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Variety is the spice of life: Strategies for promoting fruit and vegetable acceptance during infancy ☆

Julie A. Mennella^{*}, Sophie Nicklaus, Amanda L. Jagolino, and Lauren M. Yourshaw
Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104–3308, United States

Abstract

The present manuscript describes two experimental studies that were conducted to explore the effects of an 8-day exposure to a particular food or a variety of foods between and/or within meals on fruit and vegetable acceptance in 74 infants. Whether the dietary experience modified acceptance depended on the flavors of foods experienced, whether the experience occurred between or within meals or both, and whether the target food was a fruit or vegetable. In the first study, we found that 8 days of dietary exposure to pears or a variety of fruits between meals (not including pears) resulted in greater consumption of pears by the infants but this increased acceptance did not generalize to green beans. In the second study, we found that 8 days of vegetable variety both between and within meals led to increased acceptance of green beans, carrots and spinach. Those infants who experienced green beans alone or a variety of vegetables between meals also tended to eat more green beans after the exposure. These findings suggest that not only can infants clearly discriminate flavors but repeated opportunities to taste a particular or a variety of foods may promote willingness to eat fruits and vegetables, the consumption of which is generally low in the pediatric population and the acceptance of which is difficult to enhance beyond toddlerhood.

Keywords

Infant nutrition; Fruits; Vegetables; Variety; Taste; Flavor; Feeding; Diet

1. Introduction

Experience with variety sets the pattern for a diversified diet [1–5]. By offering a variety of foods, animals ingest more of an otherwise monotonous diet [1]. Because flavor variety is associated with greater variety in the nutritive content of foods [3,6], a preference for varied flavors should ultimately increase the range of nutrients consumed and the likelihood that a well-balanced diet is achieved. In other words, the variety effect may reflect an important adaptive mechanism in the regulation of food intake among omnivores.

That the effects of experience with variety may be more pronounced during early development is suggested by laboratory and field studies [2,5]. Immature and mature laboratory rats drank either one or three different types of flavored water with their food for twelve days. Initial acceptance of a novel liquid was greater in those immature animals that experienced a variety of flavored waters. Comparable findings were not observed in mature animals [2]. In field studies, Provenza and colleagues demonstrated that when the nutritional content of the diet

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* Corresponding author. 3500 Market Street, Philadelphia, PA 19104–3308, United States. Tel./fax: +1 267 519 4880. E-mail address: mennella@monell.org (J.A. Mennella).

was held constant, lambs preferred to forage in locations that offered a variety of flavors [5]. Exposing young calves and sheep to a variety of foods and different locations minimized transition problems to new environments. In other words, early experiences with diversity prepared young animals for diversity or unfamiliarity later in life which, in turn, enabled them to best select a diet that suits their needs. It is not that older animals cannot learn to accept new foods; it is just *easier* and *quicker* to teach a younger animal [7].

To date, there has been a few experimental studies on how different types of early dietary experience impact upon food acceptance at weaning. One type of experience entailed repeated dietary exposure to a particular vegetable for at least 8 days. Like children [8], infants ate significantly more carrots [9] and green beans [10,11] after repeated exposure to that particular vegetable. Merely looking at the food does not appear to be sufficient since children have to *taste* the food to learn to like it [11,12].

A second type of dietary experience did not require actual tasting of the vegetable but rather experience with a variety of flavors. Infants who were repeatedly exposed to a different starchy vegetable each day ate as much carrots after the exposure as did infants who were repeatedly exposed to carrots [9]. Similarly, infants who had more exposure to a variety of fruits were more accepting of carrots when compared to those with no fruit experience [9]. Whether experience with a variety of fruits or vegetables would increase acceptance of a green vegetable or fruits is not yet known.

The present manuscript describes two experimental studies that were conducted to explore the effects of repeated exposures and variety on fruit and vegetable acceptance in infants. The first study was designed to examine the effects of repeated dietary experience with either one fruit (i.e., pears) or a variety of fruits on infants' acceptance of pears and green beans. We hypothesized that both types of dietary experiences would lead to greater infants' acceptance of pears but this acceptance would not generalize to green beans since the latter tastes bitterer and less sweet than pears. Because rejection of bitter taste is innate [13], infants may need actual experience with bitter taste, more exposures, or a different type of variety experience to enhance acceptance of green vegetables [14].

The second study determined whether different dietary variety experiences affect infants' acceptance of the target vegetables. We tested the hypothesis that experience with a variety of vegetables *within* a meal as well as *between* meals would lead to greater acceptance of vegetables since animal model studies revealed that rats repeatedly offered foods, albeit more palatable, both within- and between- meals ate more than those exposed to variety between meals (i.e., every 12 h); both variety groups ate more than those exposed only to lab chow [15].

