme sour candy such as

Warheads™, and to report that they liked the flavor of these candies when compared with the Low-Sour group. Therefore, we hypothesize that children who preferred extreme sour tastes are not only more likely to *try* extreme sour foods but they continue to eat such foods and subsequently develop a preference for extremely sour flavors.

This hypothesis is consistent with previous research on adults (Moskowitz *et al.*, 1975) and children (Liem and Mennella, 2002; Mennella and Beauchamp, 2002) that revealed that repeated exposure to sour flavors may lead to subsequent preferences. Children who were fed a formula that has a sour and bitter flavor component (i.e. protein hydrolysate formulas) during their infancy preferred sour-flavored juices significantly more than did children who were not exposed to such formulas (Mennella and Beauchamp, 2002). Because no differences were observed in their sweet preferences, the effect of early experience appeared to be specific to sour tastes. Of interest is the finding that Indian laborers, whose diet consists of many sour foods, such as tamarind fruits, preferred higher levels of citric acid in water when compared with those living in Western populations whose diet had less of an emphasis on sour foods (Moskowitz *et al.*, 1975).

The present study revealed that children who preferred extreme sour candies such as Warheads™ were significantly more likely to prefer the extreme sour tastes in gelatins. It should be noted that the methods used to assess preference for gelatins (i.e. rank-by-elimination procedures) are limited because the determined level of preferences is relative to the other stimuli presented. However, we emphasize that children in the High-Sour group also reported that they preferred a variety of other sour-flavored food items thus suggesting that these children indeed preferred sour taste.

Whether the heightened sour preference for these sour tasting candies and food exhibited in one-third of the children decreases with age is unknown. Nor do we know whether the preference for sour tastes is due to repeated exposure to these extreme sour candies, which were introduced into the American market during the past decade (Frauenfelder, 1999). However, Darwin's description of his children's preference for tart apples (Darwin, 1877) and the report by mothers in the present study that their children went through a sour phase (e.g. preferred lemons) suggest that the heightened sour preferences during childhood can be expressed via a variety of sour-tasting foods, not just candies.

An alternative explanation is that the effects of experience with sour foods may be secondary to effects of experience with dietary diversity since the present study also revealed that children who preferred extreme sour tastes tended to experience a larger variety of fruits. Of interest is the recent finding that children who are food neophobic consume a diet consisting of less dietary variety when compared with children who do not exhibit such behavior (Carruth *et al.*, 1998; Falciglia *et al.*, 2000). That dietary diversity enhances acceptance of new foods has been demonstrated in human infants (Gerrish and Mennella, 2001) as well as animal models (Capretta *et al.*, 1975). In young children, dietary diversity is determined, in part, by the availability of foods provided by their caretakers and dietary patterns and attitudes towards foods are largely influenced by mothers (Klesges *et al.*, 1991; Fisher *et al.*, 2002). In particular, fruit and vegetable intake by young children is positively related to parental fruit and vegetable intake (Fisher *et al.*, 2002). The present study revealed that mothers, who reported being picky eaters as children, tended to view their own children as picky eaters and food neophobic. Whether such mothers are providing less dietary diversity, which, in turn, is related to their children's sour preferences and consumption of sour tasting foods, is unknown.

A third, and not mutually exclusive, hypothesis is that there are ontogenic changes in taste perception, independent of experience, that underlie the heightened sour preferences in some children. Responsiveness to salt and sweet tastes provides perhaps the clearest example of a

developmental change to taste stimuli that occurs postnatally (Desor *et al.*, 1975; Beauchamp and Cowart, 1987; Mennella, 1999). Although human newborns are indifferent to salt taste, preference for salt emerges at ~4–6 months of age, remains heightened throughout childhood and adolescence, and then decreases to levels resembling that of the adult during late adolescence (Desor *et al.*, 1975). The shift from indifference to preference is thought to be largely unlearned and due to postnatal maturation of central and/or peripheral mechanisms underlying salt taste perception, as suggested in animal model studies (Hill and Mistretta, 1990). Like salt taste, preferences for sweet tastes remain heightened during infancy and childhood and decrease to levels resembling that of the adult during late adolescence (Beauchamp and Cowart, 1987). That heightened sweet preferences during development has been observed in animal model studies (Bertino and Wehmer, 1981) suggested that experience with sweets during ontogeny cannot exclusively account for this decline in sweet preference (Beauchamp and Cowart, 1987).

