

## Effects of repeated exposure on acceptance of initially disliked vegetables in 7-month old infants

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### Abstract

In the weeks following the start of weaning, 70 mothers were asked to identify a vegetable purée that their infant disliked and that they normally would not offer again. The 49 who did so were then asked to offer that vegetable on alternate days for 16 days, and to offer a well-liked one (carrot purée) on the other days. Amount eaten and acceptance were measured at each meal. On the first day of exposure, mean intake of the initially disliked vegetable was  $39 \pm 29$  g and of the liked one,  $164 \pm 73$  g (mean  $\pm$  SD). Over the following days, intake of the initially disliked vegetable increased rapidly and by the eighth exposure was  $174 \pm 54$  g, similar to that of the liked vegetable ( $186 \pm 68$  g). A similar pattern of results was found for mother-reported liking ratings. These effects of repeated exposure appear to be long lasting because nine months later, 63% of the infants were still eating and liking the initially disliked vegetable. The present study shows that when a vegetable is initially disliked it is worth persisting in feeding it for at least eight subsequent meals.

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### 1. Introduction

Many infants initially appear to dislike or reject a new food (Birch, Gunder, Grimm-Thomas, & Laing, 1998; Caruth, Ziegler, Gordon, & Barr, 2004), but if given the opportunity to try the food once or twice more (and if it produces no adverse effects), then many will accept it and rapidly increase their intake. Thus, early in weaning, infants who ate only small amounts of a vegetable the first time they were offered it ate much more in subsequent meals (Birch et al., 1998). As Rozin (1976), Birch (2002) and Pliner and Salvy (2006) have pointed out, reluctance to eat more than a small amount of a new food, usually referred to as food neophobia, is frequently observed in omnivores. The potential survival value of consuming only

small quantities of a potentially unsafe new food until sure it leads to no negative consequences is self-evident.

The intensity of reluctance to consume new foods seems to change over the first few years of life. During the first 4 months, infants tend to accept even quite bitter tasting formulae easily (Mennella & Beauchamp, 2005). They show moderate levels of food neophobia until about 1.5–2 years of age followed by a significant increase until about 5 years of age (Cashdan, 1994) and a gradual decrease thereafter (Cashdan, 1994; Pliner & Salvy, 2006).

Acceptance of new foods by infants at the start of weaning was explored in some detail by Birch and her colleagues. In a first study, Sullivan and Birch (1994) offered the same new vegetable (pea or green bean purée) on 10 consecutive days to 4–6 month old infants and noted a marked increase in mean intake between the first and the 10th day (from about 30 g to about 60 g). They also found that breast-fed infants showed a greater increase in intake during the exposure period (from 39 g to 72 g) than did

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formula-fed infants (25–46 g), and suggested that experience with the varied flavour cues in breast milk facilitated acceptance of novel vegetables. In a second study, daily measures of intake during the 10 days of exposure showed that most of the increase occurred between the first and the second days (from 35 g on day 1 to 61 g on day 2) and increased more slowly thereafter, reaching 69 g on day 10 (Birch et al., 1998). Acceptance of new foods is not always so rapid. As Carruth et al. (2004) noted, nearly 30% of 7–11 month old infants were described by their caretakers as being “picky eaters” in that they accepted a limited number of foods, were unwilling to try new foods, and showed strong food preferences. Carruth et al. (2004) also found that less than 7% of caretakers offered an initially disliked food more than 3–5 times before deciding that it was not worth offering it again. This finding was confirmed in a recent survey of weaning practices in Southern Germany where 85% of mothers reported that during the first few months of weaning, their infant refused to eat at least one vegetable (Maier, Chabanet, Schaal, Leathwood, & Issanchou, 2007). Among the mothers reporting refusal, 6% said they immediately decided their infant definitively disliked the vegetable, 33% after 2 meals, 57% after 3–5 meals, and only 4% continued trying for longer.

As may be expected, the taste of a new food seems to influence acceptance. Beauchamp and Moran (1982) reported that 6-month old infants consumed more of a sucrose solution than of unsweetened water even if they had not previously been fed sweetened water. This shows that, among infants in the age range we studied, sweet tastes are readily accepted. In a study on older (44–71 months) infants, Sullivan and Birch (1990) offered tastes of sweetened, salted or unflavoured tofu twice per week for 8 weeks and measured preferences after 1, 8 and 15 exposures. The infants exposed to sweetened or salted tofu developed clear preferences for them by the eighth exposure. In contrast, preference for the unflavoured tofu over sweetened tofu only appeared after the 15th exposure.

There is little specific information available about change in acceptance during repeated exposure to an initially disliked vegetable in 6–12 month old infants. The work of Birch and colleagues on new (but not refused) foods, suggests that early in weaning acceptance should increase after one or two exposures (Birch et al., 1998), while (at least in older infants) more exposures may be necessary for “less tasty” foods (Sullivan & Birch, 1990). As Carruth et al. (2004) noted, these less tasty foods are often vegetables, suggesting that if one can identify the number of exposures to vegetable purées needed to increase intake and perceived liking to the same level as for a well-liked food, this information would be practically useful in helping caregivers decide to what extent they should persist with initially disliked foods.

Several factors related to mothers’ and infants’ characteristics have been shown to influence the acceptance of new foods by infants. As noted above, at weaning breast-fed infants more rapidly accepted new foods than did for-

mula-fed infants (Sullivan & Birch, 1994). In addition, infants given a greater variety of vegetables early in weaning also accepted new foods more readily, at least over the next few days (Gerrish & Mennella, 2001). Similarly, the mother’s attitude to new foods may influence her child’s food acceptance: Pliner (1994) reported a significant but modest correlation ( $r = 0.31$ ) in food neophobia scores between children and their mothers, while Koivisto Hursti and Sjöden (1997) obtained similar results using parental ratings of child food neophobia and an *ad hoc* food frequency questionnaire.