2. Methods

2.1. Subjects

Seventy-four mothers whose infants were between the ages of 4 and 9 months were recruited from advertisements in local newspapers and from Women, Infant and Children Programs in Philadelphia, PA. Their ethnic background was 55.4% ($N=41$) Black; 29.7% ($N=22$) White; 2.7% ($N=2$) Hispanic and 12.2% ($N=9$) Other/Mixed Ethnicity. All infants were born full-term and healthy as reported by their mothers. To qualify the infants had to have at least two weeks of experience eating cereal or fruit from a spoon and little experience with the target fruits and vegetables. The Office of Regulatory Affairs at the University of Pennsylvania approved all procedures and informed consent was obtained from each mother prior to the study.

The mother–child dyads were randomly assigned to participate in one of two experimental studies and within each study they were randomized to an experimental group, as described below and illustrated in Fig. 1. Each mother–infant dyad came to the Monell Center 2 days before (Days 1 and 2) and after (Days 11 and 12) the 8-day home exposure period. The exposure occurred during a target meal that occurred at the same time of day as each of the Monell Test Sessions and the eight consecutive days of the home exposure period. Although the general procedures were similar for both studies, the types of foods fed to the infants differed between the two studies and among the experimental groups.

2.1.1. Study 1: Fruits—As illustrated in Fig. 1, we evaluated infants' acceptance of pears on Days 1 and 11 and green beans on Days 2 and 12. During the home exposure period, one group fed only pears at the target meal (Pear Group, $N=20$) whereas the other group fed a fruit which was different than the one experienced during the previous 2 days (Between-Meal (BM) Fruit Variety Group, $N=19$). Seven additional mother–infant pairs began testing but were excluded from the final analyses because either mothers did not comply with experimental procedures ($N=5$); the child was sick during the home exposure period ($N=1$) or ate less than five grams on each of the testing days ($N=1$).

2.1.2. Study 2: Vegetables—As illustrated in Fig. 1, we evaluated infants' acceptance of green beans on Days 1 and 11 and alternating spoonfuls of carrots and spinach on Days 2 and 12 (see Monell Test Sessions below). The three groups differed in the type, amount and variety of foods that infants were fed during the target meal during the 8-day home exposure period. The infants in the Green Bean Group ($N=11$) were fed only the target vegetable, green beans, whereas those in the Between-Meal variety group (BM Vegetable Variety Group, $N=12$) and the Between-Meal and Within-Meal Variety Group (BM–WM Vegetable Variety Group, $N=12$) were fed a variety of vegetables. The BM Variety Group was fed only one vegetable each day and green and orange vegetables were alternated daily, whereas the BM–WM Variety Group was fed two vegetables each day (one green, one orange). In the latter group, the pair of vegetables varied from day-to-day but one of the pair was experienced the prior day. Seven additional mother–infant pairs began testing but were excluded from the final analyses because either they did not comply with experimental procedures ($N=2$); they did not complete the study ($N=2$); or the child ate less than five grams during the test sessions at Monell ($N=3$).

2.2. Foods

All foods used in both studies were commercially available infant foods from Gerber Products Company (Fremont, MI). In Study 1, the fruits were Stage 1 pureed pears (0.56 kcal/g), peaches (0.49 kcal/g), prunes (0.99 kcal/g), apples (0.56 kcal/g), and the vegetable was Stage 2 green beans (0.31 kcal/g). The maximum amount that could be extracted from each container of fruits was 71 g and green beans was 110 g.

In Study 2, five different Stage 2 vegetables were used: green beans (0.31 kcal/g), carrots (0.31 kcal/g), spinach (0.44 kcal/g), peas (0.53 kcal/g) and squash (0.35 kcal/g). The maximum amount of food that could be extracted from each jar of vegetables was 110 g.

2.3. General procedures

To accustom infants to aspects of the testing procedures [9], mothers were sent items (e.g., waterproof bib, infant feeding spoon, face mask) to use every time they fed their infants during the 3 days that preceded the first testing session and throughout the experimental period. No additional foods or beverages were introduced to the infants' diet during the study. To increase compliance, phone contact was made with the mothers who recorded the time of day and types and quantity of foods and liquids they fed their infants throughout the study. All of the mothers complied with these instructions.

2.3.1. Monell Test Sessions—To minimize potential confounds due to different levels of satiation, the four test sessions occurred at the same time of day as the home exposure meals and at least 1 h after they were last formula or breastfed. There were no significant differences among the groups in each of the two studies in the length of time since infants were last fed before testing sessions. Testing occurred under naturalistic conditions in which the infants determined the pacing and duration of the feed [9]. Following a brief period of acclimation, infants were videotaped as they were fed by their mothers in a highchair with an attached tray (Peg Perego, Prima Pappa™, Fort Wayne, IN). The experimenter sat out of view of the mother and infant and monitored the feeding on a monitor.