Although the mechanisms underlying these age-related changes in sweet and salt preferences during late adolescence remain unknown, we suggest that similar age-related changes may be occurring for sour taste in some children. In adults, the perception of sour is related, but not exclusively, to pH and salivary flow (Norris *et al.*, 1984; Christensen *et al.*, 1987; Spielman, 1990). That is, adults with high salivary flow rates and pH rated sour stimuli consistently more intense when compared with those with lower salivary flow rates and pH (Norris *et al.*, 1984). This elevation in perceived intensity is presumably due to the greater contrast between the pH of the stimulus and individual's salivary pH. Whether the enhanced sour preferences observed in some children is related to differences in these physiological measures remains to be determined. Moreover, longitudinal studies on sour preferences, like those conducted on the ontogeny of sweet and salt taste preferences, are needed.

The findings of the present study further support the contention that children are living in different chemical sensory worlds when compared with each other as well as to adults. Such differences in sensory preferences may play a role in acceptance of and preference for certain foods and flavors. Previous research suggests that sensory preferences and experiences with foods are better predictors of fruit and vegetable consumption in children than the foods' nutritional content or social value (Resnicow *et al.*, 1997). Consideration of the relationship between the level of sour taste preferred and actual consumption of sour-tasting foods and flavors is an important area for future research.

Acknowledgments

We acknowledge the expert technical assistance of Mr Brian Pollack and the student apprentices Ms Mayla Henderson and Ms Kelly Walker, whose research apprenticeships were supported by grants from The Annenberg Foundation and Mrs Patricia Kind. This work was supported by grant HD37119 from the National Institute of Child Health and Human Development. The research reported in this paper was completed as part of the first author's dissertation in the Department of Human Nutrition and Epidemiology, Wageningen University, The Netherlands.

References

Beauchamp, GK.; Cowart, BJ. Development of sweet taste. In: Dobbing, J., editor. Sweetness. Berlin: Springer-Verlag; 1987. p. 127-138.

Bertino M, Wehmer F. Dietary influence on the development of sucrose acceptability in rats. Devl Psychobiol 1981;14:19–28.

Birch LL. Dimensions of preschool children's food preferences. J. Nutr. Educ 1979;11:77–80.

Birch LL, Marlin DW. I don't like it; I never tried it: effects of exposure on two-year-old children's food preferences. Appetite 1982;3:353–360. [PubMed: 7168567]

Birch LL, Gunder L, Grimm-Thomas K. Infants' consumption of a new food enhances acceptance of similar foods. Appetite 1998;30:283–295. [PubMed: 9632459]

Capretta PJ, Petersik JT, Stewart DJ. Acceptance of novel flavours is increased after early experience of diverse tastes. Nature 1975;254:689–691. [PubMed: 1124124]

Carruth BR, Skinner J, Houck K, Moran J, Coletta F, Ott D. The phenomenon of 'picky eater': a behavioral marker in eating patterns of toddlers. J. Am. Coll. Nutr 1998;17:180–186. [PubMed: 9550462]

Chauhan J, Hawrysh ZJ. Suprathreshold sour taste intensity and pleasantness perception with age. Physiol. Behav 1988;43:601–607. [PubMed: 3200915]

Christensen CM, Brand JG, Malamud S. Salivary changes in solution pH: a source of individual differences in sour taste perception. Physiol. Behav 1987;40:221–227. [PubMed: 3628532]

Darwin C. Biographiche skizze eines kleinen kindes. Kosmos 1877:367–376.