The objectives of the present study were (1) to assess the proportion of mothers reporting that during the first months of vegetable feeding their infant disliked or refused a vegetable purée to the extent that they would not normally offer it again; (2) to measure the change in acceptance of one initially disliked vegetable across repeated exposures vs. the change in acceptance of an initially well-liked, control vegetable and (3) to examine the possible influences of breastfeeding, experience with variety and mother’s neophobia, variety seeking and anxiety on the frequency of vegetable dislike and on acceptance of a disliked vegetable during repeated exposure.

## 2. Participants and methods

### 2.1. Participants

The participants in this study were members of an initial group of 75 mother–infant pairs from South Germany who took part in a larger study on the effects of breastfeeding and experience with variety at the start of weaning on acceptance of new foods. At the beginning of weaning, infants were exposed to one of the following three different vegetable variety regimens during 9 days: (a) same vegetable (no change), (b) change every 3 days (four changes), and (c) daily change (10 changes). Of these mothers, 70 accepted and five declined to participate in this second phase of the study. The mothers had been recruited using flyers posted at local hospitals, paediatric practices, day-care centres, nurseries and kindergartens, asking them to contact the research team by telephone if interested in participating in a study of infant feeding. The mean age of infants at recruitment was  $5.2 \pm 0.9$  (SD) months and their mean age at the start of this phase was  $7.0 \pm 0.9$  months. The results of the first phases (on early experience effects on acceptance of new foods) are reported elsewhere (Maier, Issanchou, Schaal, Chabanet, & Leathwood, 2005; Maier, Leathwood, Chabanet, Issanchou, & Schaal, 2006).

During the first 1–2 months of complementary feeding, each of the 70 mothers was asked to identify a vegetable purée that her infant disliked so much that she would normally not offer it again, and a vegetable purée that her infant liked well. The 49 mothers who did so were asked to participate in this study. Each mother was allowed to use her own subjective criterion when identifying a food as sufficiently “disliked” that she would not offer it again.

We did not make a detailed enquiry into how she made this decision because we feared that drawing her attention to the criterion might influence her judgement. Thus the exact number of previous exposures to the “disliked” vegetable the infant had experienced was not measured but most probably was between 1 and 5. The time since the mother decided her infant disliked a vegetable and the beginning of the repeated exposure to that vegetable also varied from 2 to 9 weeks. Of the 49 infants, 24 had been breast-fed ( $168 \pm 70$  days) and 25 had been formula-fed (22 entirely on formula and three breast-fed for 2 weeks or less). The characteristics of the infants and mothers are compared in Table 1. The study protocol was approved by the Landesärztekammer in Baden-Württemberg, Germany.

## 2.2. Foods

Most of the purées (carrot, pumpkin, green beans, peas, artichoke, and zucchini–tomato) had been specially prepared for use in the first phase of this study. The choice of these vegetable purées was based on the results of an earlier questionnaire-based study on weaning practices in the same region of southern Germany, which showed that mothers considered them plausible to offer at that stage of feeding (Maier et al., 2007). All purées except cauliflower and spinach were prepared at the Nestlé Product Technology Center, Singen, Germany, or at the Factory in Epinal,

France. All the Nestlé products contained 49–52 kcal (205–217 kJ) per 100 g, were stored in 130 g jars, and were labelled with (1) the name of product, (2) the ingredient list, (3) the “use by” date, (4) the investigator’s and sponsor’s name and (5) the study identification number. All the purées were appropriate for infants from the age of about 6 months and their composition corresponded to EU requirements regarding baby foods for infants and young children (Commission Directive 2006/125/EC, 2006). Sensory profiles were obtained using a 12-member trained sensory panel and with two repetitions (Fig. 1a and b). They were used to examine if the disliked vegetables had sensory characteristics (compared to the liked ones) that might explain why they were often disliked.

## 2.3. Methods

Each mother was asked to offer her infant, at home, on alternate days over a period of 16 days, the initially disliked vegetable and the initially liked vegetable (for the liked vegetable, all mothers chose carrots). She was given three 130 g-pots of the appropriate vegetable purée for each meal in the study and was asked to feed it until the infant refused three consecutive spoons or until she considered the infant had eaten enough. Mothers naturally had their own ideas about the maximum amount of food it was appropriate to feed their infant and most of them actually stopped at two pots (about 260 g).

Table 1

Characteristics of mothers and infants categorised by participation in the study (i.e., infants who disliked at least one vegetable) vs. those who did not (i.e., infants who liked all vegetables offered so far) and by breastfeeding or formula feeding

Characteristic	Disliked at least one vegetable ( $n = 49$ )		Liked all vegetables ( $n = 21$ )	
	Breast-fed	Formula-fed	Breast-fed	Formula-fed
<i>Infants</i>				
Number	24	25	13	8
Male	12	14	5	5
Female	12	11	8	3
Changes in vegetables offered during first 10 days of vegetable feeding				
0 changes ( $n$ )	9	9	3	1
4 changes	9	9	4	2
10 changes	6	7	6	5
Age (months)	$7.3 \pm 0.8^a$	$6.6 \pm 1.0$	$7.2 \pm 0.7$	$6.7 \pm 0.9$
Length of breastfeeding (days)	$168 \pm 70$	$1.1 \pm 3.3$	$173 \pm 55$	$5.3 \pm 7.3$
Weight (kg)	$7.8 \pm 1.1$	$7.7 \pm 0.9$	$8.0 \pm 1.2$	$8.5 \pm 1.5$
Height (cm)	$68.1 \pm 3.1$	$66.9 \pm 3.2$	$67.8 \pm 2.8$	$66.8 \pm 3.3$
<i>Mothers</i>				
Age (years)	$32.5 \pm 4.6$	$29.2 \pm 4.9$	$32.2 \pm 4.4$	$34.0 \pm 2.5$
Parity				
Primiparous	12	11	6	2
Multiparous	12	14	7	6
Education				
Primary	3	7	2	3
Secondary	17	12	6	5
Tertiary (degree or higher)	4	6	5	0
Neophobia (possible range: 10–70)	$35.0 \pm 9.9$	$32.5 \pm 11.3$	$33.2 \pm 7.6$	$30.8 \pm 6.2$
Variety seeking (possible range: 8–56)	$31.4 \pm 10.2$	$32.9 \pm 12.7$	$36.2 \pm 7.8$	$37.3 \pm 4.2$
Anxiety trait (possible range: 20–80)	$34.7 \pm 6.5$	$34.8 \pm 8.4$	$38.5 \pm 10.1$	$39.4 \pm 9.2$