Mothers fed their infants using the same type of bib and spoon used prior to the study. Throughout each feed, the mothers wore the mask and refrained from talking to eliminate any potential influence of facial or verbal responses on the infants' feeding behaviors [16]. In Study 1, mothers were given one jar of food and fed their infants at their customary pace until the child rejected the food on three consecutive times using the criterion that the infant exhibited behaviors such as turning his or her head away, pushing the spoon away, crying, or becoming playful. If the baby finished the contents of the jar, the jar was replaced with another such that the maximum amount of food offered was 220 g (2 jars of green beans, 3 jars of pears). Four infants ate the maximum amount of pears after the exposure on Day 11 of testing whereas none ate the maximum amount of green beans on either test Days 2 and 12.

Unlike Study 1, mothers in Study 2 were given two jars of food for each target meal during Monell Test Sessions. Here they offered 1–2 spoonfuls of the first jar and then 1–2 spoonfuls of the second jar. On Days 1 and 11, these two jars both contained green beans whereas on Days 2 and 12, one jar contained carrots and the other spinach. This alternation continued until the infant ate the maximum amount (220 g) or refused the food on three consecutive occasions, using the criteria described above. Only one infant ate the maximum amount of green beans on Day 11 and one the maximum amount of carrots and spinach on Day 12.

The amount of food consumed during each session was assessed by weighing the container of food and the bib immediately before and after each feed on a Mettler PM 15 top-loading balance. The difference in the weight of the bib before and after the feed was subtracted from the weight of the food to account for any food that was spilled during the test session. Immediately after each feeding session, the mothers rated how much they thought their infant liked the food on a 9-point scale. Intermediate ratings were indicated at appropriate locations between the extremes such that ratings ranged from 1 (extreme dislike) to 9 (extreme like).

2.3.2. Home-feeding exposure period—At the end of Test Day 2 at Monell, mothers were given assigned jars of pureed baby food to feed their infant at the same time of day that the testing occurred every day for the duration of the 8-day home exposure period. The length of exposure period was based on the finding that infants require at least 8 exposures to a new food to increase acceptance [9,10]. The original labels on the jars were removed and replaced with another that indicated the date on which the contents of that particular jar should be fed. Mothers, who were trained on all feeding procedures on the first and second day at Monell, offered their infants the contents of either one or two jars (Study 2 — BM–WM Vegetable Variety Group) until they refused the food as described above on at least three separate occasions. Mothers then rated their infants' enjoyment of the food, resealed the jar and stored it in a freezer until they returned to Monell. Phone contact was made with mothers during the exposure period.

2.3.3. Questionnaires—Mothers were queried about the feeding history of their infants. Those who breastfed their infants exclusively until they started introducing cereal were classified as Exclusively Breastfed; those who were formula fed but never experienced

breastmilk were classified as Exclusively Formula Fed where the remainder were classified as Breast and Formula Fed. In addition, mothers completed a 10-item scale that measured their food neophobia (the propensity to approach or avoid novel foods), an 8-item scale that measured their general neophobia [17] and a 95-item questionnaire that measured their infants' temperament [18].

2.4. Statistical analyses

For each infant, we determined the total intake (g), caloric intake (kcal), length (min) of each feed, rate of feeding (g/min) and mothers' ratings of their infants' enjoyment of the foods during each of the four Monell Test Sessions. Separate analyses of variance were conducted for each measure, target food and experimental group to determine whether there was an effect of exposure. STATISTICA (1998; Statsoft, Inc, Tulsa, OK) was used for the analysis and all summary statistics are expressed as means $\pm$ SEM.

3. Results

3.1. Study 1: Fruits

The characteristics of the mother–infant dyads are listed in Table 1. There were no significant differences between the experimental groups in any of the measures taken with the exception that mothers in the BM Fruity Variety Group rated their infants higher on approachability when compared to the infants in the Pear Group ($F(1, 37df)=5.34, p=0.03$).

In addition, the groups did not differ in their initial acceptance of pears (Day 1; $F(1, 32df)=0.58, p=0.45$) or green beans (Day 2; $F(1, 34df)=1.15, p=0.29$) or their average daily intake during the home exposure ($F(1, 37df)=0.69, p=0.41$).

During the home exposure period (see Fig. 2), infants in the Pear Group consumed, on average, 49.2 ± 3.2 g of pears during each day of the home exposure period and those in the BM Fruit Variety Group consumed similar daily amounts of peaches (52.8 ± 3.8 g), prunes (51.8 ± 4.1 g), and apples (56.0 ± 3.8 g). Because of the variation in caloric content of the fruits such that prunes were more caloric than the others, there were day-to-day fluctuations in caloric intake during this target meal for the BM Fruit Variety Group such that infants consumed more calories during the target meal in which they ate prunes ($F(7,112)=24.99; p<0.0001$).

Fig. 2 shows that infants repeatedly exposed to either pears (Pear Group; $F(1, 17df)=4.94, p=0.04$) or a variety of fruits (BM Fruit Variety Group; $F(1, 15df)=6.44, p=0.02$) consumed significantly more pears after the 8-day home exposure. As shown in Table 2, infants in the Pear Group ate 1.5 ± 0.1 times more pears after when compared to before the home exposure period, while the BM Fruit Variety Group consumed 1.5 ± 0.2 times more pears after the exposure period. Although pear intake increased after the home exposure period, mothers were apparently unaware of the difference since their ratings of the infants' liking of the pears did not differ before when compared to after home exposure period (see Table 2).