Desor JA, Beauchamp GK. Longitudinal changes in sweet preferences in humans. Physiol. Behav 1987;39:639–641. [PubMed: 3588712]

Desor JA, Greene LS, Maller O. Preferences for sweet and salty in 9- to 15-year-old and adult humans. Science 1975;190:686–687. [PubMed: 1188365]

Desor JA, Maller O, Andrews K. Ingestive responses of human newborns to salty, sour, and bitter stimuli. J. Comp. Physiol. Psychol 1975;89:966–970. [PubMed: 1184802]

Enns MP, Van Itallie TB, Grinker JA. Contributions of age, sex and degree of fatness on preferences and magnitude estimations for sucrose in humans. Physiol. Behav 1979;22:999–1003. [PubMed: 504405]

Falciglia GA, Couch SC, Gribble LS, Pabst SM, Frank R. Food neophobia in childhood affects dietary variety. J. Am. Diet. Assoc 2000;100:1474–1481. [PubMed: 11138439]

Fisher JO, Mitchell DC, Smiciklas-Wright H, Birch LL. Parental influences on young girls' fruit and vegetable, micronutrient, and fat intakes. J. Am. Diet. Assoc 2002;102:58–64. [PubMed: 11794503]

Frank RA, van der Klauw NJ. The contribution of chemosensory factors to individual differences in reported food preferences. Appetite 1994;22:101–123. [PubMed: 8037436]

Frauenfelder, M. Gross National Product. 1999. Wired archive [serial online] 6, http://www.wired.com/wired/archive/7.06/candypr.html

Gerrish CJ, Mennella JA. Flavor variety enhances food acceptance in formula-fed infants. Am. J. Clin. Nutr 2001;73:1080–1085. [PubMed: 11382663]

Hill DL, Mistretta CM. Developmental neurobiology of salt taste sensation. Trends Neurosci 1990;13:188–195. [PubMed: 1693238]

James CE, Laing DG, Oram N. A comparison of the ability of 8–9-year-old children and adults to detect taste stimuli. Physiol. Behav 1997;62:193–197. [PubMed: 9226362]

Klesges RC, Stein RJ, Eck LH, Isbell TR, Klesges LM. Parental influence on food selection in young children and its relationships to childhood obesity. Am. J. Clin. Nutr 1991;53:859–864. [PubMed: 2008864]

Liem DG, Mennella JA. Sweet and sour preferences during childhood: role of early experiences. Devl Psychobiol 2002;41:388–395.

Maller, O.; Desor, JA. Effect of taste on ingestion by human newborns. In: Bosma, JF., editor. Fourth Symposium on Oral Sensation and Perception: Development of the Fetus and Infant. Washington, DC: Government Printing Office, DHEW Publication NIH 73–546; 1973. p. 279-291.

Mennella, JA. Taste and smell. In: Swaiman, KF.; Ashwall, S., editors. Pediatric Neurology: Principles and Practice. Philadelphia, PA: CV Mosby Company; 1999. p. 104-113.

Mennella JA, Beauchamp GK. Flavor experiences during formula feeding are related to preferences during childhood. Early Human Dev 2002;68:71–82.

Moskowitz HW, Kumaraiah V, Sharma KN, Jacobs HL, Sharma SD. Cross-cultural differences in simple taste preferences. Science 1975;190:1217–1218. [PubMed: 1198109]

Moskowitz HR, Kumraiah V, Sharma KN, Jacobs HL, Sharma SD. Effects of hunger, satiety and glucose load upon taste intensity and taste hedonics. Physiol. Behav 1976;16:471–475. [PubMed: 959349]

Murphy C, Withee J. Age-related differences in the pleasantness of chemosensory stimuli. Psychol. Aging 1986;1:312–318. [PubMed: 3267412]

Nisbett RE, Gurwitz SB. Weight, sex and the eating behavior of human newborns. J. Comp. Physiol. Psychol 1970;73:245–253. [PubMed: 5493265]

Norris MB, Noble AC, Pangborn RM. Human saliva and taste responses to acids varying in anions, titratable acidity, and pH. Physiol. Behav 1984;32:237–244. [PubMed: 6718550]

Oram N, Laing DG, Freeman MH, Hutchinson I. Analysis of taste mixtures by adults and children. Devl Psychobiol 2001;38:67–77.