There were no significant differences in frequencies or means for participants vs. non participants or for breast vs. formula-fed infants.

<sup>a</sup> Mean  $\pm$  SD for all such values.

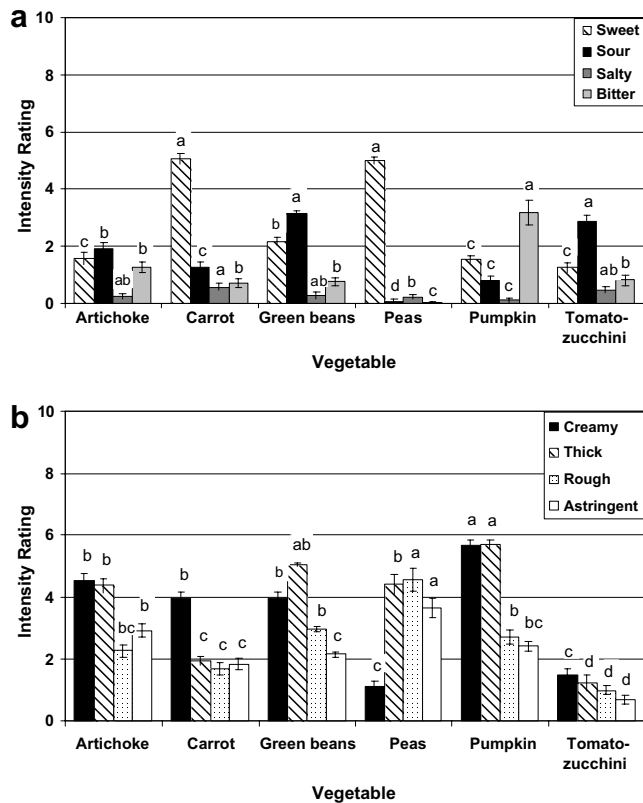


Fig. 1. Sensory characteristics of six vegetable purées produced for the experimental study: Taste (a) and Texture (b). Mean intensity scores  $\pm$  SEM. Means with a same letter are not significantly different. Intensity of each attribute was rated on a scale ranging from 0 = “not at all” to 10 = “very intense”, as defined by the panel during training.

At the end of each meal, the mother was instructed to rate how much she thought her infant had liked the vegetable using a 9-point scale ranging from 1 = “dislikes very much”, via 5 = “neither likes nor dislikes”, to 9 = “likes very much”. She was instructed to close the used pots, keep them in the refrigerator, and bring them to the laboratory for measurement of the quantities eaten.

Nine months after this phase was completed, when the infants were 15–19 months old, 48 of the 49 mothers completed a food-consumption and acceptance questionnaire that included questions about intake of, and liking for, the test vegetables. This allowed us to check whether acceptance and liking for the initially disliked vegetable persisted beyond the experimental exposure period.

#### 2.4. Questionnaires

Each mother was asked if she: (1) was still breastfeeding, (2) had breast-fed and now had stopped, or (3) had never breast-fed her infant. If she had already stopped breastfeeding, she was then asked when she stopped.

Each mother also completed the 10-item food neophobia questionnaire (Pliner & Hobden, 1992), the 8-item vari-

ety-seeking questionnaire with respect to foods (van Trijp & Steenkamp, 1992), and the 20-item anxiety trait questionnaire (Spielberger, 1993), which evaluated anxiety as a general tendency to be anxious.

The questionnaires were translated into German and then back translated to check their precision. They were then tested on a separate group of 10 mothers to ensure that the questions were well understood. Final versions were then prepared. Overall scores for food neophobia, variety seeking and anxiety trait were calculated by summing responses for each item (possible ranges: 10–70 for neophobia, 8–56 for variety seeking, and 20–80 for anxiety trait).

The food-consumption and acceptance questionnaire completed 9 months later, when the infants were approximately 16 months old, included questions on current weight and height, and on intake and acceptance of a wide range of foods (cereals, fruit, vegetable, meat, fish, milk-products, etc.), including acceptance of 42 different vegetables. Mothers noted for each vegetable if the infant (1) ate and liked it, (2) ate it but did not particularly like it, (3) had been offered it at least once but did not like it, (4) had been offered it but refused to taste it, or (5) had never been offered it.

#### 2.5. Data analysis

##### 2.5.1. Sensory profiles of the six vegetable purées

Analysis of variance was used to test for overall difference between the purées for each sensory attribute and Duncan’s multiple range test was used to identify differences between purées (Nestlé Sensory Statistics Programme “SAGESSE”, Nestec Ltd., NRC, Lausanne). A criterion of  $p < 0.05$  was set for significant difference.