Unlike that observed for pears, neither group increased their consumption of green beans after the home exposure period (see Fig. 2). Similarly, the length of the feed, and the mothers' ratings of the infants' liking of the green beans did not change after the home exposure period. However, children in both groups did consume the green beans at a faster rate after the home exposure period relative to before (Pear Group; $F(1, 16df)=4.86, p=0.04$; BM Fruit Variety Group; $F(1, 18df)=5.07, p=0.04$).

3.2. Study 2: Vegetables

As seen in Table 1, there were no significant differences among experimental groups for any of the measures. Prior to the exposure period, the three groups of infants ate similar amounts of green beans (Day 1) ($F(2, 32df)=1.46, p=0.25$) as well as carrots ($F(2, 31df)=1.19, p=0.32$) and spinach ($F(2, 31df)=1.34, p=0.28$) on Monell Test Days 1 and 2, respectively. Children ate more carrots (36.7 ± 3.5 g) than spinach (25.3 ± 2.9 g; $t(34df)=4.49, p<0.001$). However, because spinach is more calorically dense than carrots, there was no significant difference in the amount of calories consumed between the foods (carrot: 11.4 ± 1.1 kcal; spinach: 11.2 ± 1.3 kcal; $t(34df)=0.21, p=0.84$).

During the home exposure period, there was no significant difference in the average daily intake of the test foods among the three experimental groups ($F(2, 24df)=1.44, p=0.26$). The Green Bean Group ate, on average, 58.2 ± 9.1 g of green beans each day during the home exposure. The BM Vegetable Variety Group consumed, on average, 94.4 ± 7.8 g of carrots, 78.4 ± 8.1 g of squash, 63.0 ± 9.8 g of peas, and 57.2 ± 8.7 g of spinach during the days they were fed these foods during the home exposure (Mean daily intake: 73.5 ± 7.4 g). The BM-WM Variety Group consumed similar amounts (77.2 ± 11.6 g) of the target foods each day of the home exposure (carrots and peas: 84.9 ± 14.9 g; squash and peas: 80.35 ± 12.5 g; squash and spinach: 62.1 ± 9.3 g). As shown in Fig. 3, there were significant differences in day-to-day intake during the home exposure for the BM Vegetable Variety Group ($F(7, 56df)=1.75, p=0.0002$) but not for the Green Bean Group ($F(7, 49df)=0.43, p=0.88$) and the BM-WM Vegetable Variety Group ($F(7, 63df)=1.64, p=0.14$). BM Vegetable Variety Group infants ate more food on Days 5 and 9 when carrots were offered when compared to Days 4 and 10 when spinach and peas respectively were offered. However, when considering the differences in caloric content of these foods, we found that there was no significant difference in the caloric daily intake during the target meal throughout the home exposure period ($F(7, 56df)=5.01, p=0.12$).

Fig. 3 shows that the BM-WM Vegetable Variety Group consumed significantly more green beans ($F(1, 11df)=15.64, p=0.002$) as well as carrots and spinach ($F(1, 11df)=6.37, p=0.03$) after the exposure period. As shown in Fig. 3, infants consumed 3.2 ± 0.6 times more green beans, 3.6 ± 1.7 times more carrots, and 5.1 ± 2.2 times more spinach after the 8-day home exposure. For the other two groups, there was a significant increase in the rate at which they ate green beans after the home exposure period (Green Bean Group: ($F(1, 10df)=19.73, p=0.001$) and BM-WM Vegetable Variety Group: ($F(1, 11df)=9.91, p=0.009$) and a tendency for them to eat more green beans as well (Green Bean Group: ($F(1, 10df)=4.22, p=0.07$); BM Vegetable Variety Group: ($F(1, 11df)=3.82, p=0.08$). Mothers were apparently unaware of any changes in their infants' acceptance of these foods since their ratings of the infants' liking of the green beans or carrots/spinach after the home exposure did not significantly differ from ratings of liking before exposure for each of the groups (see Table 3).

4. Discussion

The findings from the present set of experimental studies shed light on how different types of dietary experiences facilitate the acceptance of fruits and vegetables during early stages of weaning. Whether the dietary experience modified acceptance depended on the flavor or flavors of foods experienced, whether the experience occurred between or within meals or both, and whether the target food was a fruit or vegetable.

The first type of dietary experience involved repeated feedings of the same food at a target meal for 8 days. Such repeated dietary exposure to pears and green beans resulted in babies tending to eat more of that particular food, findings consistent with previous studies using pureed carrots, potatoes or green beans as the target food [9-11]. The minimum number of exposures required to enhance acceptance appears to be more than two since infants in the BM

Vegetable Variety Group had two exposures to carrots and spinach but did not show increased acceptance of either. Likewise, all infants in Study 1 were exposed to green beans on one occasion but neither group ate more green beans, although they did eat this food at a faster rate which may reflect that they were becoming more efficient feeders.