Peiper, A. Cerebral Function in Infancy and Childhood. New York: Consultants Bureau; 1963.

Pliner P, Hobden K. Development of a scale to measure the trait of food neophobia in humans. Appetite 1992;19:105–120. [PubMed: 1489209]

Pliner P, Loewen ER. Temperament and food neophobia in children and their mothers. Appetite 1997;28:239–254. [PubMed: 9218097]

Pliner P, Stallberg-White C. 'Pass the ketchup, please': familiar flavors increase children's willingness to taste novel foods. Appetite 2000;34:95–103. [PubMed: 10744896]

Resnicow K, Davis-Hearn M, Smith M, Baranowski T, Lin LS, Baranowski J, Doyle C, Wang DT. Social-cognitive predictors of fruit and vegetable intake in children. Health Psychol 1997;16:272–276. [PubMed: 9152706]

Siegel, S.; Castellan, NJ. The case of *k* related samples. In: Anker, JD., editor. Nonparametric Statistics for Behavioral Sciences. New York: McGraw-Hill; 1988. p. 168-189.

Snedecor, GW.; Cochran, WG. The binomial distribution. In: Snedecor, GW.; Cochran, WG., editors. Statistical Methods. Ames, IA: Iowa State University Press; 1989. p. 107-134.

Spielman AI. Interaction of saliva and taste. J. Dent. Res 1990;69:838–843. [PubMed: 2182682]

Steiner, JE. Facial expressions of the neonate infant indication the hedonics of food-related chemical stimuli. In: Weiffenbach, JM., editor. Taste and Development: the Genesis of Sweet Preference. Washington, DC: U.S. Government Printing Office; 1977. p. 173-188.

Urbick, B. Part two: what we have learned about kids. In: Urbick, B., editor. What about Kids: Food and Beverages. Surrey: Leatherhead Publishing; 2000. p. 17-39.

Zandstra EH, De Graaf C. Sensory perception and pleasantness of orange beverages from childhood to old age. Food Qual. Pref 1998;9:5–12.