##### 2.5.2. Differences in infants’ and mothers’ characteristics between the group that “liked all vegetables” and the group that “disliked at least one vegetable”

The group liking “all vegetables” (Group LV) was compared with the one disliking at least one vegetable (Group DV) using Student’s *t*-tests for the continuous variables (infants’ age, breastfeeding duration, and mothers’ age, neophobia, variety seeking or anxiety scores) and Chi-squared tests for the categorical variables (gender, milk feeding type, level of exposure to variety early in weaning and mothers’ parity and education).

##### 2.5.3. Sensory attributes associated with disliking a given vegetable purée

The number of mothers saying their infant disliked a given vegetable purée so much she would normally not offer it again provided an approximate measure of dislike for that vegetable among the infants. We used simple correlations and an adaptation of external preference mapping (Stone & Sidel, 2004), to explore possible links between the sensory attributes or combinations of



sensory attributes and this measure of vegetable acceptance.

#### 2.5.4. Effects of repeated exposure on intake and liking for the two vegetables

Mean intakes and liking scores for vegetables eaten on each of the 16 days (the initially disliked one offered on odd days and the initially liked on even days) were measured and plotted. Overall differences were compared using analysis of variance (2 treatments  $\times$  8 days, with days as repeated measures). Changes in intake and liking for the initially disliked vegetable and initially liked vegetable over days were tested for linear trend. Intake and liking scores for the initially disliked vegetable on each day were compared with intake and liking for the initially liked vegetable after the same number of exposure days using paired *t*-tests. Possible influences of type of milk feeding (breast or formula) were assessed using analysis of variance. As the breast-fed infants were, on average, 21 days older than those who had been fed formula, age was included as a covariate in the analysis. Potential effects linked to experience with a variety of vegetables early in weaning, gender and age of the infant and mothers' neophobia, variety seeking and anxiety (as a trait) on intake and liking scores were separately assessed using analysis of variance.

A practical interest of this study was to identify if and when infants (1) ate as much of the initially disliked vegetable as of the initially liked one and (2) were rated by the mother as liking the initially disliked vegetable as much as the initially liked one. Linear equations were fitted to intakes (and to liking scores) of the initially disliked and liked vegetables over the 8 days of exposure and the number of days to convergence of the two regressions was calculated.

Lastly, for each infant, the amount eaten of the originally disliked vegetable that corresponded to "neither likes nor dislikes" (a liking score of 5) was estimated using linear regression.

### 3. Results

#### 3.1. Sensory profiles of the vegetable purées

Fig. 1a and b show mean intensity ratings by the sensory panel for the attributes: sweet, sour, salty, bitter, creamy, thick, rough and astringent for six of the vegetable purées. Overall, the purées differed significantly for each of these attributes. Carrot and peas were the sweetest, green beans, zucchini–tomato and artichoke the most acid, and pumpkin and artichoke the most bitter. All the purées were low in saltiness but carrot was significantly more salty than peas and pumpkin. Artichoke, carrot, green beans and pumpkin were the most creamy purées, and pumpkin the thickest. Lastly, the pea and the artichoke purées were rated highest in astringency.

#### 3.2. Prevalence of disliking at least one vegetable and variations related to infants' and mothers' characteristics and to sensory attributes of the purées

Of the original 75 mothers, five declined to participate in the study. One declined because her infant was allergic and four said they had identified a disliked vegetable but were not interested in offering it again. Of the remainder, 21 (30%) said their infant "liked all vegetables offered so far" and 49 (70%) identified at least one disliked vegetable that they would normally not offer again. The disliked vegetables were artichoke (18); peas (10); cauliflower (6); green beans (6); pumpkin (6); spinach (2) and zucchini/tomato (1). Some mothers identified more than one disliked vegetable. The one she considered to be most disliked was used for the repeated exposure phase.

In comparisons between infants who disliked at least one vegetable (DV group) compared with LV infants who liked all vegetables offered so far, there were no significant differences in any of the variables evaluated (frequency or length of breastfeeding; exposure to different levels of variety of vegetables early in weaning; infants' age or gender; mothers' age, parity or education and mothers' neophobia, variety seeking, or anxiety ratings (see Table 1).

Simple correlations between the intensities of the sensory attributes of the six vegetable purées described in Fig. 1a and b and the number of infants disliking each purée (to the extent that mothers said they would normally not offer it again) showed that astringency was the only attribute with a significant correlation with this measure of disliking ( $r_4 = 0.74$ ;  $p < 0.05$ ). External preference mapping did not reveal any combination of attributes with a better fit to this measure of liking/disliking.

#### 3.3. Mean intake and variations related with infant feeding and maternal traits

Over the eight exposure days that the initially disliked vegetable was presented, mean intake rose linearly ( $r = 0.99$ ) from  $39 \pm 29$  to  $174 \pm 54$  g (mean  $\pm$  SD), a rate of increase of 17 g/exposure. This was a highly significant linear trend ( $p < 0.0001$ ). In contrast, for the initially liked vegetable, intake rose from  $164 \pm 73$  to  $186 \pm 68$  g (2.8 g/day). The linear trend was also significant ( $p = 0.03$ ). Paired *t*-tests showed that over the first seven exposures, intake of the initially disliked vegetable was significantly less than that of the initially liked vegetable after the same number of exposures. By the eighth exposure the difference was no longer significant (Fig. 2).