The preference that developed after repeated experience with a particular food did not generalize since repeated exposure to pears did not modify acceptance of green beans. Similarly, repeated exposure to pureed potatoes did not modify acceptance of carrots [9]. To be sure, these foods differ from each other in color, texture and flavor. Whether experience with a food such as carrots would generalize to another that is more similar in these flavor properties (e.g., squash) is not known. However, we do know that the acceptance pattern that develops in infants after repeated exposure to a formula appears to be specific to the flavor profile experienced. Although two brands of hydrolysate formula (i.e., Nutramigen, Alimentum) are equally unpalatable to naïve infants and share similar flavor notes, infants who were repeatedly fed one brand of hydrolysate formula developed a preference for its flavor when compared to the alternative unfamiliar hydrolysate formula [19]. How similar the flavor has to be for the baby to generalize remains unknown. However, as will be discussed below, experience with a variety of flavors does appear to generalize to foods within a particular category (e.g., fruits).

The second type of experience involved infants experiencing between-meal variety. That is, infants who ate a variety of fruits increased their intake of pears even though they had no direct experience with pears during the exposure period. Experience with fruit variety did not generalize to green bean acceptance, however. Neither did repeated exposure to a variety of vegetables between meals alter acceptance of green beans, carrots or spinach, although there was a tendency for increased acceptance of the green beans. In a previous study, we found that repeated exposure to between-meal variety to three starchy vegetables (i.e., peas, potatoes, and squash) enhanced the intake of carrots [9]. Perhaps acceptance of green vegetables such as green beans or spinach is more difficult to enhance because they taste bitterer and thus more exposures may be needed. In addition, the exposure may require that some or all of the foods are bitter tasting [14]. In other words, it is not just experience with between-meal variety that is important, but the flavor of the foods experienced and how it relates to the target food. How long the effect persists in the absence of continued exposure to particular foods or a variety of food remains unknown.

The third type of experience involved infants experiencing vegetable variety both within and between meals. Infants exposed to this type of variety ate more of all three of the target foods (i.e., green beans, carrots, spinach) after the exposure period. It is unclear what infants “learned” from the between- and within-meal varied diet. Studies on rats and humans [3,15,20] indicated that the variety effect was more robust when there were pronounced sensory differences between the foods. Because the pairs of foods fed to the infants within each meal always included a green and orange vegetable, infants experienced contrasts across many sensory domains such as color, texture and flavor. Moreover, these infants also experienced different pairs of food and ate varying amounts of these from one day to the next, providing them with sensory diversity. Exposure to such multiple sensory contrasts might have accelerated the “transfer of diversity” effect [2] by providing more varied flavor experience and more opportunities to condition flavor preferences based on the post-ingestive reinforcing effects of these nutritious foods [8,21,22]. Because one member of the pair was experienced the day before, the infants were also provided with continuity in flavor experiences which may have eased the acceptance of the novel food in the pair [8,23]. Such feeding strategies, providing novelty in the context of a familiar food, might prove to be an optimal combination to progressively accustom infants to a diversity of novel foods. Moreover, the sensory diversity within a meal might help to prevent sensory specific satiety, i.e. the decrease in liking of a

specific food during the course of a meal [3]. It should be emphasized that if experiencing within- and between-meal variety is effective not only in promoting intake within a food category but generalizes to other foods, this raises questions regarding the acquisition of overeating pattern as of an early age. Indeed, the availability of a variety of palatable foods is an important factor in the etiology of obesity, as shown in animal models [15] and suggested by short-term human studies [24-26].

Day-to-day fluctuations in the caloric intake of the fruits (Study 1, BM Fruit Variety Group) or vegetables (Study 2, BM and BM-WM Vegetable Variety Group) during home exposure may reflect that infants are regulating calories [27]. However, it should be emphasized that the present study was not specifically designed to address the issue of caloric intake regulation during the home exposure period. Although mothers were trained on the feeding procedure during the first two experimental days at Monell, the data may reflect their own biases toward continuing to feed a food they deemed unpalatable or misinterpreting signs of satiation from their infants. During the Monell Test Sessions, the infants determined the amount and pacing of feeding and thus these data are more reliable in gauging their acceptance of a food. This underlines the importance of a controlled feeding procedure to assess infant's food acceptance and calls into question data obtained from maternal reports. Because the majority of infants were both breastfed and formula fed, which reflects current feeding practices [28], we were not able to assess the influence of history of milk feeding on fruit and vegetable acceptance, which is however likely to impact solid foods acceptance as suggested by previous studies [10,11,23,29]. Nor were we able to determine in the present study why mothers' ratings of infants' liking of the foods did not change after the exposure period, despite greater acceptance of the food. However, a recent study which analyzed the infants' facial expressions during feeding revealed that 8 days of dietary exposure to a particular vegetable did not reduce the number of negative faces made by the infant during feeding [11]. We hypothesize that facial expressions may have evolved to signal that infants are eating something harmful, and consequently, are more salient cues for the mothers.