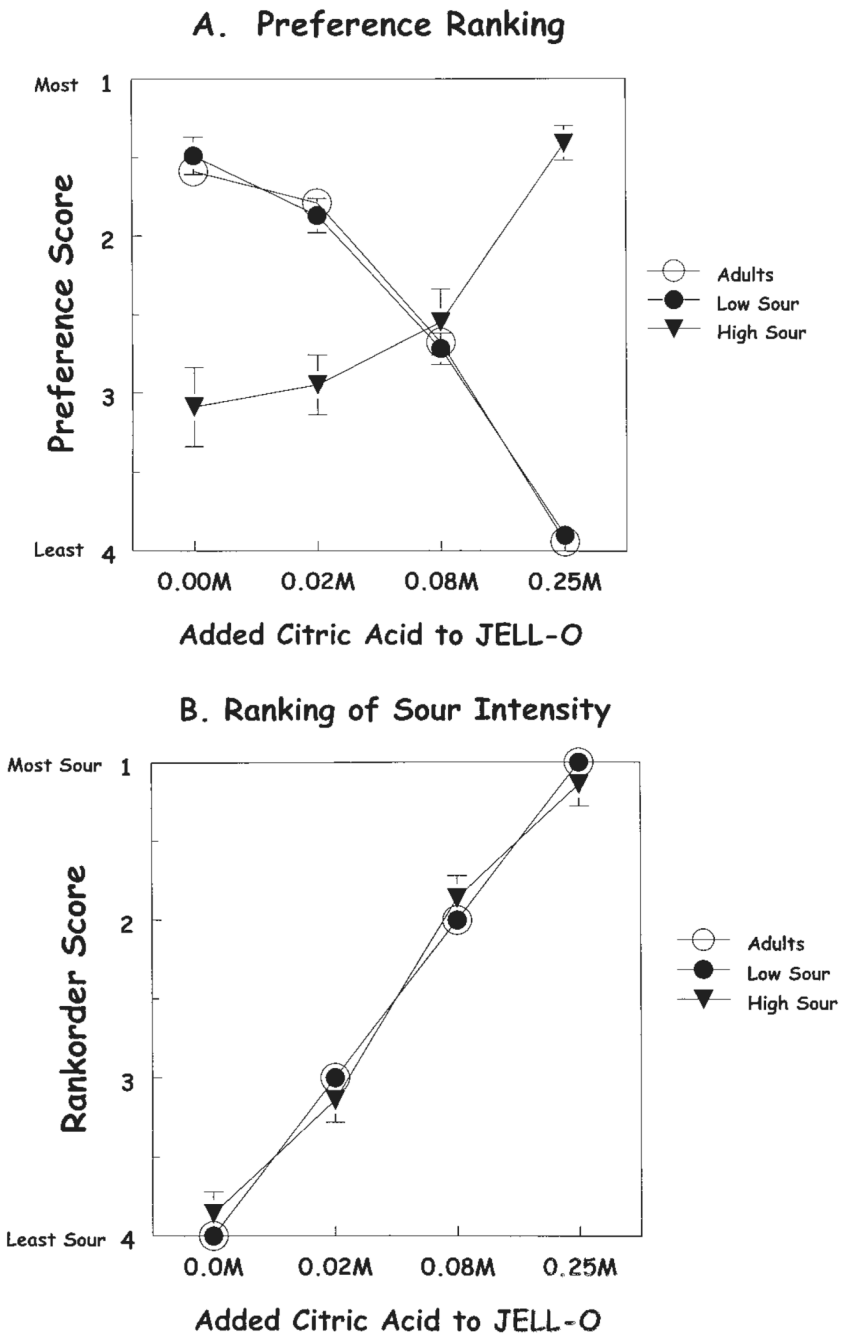

Figure 1.

Mean (± SEM) preference ranking **(A)** and sour intensity ranking **(B)** for 0.00, 0.03, 0.08 and 0.25 M added citric acid to gelatin in children (closed symbols) and their mothers (open circles). Children were divided into groups based on the level of sourness preferred in gelatin; those in the High-Sour group (closed triangle, $n = 22$) ranked the 0.25 M gelatin as one of their most preferred gelatins whereas those in the Low-Sour group (closed circle, $n = 39$) did not.

Table 1

Subject characteristics of children who preferred 0.25 M citric acid in gelatin (High-Sour group) and those who did not (Low-Sour group)

	Preference group based on level of sourness preferred in gelatin	
	High-Sour group	**Low-Sour group**
Children's characteristics		
Age (years)	7.6 ± 0.3	7.3 ± 0.2
Sex (girls:boys)	12:10	17:22
BMI (kg/m^2)	18.2 ± 1.3	16.9 ± 0.5
Temperament measures[1]		
Shyness	2.2 ± 0.2	2.3 ± 0.1
Emotionality	2.8 ± 0.2	2.9 ± 0.2
Sociability	3.7 ± 0.1	3.6 ± 0.1
Negative reactions to foods	3.0 ± 0.2	3.2 ± 0.1
Activity	3.5 ± 0.2	3.7 ± 0.1
Percentage who tried sour candies	100.0	73.7*
Percentage who preferred sour candies	95.0	57.9*
Mothers' characteristics		
Age (years)	36.9 ± 1.2	38.4 ± 1.0
Food neophobia score[2]	37.1 ± 2.6	34.3 ± 2.0
General neophobia score[3]	21.5 ± 1.4	24.4 ± 1.4
Percentage of mothers who reported child went through a 'sour phase'	60.0	29.7*

*Statistically significant differences between groups at $P < 0.05$.

[1]Child temperament measures could range from 1 to 5 (1 = not at all characteristic of the child and 5 = very characteristic of the child (Fisher *et al.*, 2002).

[2]The food neophobia score could range from 10 to 70.

[3]The general neophobia score could range from 8 to 56.