There was no significant difference between breast and formula-fed infants in intake of the initially liked vegetable. In contrast, for the initially disliked vegetable, type of milk feeding did have a marked effect on intake. On the first day of feeding the initially disliked food, breast-fed infants consumed  $52.5 \pm 33$  g (mean  $\pm$  SD) while formula-fed infants consumed  $26 \pm 18$  g ( $F_{1,46} = 9.8$ ;  $p = 0.003$ ). For

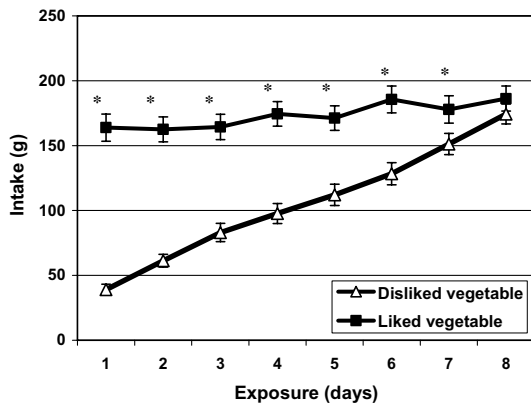


Fig. 2. Effect of exposure on mean intakes ( $\pm$ SEM) of the initially disliked and liked vegetables. \*Mean intake of the initially disliked vegetable is significantly different from mean intake of the initially liked vegetable.

the breast-fed group, the mean daily increase in intake ( $16.5 \pm 8.5$  g/day) was significantly lower than for the formula-fed infants ( $20.4 \pm 7.3$  g/day;  $F_{1,47} = 7.0$ ;  $p = 0.01$ ). By the seventh exposure day, intakes were the same (Fig. 3).

There was also a significant difference in intake of the initially disliked vegetable linked to mothers' neophobia. Using a median split to separate mothers "low" and "high" in neophobia, we observed that over the 8 days of exposure, infants of mothers "high" in neophobia showed a greater overall consumption ( $122 \pm 7.9$  vs.  $91 \pm 7.4$  g;  $F_{1,47} = 7.7$ ,  $p = 0.008$ ). Initial levels of intake were similar ( $F_{1,47} = 0.8$ , NS) for high ( $42.9 \pm 6.1$  g) vs. low ( $35.5 \pm 5.7$  g); but infants of mothers "high" in neophobia showed a more rapid increase in intake of the initially disliked vegetable so that by the fifth, sixth and seventh exposure days, intake in the high maternal neophobia group was significantly higher.

Neither experience with variety early in weaning (i.e., "no change", "4 changes" and "10 changes" of vegetables offered during the first 10 days of vegetable feeding), nor infants' age or gender, nor mothers' variety seeking or anxiety score had any detectable effects on intake of the initially liked or the initially disliked vegetables.

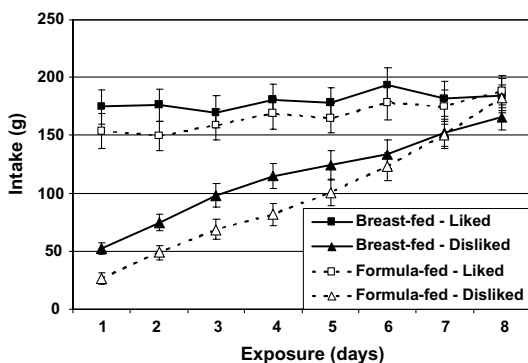


Fig. 3. Effect of exposure on mean intakes ( $\pm$ SEM) of the initially disliked and liked vegetables for the breast-fed and the formula-fed infants.

### 3.4. Mean liking and variations related to infant feeding and maternal traits

The pattern of mother-reported liking scores was similar to that for intake (Fig. 4). Liking for the initially disliked vegetable was at first low, at  $3.1 \pm 1.5$  units on the 9 point scale (mean  $\pm$  SD) and rose linearly ( $r = 0.99$ ) to  $8.0 \pm 1.1$ , a rate of increase of 0.6 scale units per day; liking for the initially liked vegetable rose slightly, but not significantly, from  $7.3 \pm 1.3$  to  $7.6 \pm 1.3$  units. Paired  $t$ -tests showed that over the first six exposures, liking for the initially disliked vegetable was significantly lower than for the initially liked one. However, by the seventh exposure the difference was no longer significant (Fig. 4).

Type of milk feeding (breast or formula) had a marked effect on liking scores for the initially disliked vegetable. On the first day, liking scores for breast-fed infants were  $3.9 \pm 1.5$  (mean  $\pm$  SD) whereas for formula-fed infants it was  $2.2 \pm 1.1$  ( $F_{1,46} = 20.6$ ;  $p < 0.0001$ ). For the breast-fed group the mean daily increase in liking scores ( $0.59 \pm 0.24$  units/day) was significantly lower than for the formula-fed infants ( $0.79 \pm 0.21$  units/day;  $F_{1,47} = 20.1$ ;  $p = 0.001$ ). By the sixth exposure day, liking scores were similar (Fig. 5). There was no significant difference between breast- and formula-fed infants in liking scores for the initially liked food nor did any of the other factors have any effect on liking for either the initially liked or the initially disliked vegetables over the exposure period.

### 3.5. Individual intake and liking patterns

Of the 49 infants, 42 showed a significant linear increase ( $r > 0.71$ ) in intake of the initially disliked vegetable. Of these, 29 showed a strictly linear increase in intake; seven showed a rapid initial increase during the first 5–6 days that flattened off once intake was equal that of the initially liked vegetable, and six showed little change in intake during the first 2–6 exposures followed by a rapid increase to the same level of intake as for the initially liked vegetable. Of the

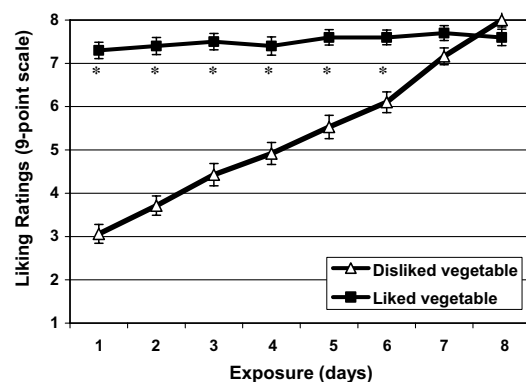


Fig. 4. Mean scores of mother's report of infants' liking ( $\pm$ SEM) for the initially disliked and liked vegetables. \*Mean liking of the initially disliked vegetable is significantly different from mean liking of the initially liked vegetable.