The well-documented pediatric obesity epidemic and dramatic increases in its associated clinical diseases are major public health challenges facing most developed countries [30]. One dietary strategy to prevent or treat obesity couples increasing consumption of foods that are nutrient and fiber rich, yet low in excess energy from added sugars and fats (e.g., fruits, vegetables), with decreasing consumption of energy-dense and less nutritionally desirable foods [31-33]. Increased fruit and vegetable consumption early in life may have other long-term benefits. For example, a diet rich in fruits early in life may have a protective effect on cancer risk in adult [34] and a diet rich in fruits, vegetables, and dairy products during preschool years may have beneficial effects on blood pressure during childhood and adolescence [35].

Despite such benefits, recent surveys alarmingly revealed that the intakes of fruits and vegetables are quite low in US pediatric populations [28,36]. Three out of ten toddlers do not consume even a single fruit and one in four a single vegetable in a given day; none of the top five vegetables was a dark green vegetable [28,36]. Instead, toddlers were more likely to be eating fatty foods such as French fries and sweet-tasting snacks and beverages, flavors that are innately preferred by children [28].

The findings from the present study and others conducted in our laboratory [9,11,23] suggest that not only can infants clearly discriminate the flavors of different fruits and vegetables but repeated opportunities to experience a particular fruit or vegetable or a variety of these foods promote the willingness to eat these foods and hopefully, in the long term, preferences for the 'tastes' of these foods. Developing strategies to promote the liking of the taste of these foods is extremely important since the best predictor of fruit and vegetable intake is whether children like how it tastes [37]. *The Start Healthy Feeding Guidelines* which were recently developed

by an expert panel of pediatric health and nutrition professionals in response to the need for practical, evidence-based advice on introducing solid foods to infants and toddlers concluded that there was no evidence that supports the need to restrict or avoid any foods for weaned infants who are not at risk for allergies [38]. The present study suggests that by introducing a variety of fruits and vegetables, both within and between meals, infants might be more accepting of fruits and vegetables, the consumption of which is generally low in the pediatric population [28], and the acceptance of which is difficult to enhance beyond toddlerhood [39, 40]. Because mothers were apparently unaware of changes in acceptance, they may give up too soon when introducing these foods [10,11]. Instead, they should be encouraged to focus on their infants' willingness to eat the food and to continue to provide their infants with repeated opportunities to taste it as well as others within that food category.

Research has shown that greater diversity of social stimulation during early infancy is associated with higher scores on measures of cognitive development in domains such as language, reading, and mathematics [41]. The present findings suggest that the beneficial effects of varied experiences during early development are not limited to cognitive functioning and provide experimental evidence to support the claim that experience with diversity of flavors sets the pattern for a diversified diet [42,43]. Such information may prove valuable to health care providers and parents in developing strategies for promoting fruit and vegetables. An appreciation of the complexity of early feeding and a greater understanding of the cultural and physiological mechanisms underlying the development of food preferences will aid in our development of evidence-based strategies to facilitate fruit and vegetable acceptance by children.

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Study 1:

Day of Study:	1	2	3	4	5	6	7	8	9	10	11	12
Pear Group	Pears	GB	Pears	Pears	Pears	Pears	Pears	Pears	Pears	Pears	Pears	GB
BM Fruit Variety Group	Pears	GB	Peach	Pru	App	Peach	Pru	App	Peach	Pru	Pears	GB

Study 2:

Day of Study:	1	2	3	4	5	6	7	8	9	10	11	12
Green Bean Group	GB-GB	Car-Spi	GB	GB	GB	GB	GB	GB	GB	GB	GB-GB	Car-Spi
BM Vegetable Variety Group	GB-GB	Car-Spi	Sq	Spi	Car	Pea	Sq	Spi	Car	Pea	GB-GB	Car-Spi
BM-WM Vegetable Variety Group	GB-GB	Car-Spi	Sq-Pea	Car-Pea	Sq-Pea	Sq-Spi	Sq-Pea	Car-Pea	Sq-Pea	Sq-Spi	GB-GB	Car-Spi

Fig. 1.

The design of the experimental protocol for the two groups in Study 1 (Top Panel) and three groups in Study 2 (Bottom Panel) illustrating the type of foods fed on each day of the 12-day study. On days 1, 2, 11, and 12, the mothers fed their infants the test food(s) at the Monell Center (shaded boxes) whereas on days 3–10 they fed their infants the exposed food(s) at home (unshaded boxes). The exposure occurred during the same meal on each Monell test day and home exposure day. Within each study, the groups differed in the types of foods mothers fed their infants during the home exposure period. Pears indicates the days that the mothers fed their infants pureed pears, GB indicates pureed green beans, Pru indicates pureed prunes, App indicates pureed apples, and Car indicates pureed carrots, Spi indicates pureed spinach, Pea indicates pureed peas and Sq indicates pureed squash.