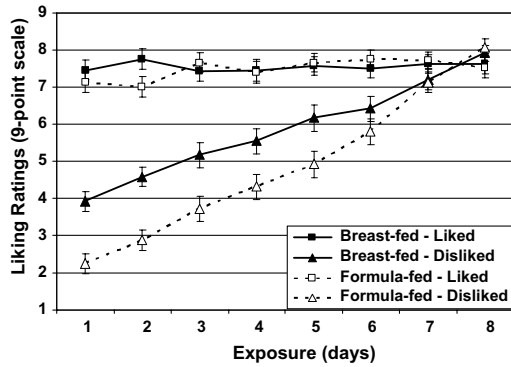


Fig. 5. Effect of exposure on mean scores of mother’s report of infants’ liking ( $\pm$ SEM) of the initially disliked and liked vegetables for the breast-fed and the formula-fed infants.

seven with non-significant change, only one showed no increase in intake at all. Fig. 6a–d shows plots of intake over the eight exposure days of individual infants illustrating these different patterns.

Linear regression equations for each infant were used to identify the day (if it occurred) that intake of the initially disliked vegetable reached the same level as that of the initially liked one. The results are shown in Fig. 7. At the first exposure, two infants ate as much of the initially disliked vegetable as of the liked one. After three exposures to the initially disliked vegetable, only three infants (6%) were

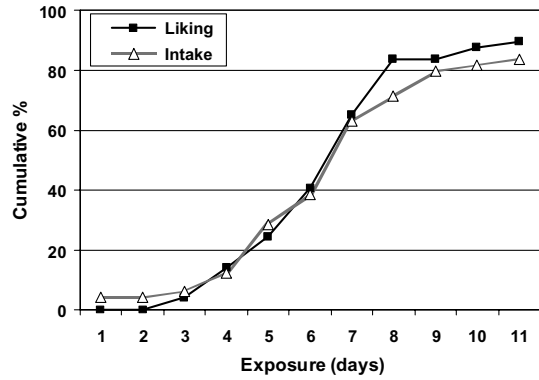


Fig. 7. Cumulative distribution of number of days to complete individual “catch-up” for intake and liking. “Catch-up” means that intake (or liking) of the initially disliked food equals or exceeds intake (or liking) of the initially liked food.

eating as much of the initially disliked vegetable as they ate of the liked one. After eight exposures, this rose to 35 infants (71%). Extrapolation of the linear regressions showed that 41 infants (84%) might be expected to show complete catch-up by the 11th exposure. For the remainder, extrapolation suggested that one infant might have caught up after 16 exposures; six showed parallel increases in intake for both the initially liked and the initially disliked vegetables, and only one infant showed no increase

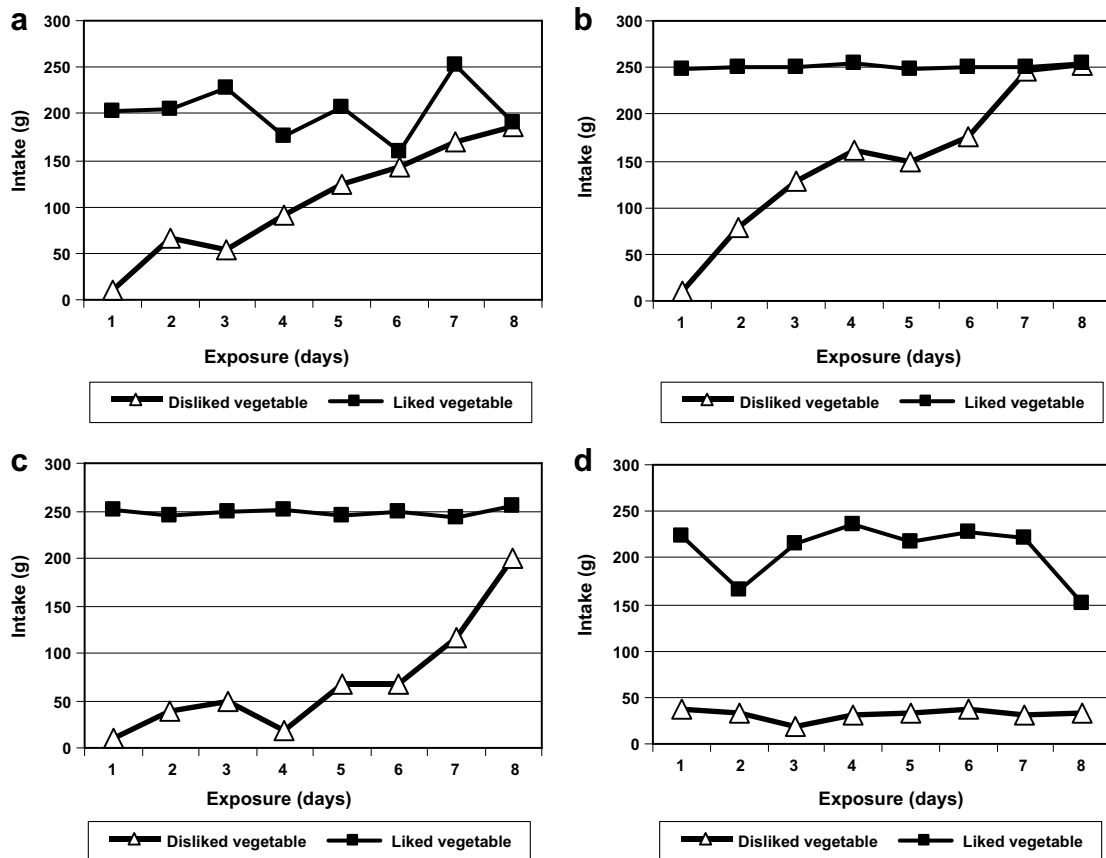


Fig. 6. Effect of exposure on intake. Examples of individual patterns: (a) Linear increase in intake ( $n = 29$ ); (b) initial increase in intake followed by a plateau ( $n = 7$ ); (c) initial plateau and then increase in intake ( $n = 6$ ); (d) no increase in intake ( $n = 1$ ).

at all in intake of the initially disliked vegetable over the whole exposure period.

For liking, the pattern was similar except that: (1) on the first and second exposures, all infants were rated by their mothers as liking the initially liked vegetable more than the initially disliked vegetable; (2) by the eighth exposure, 41 infants (84%) were rated as liking the two vegetables equally well, and (3) linear extrapolations of liking for the liked and disliked vegetables all converged, and by the 17th exposure, all mothers could be expected to rate the initially disliked vegetable and the initially liked vegetable as equally well-liked.

### 3.6. Relationship between liking and intake

For all infants, amounts of vegetable purée eaten showed a linear correlation with the liking scores reported by the mother. Linear regression was used to calculate the amount eaten corresponding to a liking score of 5 (neither likes nor dislikes). On average, this occurred at an intake of  $89 \pm 39$  g (mean  $\pm$  SD).

### 3.7. Follow-up questionnaire 9 months later

At follow-up 9 months later on 48 of the 49 infants, 40 (83%) of the infants were rated by their mothers as eating and liking carrot (the initially liked vegetable) and 8 (17%) as eating them but “not particularly liking them”. For the initially disliked vegetable, 7 (15%) had not been offered it again, 30 (63%) were rated as eating and liking it, 6 (12.5%) as eating it but not particularly liking it and only 5 (10%) as disliking or refusing it.

## 4. Discussion

Many children do not eat the currently recommended amounts of vegetables and parents are frequently searching for practical ways to increase vegetable acceptance. Food intake surveys often report that vegetables are among the least liked group of foods (Beyer & Morris, 1974; Phillips & Kolasa, 1980) or are not often selected during a luncheon at a nursery (Nicklaus, Boggio, & Issanchou, 2005). This rejection of vegetables is observable early on and persists throughout childhood (Nicklaus, Boggio, Chabanet, & Issanchou, 2004; Skinner, Carruth, Bounds, & Ziegler, 2002). The results of the present study offer the start of a practical solution to this problem. First, they show that, in 6–10-month old infants, when a vegetable is initially disliked it is worth persisting. When the caretaker offers that vegetable at eight subsequent meals, more than 70% of the infants will both eat and like it. As noted earlier, we observed, in the same region of Germany, that if infants initially disliked a vegetable, most mothers (85%) offered it no more than at three subsequent meals before giving up and deciding not to offer it again (Maier et al., 2007). Second, the results show that this acceptance seems to persist for some time, so that for most of these infants the vegeta-

ble will still be consumed and liked nine months later. It remains to be seen if this increased acceptance persists into childhood.

The term neophobia means an extreme or irrational fear or dislike of anything new, novel or unfamiliar (Oxford, 2001). In contrast, neophobia with respect to foods usually means a reluctance to try novel foods (Pliner & Salvy, 2006). Rozin & Fallon (1981) proposed that the three main reasons for rejection of a food are (1) *Dislike* of the sensory characteristics, (2) *Danger* or fear of negative consequences of eating, and (3) *Disgust*, based on ideas about the food's nature or origin. This approach, apart from the ideation of disgust, seems to apply well to infants in the age range studied here. They do show differing levels of liking and disliking for the taste, flavour or texture of some of the foods they are offered, especially if the food is experienced for the first time. They usually show liking and rapid acceptance for sweet foods (Beauchamp & Moran, 1982) and dislike and rejection for strongly bitter foods (Mennella & Beauchamp, 2005).

As the sensory results show, some vegetables, such as carrot and peas, are slightly sweet, and this may well contribute to their acceptance, while others are somewhat bitter (e.g., pumpkin) or astringent (e.g., peas; artichoke), which may impede acceptance. In the present study carrot purée was the well-liked vegetable for all the children tested but their enthusiasm for carrot was not clearly linked to any single sensory attribute or combination of sensory attributes. Among the vegetables that were less easily accepted by some of the infants, the only sensory attribute that was significantly linked with mothers' ratings of her infant's dislike for the vegetable was astringency. This could suggest that even the low levels of astringency observed here may be enough to slow acceptance of some vegetable purées. However, as the results show, it did not take many exposures to render these purées well-liked and highly acceptable to a majority of infants.

As pointed out by Sullivan & Birch (1990) many infants certainly behave as if a new food may be “dangerous”, consuming only a small amount on the first occasion it is offered and, if there are no untoward side effects, eating larger amounts thereafter. If the food is quite sweet and smooth, it will rapidly be accepted but if it is slightly astringent or rough in texture (as are many vegetables), then several more exposures may be required before it is accepted.

Several potential sources of bias were present in this study. First, of the original 75 mothers, four said they had identified a disliked vegetable but declined to participate in the study because they did not want to offer their child an already rejected food. We do not know if these four infants would have responded to repeated exposure in the same way as those who did participate, so this may have led to a small positive bias in the results. However, as the vast majority of infants did show a significant increase in intake of and liking for the initially disliked vegetable, any potential effect would not be large.