Panel A. Pear Group

Panel B. BM Fruit Variety Group

Fig. 2.

Intake of pears (dark bars) and green beans (grey bars) during test sessions at Monell in two groups of infants in Study 1. The groups differed in the types of fruit(s) mothers fed their infants during a target meal during the 8-day home exposure period (closed circles). One group was fed pears (Pear Group; Top Panel A), one was fed a fruit that differed from the one experienced during the preceding two days (BM Fruit Variety Group; Bottom Panel B). *Indicates significant differences when compared to before exposure at the $p < 0.05$ level.

Panel A. Green Bean Group

Panel B. BM Vegetable Variety Group

Panel C. BM-WM Vegetable Variety Group

Fig. 3.

Intake of green beans (dark bars) and carrots and spinach (grey bars; carrots represented by hatched section of the grey bar) during test sessions at Monell in three groups of infants in Study 2. The groups differed in the types of vegetable(s) mothers fed their infants during a target meal during the 8-day home exposure period. One group was fed green beans (Green Bean Group; Top Panel A), one was fed a vegetable that differed from the one experienced during the preceding two days (BM Vegetable Variety, Middle Panel B) and the other group experienced two different vegetables within a meal and one of these vegetables was different from the ones fed during the prior day (BM-WM Vegetable Variety, Bottom Panel C).

*Indicates significant differences at the $p < 0.05$ level and # indicates significance level of $p < 0.08$ when compared to before exposure.

Subject characteristics

Table 1

	Study 1: Fruits		Study 2: Vegetables		
	Pear Group	BM Variety	GB Group	BM Variety	BM-WM Variety
<i>Infants' characteristics:</i>					
Age (months)	6.7±0.2	6.7±0.2	6.6±0.4	6.3±0.4	6.4±0.4
Sex (# girls: # boys)	10:10	9:10	4:7	5:7	6:6
Weight for length percentile	67.6±7.3	74.8±5.9	78.4±8.7	82.9±6.6	87.2±3.6
Milk feeding history (number of infants)					
Exclusively Breastfed	6	3	1	3	2
Breast and Formula fed	11	13	8	9	7
Exclusively Formula fed	3	3	2	0	3
Age of cereal introduction (months)	3.6±0.3	3.7±0.3	4.1±0.5	4.1±0.2	3.4±0.4
Infant temperament measures:					
Activity	4.3±0.1	4.1±0.1	4.1±0.2	4.2±0.1	4.2±0.2
Rhythmicity	2.7±0.2	2.9±0.2	3.1±0.2	2.9±0.2	2.8±0.3
Approach	3.0±0.2	2.5±0.1*	3.3±0.2	2.6±0.2	2.8±0.2
Adaptability	2.6±0.1	2.4±0.1	3.0±0.2	2.9±0.3	2.6±0.2
Intensity	3.7±0.1	3.5±0.1	3.4±0.1	3.7±0.2	3.8±0.2
Mood	2.8±0.1	2.8±0.2	3.2±0.2	3.1±0.2	3.2±0.2
Persistence	3.1±0.2	3.3±0.1	3.2±0.2	3.0±0.3	3.2±0.3
Distractibility	2.4±0.1	2.4±0.1	2.7±0.2	2.4±0.1	2.5±0.1
Threshold	4.1±0.2	3.9±0.1	3.9±0.1	3.8±0.1	4.0±0.2
<i>Mothers' characteristics:</i>					
Age (years)	29.8±1.3	28.1±1.5	29.4±1.8	28.7±1.5	26.4±1.5
BMI (kg/m ²)	28.3±1.6	28.3±1.4	29.3±2.4	31.2±2.1	28.1±2.3
% multiparous	65.0	52.6	81.8	75.0	58.3
Food neophobia score (range: 10–70)	37.2±2.3	37.6±2.2	38.6±5.1	35.0±2.3	31.8±3.4
General neophobia score (range: 8–56)	23.2±2.2	23.6±1.4	23.3±3.0	25.0±2.0	24.6±2.7
# Mother–infant pairs	20	19	11	12	12

* Indicates significant difference at $p < 0.05$ when compared to Pear Group.

Table 2
Study 1 infants' acceptance of pears (Panel A) and green beans (Panel B) before and after an 8-day home exposure period to either pears or a variety of fruits

	Experimental group	
	Pear	BM Variety
<i>A. Pears</i>		
Intake (calories)		
Before exposure	44.7±6.5	52.6±8.1
After exposure	55.8±6.4 [*]	66.8±9.5 [*]
Difference score (After/before exposure)	1.5±0.1	1.5±0.2
Length of feed (min)		
Before exposure	13.5±1.2	13.3±1.9
After exposure	13.6±1.3	14.4±1.9
Difference score	1.2±0.1	1.3±0.2
Rate of feed (g/min)		
Before exposure	6.2±0.7	6.9±0.6
After exposure	6.8±0.7	8.6±1.2 [#]
Difference score	0.6±0.6	1.6±0.8
Mothers' rating of infants' enjoyment of pears		
Before exposure	7.5±0.5	7.8±0.4
After exposure	7.6±0.4	8.1±0.3
Difference score	1.2±0.3	1.1±0.1
<i>B. Green beans</i>		
Intake (calories)		
Before exposure	14.2±2.4	19.5±4.1
After exposure	15.7±4.0	21.0±4.4
Difference score	1.2±0.2	1.2±0.2
Length of feed (min)		
Before exposure	13.6±2.8	10.8±1.6
After exposure	9.4±1.1	10.4±1.9
Difference score	0.8±0.1	1.1±0.1
Rate of feed (g/min)		
Before exposure	3.7±0.4	5.2±0.7
After exposure	4.9±0.7 [*]	6.3±1.1 [*]
Difference score	1.4±0.2	1.2±0.1
Mothers' rating of infants' enjoyment of green beans		
Before exposure	4.8±0.5	4.8±0.6
After exposure	4.3±0.6	5.3±0.7
Difference score	1.0±0.1	1.4±0.3
[#] Mother–infant pairs	20	19

Mean±SEM.

^{*} Significantly different when compared to before exposure at $p<0.05$ level.

[#]Significantly different when compared to before exposure at $p<0.08$ level.

Table 3

Study 2 infants' acceptance of green beans (Panel A) and carrots and spinach (Panel B) before and after an 8-day home exposure period to either green beans, a variety of vegetables between meals, or a variety of vegetables both between and within meals

	Experimental group		
	Green Bean	BM Variety	BM-WM Variety
<i>A. Green beans</i>			
Intake (calories)			
Before exposure	15.7±3.7	20.4±3.8	12.2±2.9
After exposure	24.0±5.3 [#]	26.1±4.1 [#]	27.2±4.5 [*]
Difference score (After/before exposure)	2.7±1.0	1.7±0.4	3.2±0.6
Length of feed (min)			
Before exposure	10.2±1.7	13.3±2.1	11.1±1.8
After exposure	10.9±1.7	13.2±2.2	14.5±1.8
Difference score	1.6±0.6	1.2±0.2	1.7±0.4
Rate of feed (g/min)			
Before exposure	4.9±0.8	4.8±0.6	3.5±0.6
After exposure	7.2±1.0 [*]	6.4±0.9	5.9±0.6 [*]
Difference score	1.8±0.3	1.5±0.2	2.2±0.4
Mothers' rating of infants' enjoyment of green beans			
Before exposure	6.5±0.7	6.3±0.6	5.8±0.7
After exposure	6.8±0.5	6.3±0.5	7.1±0.5 [#]
Difference score	1.2±0.2	1.1±0.2	2.1±0.7
<i>B. Carrots and spinach</i>			
Intake of carrots (calories)			
Before exposure	12.5±2.2	12.7±1.6	9.0±1.9
After exposure	13.3±2.8	15.0±2.0	16.6±3.1 [*]
Difference score	1.2±0.2	1.9±0.7	3.6±1.7
Intake of spinach (calories)			
Before exposure	11.5±2.7	13.8±2.0	8.7±2.0
After exposure	13.7±3.2	14.1±2.5	19.9±4.2 [*]
Difference score	1.1±0.2	1.0±0.1	5.1±2.2
Length of feed (min)			
Before exposure	13.9±1.5	15.7±1.8	13.0±1.3
After exposure	13.5±2.3	14.4±1.1	16.7±2.5
Difference score	0.9±0.2	1.0±0.1	1.5±0.3
Rate of feed (g/min)			
Before exposure	4.9±0.8	4.3±0.5	3.8±0.6
After exposure	5.2±0.6	5.6±0.5 [*]	6.1±0.8 [*]
Difference score	1.3±0.2	1.4±0.3	2.5±0.6
Mothers' rating of infants' enjoyment of carrots			

	Experimental group		
	Green Bean	BM Variety	BM-WM Variety
Before exposure	7.5±0.5	7.5±0.3	6.7±0.7
After exposure	6.8±0.6	7.2±0.4	7.4±0.6
Difference score	1.0±0.1	1.0±0.1	1.3±0.3
Mothers' rating of infants' enjoyment of spinach			
Before exposure	5.9±0.7	6.2±0.6	5.8±0.9
After exposure	5.0±0.6	5.7±0.7	6.3±0.8
Difference score	0.8±0.1	1.0±0.1	1.9±0.6
# Mother–infant pairs	11	12	12

Mean±SEM.

* When compared to before exposure at $p<0.05$ significance level.

When compared to before exposure at $p<0.08$ significance level.