A second possible source of bias in the study is that feeding a well-liked vegetable on alternate days may have influ-



enced intake of the initially disliked vegetable or that feeding the disliked vegetable on alternate days may have influenced intake of the initially liked vegetable. While it is quite possible that the experimental procedure could have influenced the results in this way, the design is practical. If a mother intends to use repeated exposure to an initially disliked food in an attempt to increase acceptance and liking, it is unlikely she will want to offer it every day and perhaps upset the infant or even risk decreasing infant's overall food intake. Offering liked and disliked foods on alternate days is an attractive strategy and has now been shown to work well.

A third potential source of bias is that we systematically began the exposure period with the initially disliked vegetable. As food intake is increasing at this age, some of the difference in intake between the two vegetables could be because the initially liked vegetable was given 1 day later. The observation that intake of this vegetable did in fact increase consistently (by 2.8 g per exposure, i.e., every 2 days) suggests that this may well be the case, and that 1.4 g of the difference between the initially liked and initially disliked vegetables might be due to natural increasing intake with age. A plot of the correlation between mean intake of the initially liked vegetable and age showed that over the age range studied, the increase was 0.2 g per day suggesting that the increase in intake of the initially liked vegetable during the exposure period is not all explained by the systematic one-day difference between the presentation of the disliked and of the liked vegetables. Consequently, the difference in intake between the two vegetables is considerably higher than the difference in intake due to age.

A fourth potential source of bias is the difficulty in obtaining accurate food intake measures in small infants. Some of the vegetable purée inevitably fell off the spoon or was spat out by the infant during feeding. In addition, the mother may have tasted the purée when checking it was the right temperature. This would tend to exaggerate the amounts apparently consumed.

Fifth, it is probable that these mothers, who volunteered to take part in the study, may not be representative of mothers in the general population. They did, however, have similar characteristics to mothers participating in earlier, less demanding, studies in Germany (Freeman, Van't Hof, & Haschke, 2000; Maier et al., 2007), so they may well be representative of mothers in the region where the study took place.

Finally, while mean intake of the initially liked vegetable ( $173 \pm 59$  g) corresponded closely to the typical meal to offer 5–7-month old infants (190–250 g) recommended by the German Institute for Infant Nutrition (Kersting, 2001), when the infant occasionally ate a larger meal, mothers rarely gave more than two pots (i.e., about 250–260 g). In fact, while for 23 mothers the largest meal given during the whole exposure period was about 250–260 g, only three gave more. This “capping” of maximum intake occasionally (on 3 days) produced significant kurtosis in the intake patterns.

This appears to be the first study to report and compare intake of an initially liked and an initially disliked vegetable in infants younger than 10 months old over several days. Using a liked food as a control provides a reliable measure of when the initially disliked food has become fully accepted, showing that by the eighth exposure, over 70% of infants ate as much of it as of a well-liked food. It also allowed linear extrapolation a little beyond the eight exposures used here; suggesting that after 11 exposures, over 80% over the infants should consume and like the foods equally.

The observation that breast-fed infants seemed to more readily accept the initially disliked vegetable fits well with the finding of Sullivan & Birch (1994) that early in weaning, breast-fed infants accepted new foods more easily. The breastfeeding effect seen in our study is, however, open to other interpretations. For example, breastfeeding mothers may use different criteria to judge whether or not a food is “disliked” so it would be worth examining other mother–infant groups to better understand the explanation for the quite large differences in intake.

The observation that infants of more neophobic mothers showed more rapid increase in acceptance of the initially disliked vegetable can be seen as paradoxical and was not predicted. As noted in Section 1, since there tends to be a positive correlation between mothers' and infants' neophobia, one might expect infants of more neophobic mothers to more likely reject new foods, but as Table 1 shows, this was not the case. One might also expect these infants to be more reticent in accepting new foods during repeated exposure. Our results do not support this hypothesis either.

Our examination of the different patterns of change in intake of the initially disliked food showed that all the infants exhibiting little or no increase during the first few days followed by a rapid increase thereafter (Fig. 6c) were in the group “no change” (i.e., they had received the same vegetable for 10 days at the beginning of weaning) so they were expected to exhibit less rapid acceptance of a new food (see Maier et al., 2006). Although this pattern tends to confirm our expectations and the difference in distribution was significant ( $p = 0.01$ ), the sample size was too small to draw a strong conclusion.

The observation that, for a majority of the mothers, a score of 5 on the liking scale (indicating “neither likes nor dislikes”) corresponded to an intake of about 90 g of purée, i.e., about three quarters of a pot, provides a possible insight into one of the criteria mothers may use to rate liking. If at least some of the mothers assumed that one pot was an adequate serving and the infant consumed a complete pot (130 g) the mother was likely to conclude that the infants liked that vegetable purée; if the infant consumed much more than one pot, she concluded that the infant liked it a lot; if the infant ate about 90 g, then this was interpreted as neither liking nor disliking the purée, and consuming less than 90 g indicated dislike.

Lastly, the follow up survey 9 months later showed that, according to the mothers, a majority of the infants still

consumed and liked the initially disliked vegetable tested during the exposure study. This result must, however, be treated with caution because it is difficult to know if the mothers' responses to the questionnaire were influenced by their participation in the study or if the infants' preferences had subsequently been influenced by other events.

## 5. Conclusion

This study confirmed the observation of Carruth et al. (2004) that at about 7 months of age, some infants demonstrate convincing dislike for certain vegetables. However after 7–8 repeated exposures, most of them accepted the initially disliked vegetable. This acceptance appears to be maintained until the infants are about 16 months old and we are presently investigating if it persists until 3–4 years.

Whether or not rejection of vegetables poses any longer term threat to health, it is clearly an issue of concern for many parents. Feeding problems and willingness to eat new and unfamiliar foods have been cited by both paediatricians (Bakwin & Bakwin, 1972) and by parents (Pelchat & Pliner, 1986) as for reasons seeking advice. Our results provide experimental evidence to support a simple strategy to help ensure that infants more readily accept their vegetables.

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