The Journal of Nutrition
Ingestive Behavior and Neurosciences

Repeated Exposure of Infants at Complementary Feeding to a Vegetable Purée Increases Acceptance as Effectively as Flavor-Flavor Learning and More Effectively Than Flavor-Nutrient Learning[1–4]

Eloïse Remy, Sylvie Issanchou, Claire Chabanet, and Sophie Nicklaus*

INRA, UMR1324 Centre des Sciences du Goût et de l'Alimentation, Dijon, France

Abstract

Children's vegetable consumption is below the public health recommendations. This study aimed to compare learning mechanisms to increase vegetable acceptance in infants at complementary feeding, namely repeated exposure (RE), flavor-flavor learning (FFL), and flavor-nutrient learning (FNL); measure the stability of the learning effect; and examine the impact of infants' feeding history on vegetable acceptance. The study was composed of a preexposure test, an exposure period, a postexposure test, and tests at 2-wk, 3-mo, and 6-mo follow-ups. At pre- and postexposure, a basic artichoke purée and carrot purée were presented to 95 French infants (6.4 ± 0.8 mo). During the exposure period, infants were randomly split into 3 groups and were exposed 10 times to the basic (RE group; 2 kJ/g; *n* = 32), a sweet (FFL group; 2 kJ/g; *n* = 32), or an energy-dense (FNL group; 6 kJ/g; *n* = 31) artichoke purée 2 or 3 times/wk. To evaluate acceptance, intake (g) and liking were recorded at home by parents. Between pre- and postexposure, intake of the basic artichoke purée significantly increased in the RE (+63%) and FFL (+39%) groups but not in the FNL group; liking increased only in the RE group (+21%). After exposure, artichoke was as much consumed and as much liked as carrot only in the RE group. Learning of artichoke acceptance was stable up to 3 mo postexposure. Initial artichoke intake was significantly related to the number of vegetables offered before the study started. RE is as effective as and simpler to implement than FFL and more effective than FNL for increasing vegetable acceptance at complementary feeding. J. Nutr. 143: 1194–1200, 2013.

Introduction

Despite the well-established health protective effect of vegetable consumption, vegetable intake is consistently lower than the amount recommended by international public health guidelines (1). In particular, children eat 80% fewer vegetables than recommended (2–5). As childhood is an important period during which eating habits are acquired and because these eating habits will likely be maintained later in life (6–8), understanding how food preferences form early in life is of primary importance.

The rejection of vegetables by children could be due to their low energy density (9) and/or due to their unpleasant taste (6,10,11). Thus, it is important to study how the modification of these characteristics (energy density and taste) may affect vegetable acceptance learning in children. One key learning mechanism described in the literature is Pavlovian conditioning. It is based on an association between a neutral or disliked conditioned stimulus, such as a food, and a positive unconditioned stimulus to induce a positive shift in response to the conditioned stimulus even when the unconditioned stimulus is removed.

When the unconditioned stimulus is a food with high energy density that induces a positive postingestive consequence, the conditioning is described as flavor-nutrient learning (FNL)[5]. In children, several studies have reported the efficacy of this mechanism in increasing liking of a new or a neutrally liked food (12–14). The only FNL study conducted to increase vegetable liking in children failed, because they did not consume the experimental food during the conditioning phase (15).

When the unconditioned stimulus is a liked flavor, the conditioning is called flavor-flavor learning (FFL). A study on the

[1] Supported by the European Community's Seventh Framework Program (FP7/2007-2013) under the grant agreement no. FP7-245012-HabEat.
[2] Author disclosures: E. Remy, S. Issanchou, C. Chabanet, and S. Nicklaus, no conflicts of interest.
[3] This trial was registered at clinicaltrials.gov as NCT01790191.
[4] Supplemental Tables 1–3 and Figures 1 and 2 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.
* To whom correspondence should be addressed. E-mail: sophie.nicklaus@dijon.inra.fr.

[5] Abbreviations used: FFL, flavor-flavor learning; FNL, flavor-nutrient learning; FU2W, follow-up at 2 wk; FU3M, follow-up at 3 mo; FU6M, follow-up at 6 mo; RE, repeated exposure.

Manuscript received February 14, 2013. Initial review completed March 15, 2013. Revision accepted April 16, 2013.
First published online May 22, 2013; doi:10.3945/jn.113.175646.

effect of the FFL mechanism on vegetable acceptance, conducted with 5-y-old children, showed an increase in preference for the initially neutrally liked vegetable drink paired with a sweet taste after a conditioning period of 6 exposures (16).

Another strategy for increasing the acceptance of vegetables by infants is repeated exposure (RE). RE consists of increasing the familiarity of a food by offering it several times; it was demonstrated to be effective for increasing the acceptance of vegetables in infants at complementary feeding (17), even for an initially disliked vegetable (18).

To the best of our knowledge, the impact of FFL or FNL on vegetable acceptance has not been studied in early childhood. A comparison of the RE, FFL, and FNL mechanisms in increasing vegetable acceptance was recently conducted in older children (19,20) but has not been previously conducted at the beginning of complementary feeding. This was the aim of this investigation.

The acceptance of a new food at complementary feeding may depend on previous feeding experience. New foods would be more rapidly accepted by breast-fed infants than by formula-fed infants (17,18,21) and by infants who have been given a greater variety of vegetables since the beginning of complementary feeding (22–24). Therefore, duration of breastfeeding and variety of vegetables offered at the beginning of complementary feeding were taken into account in this study to explain acceptance of the target vegetable.

The objectives of this study were as follows: *1*) to investigate and compare the efficacy of the 3 mechanisms, i.e., RE, FFL, and FNL, at increasing the acceptance (intake and liking) of a vegetable at the beginning of complementary feeding; *2*) to measure the stability of the learning in the short and middle term; and *3*) to examine the influence of infants' feeding history on the acceptance of the vegetable.

Materials and Methods

The overall study design is presented in **Figure 1**.

Participants

Parents in the Dijon area of France were recruited using leaflets or posters distributed in health professionals' consulting rooms, pharmacies, and day-care centers. The criteria for infant inclusion were as follows: age between 4 and 8 mo, introduction of complementary foods was started at >2 wk and <2 mo before the start of the study, no health problems or food allergies at the beginning of the study, and gestational age ≥36 wk.

This study was conducted according to the guidelines established in the Declaration of Helsinki; the study protocol was approved by the local ethics committee (Comité de Protection de Personnes Est I Bourgogne, no. 2010/32). Written and informed consent was obtained from both parents. At the end of the study, parents received a 60€ voucher.

Study foods

Food and ingredient selection. The main criteria to select the target vegetable were low consumption and neutral acceptance in young children. Because the investigation was also conducted in Denmark and England at different childhood ages, a preliminary survey was conducted to select a vegetable matching these criteria in the 3 countries (25). The target vegetable chosen was artichoke. Carrot, the control vegetable, was chosen because it was generally liked; it was supplied by the Nestle group (NaturNes, Nestle).

Recipe development and vegetable production. To meet European regulations for the development of food recipes to be used with children <3 y old, only baby food-grade ingredients were used (26). The purées were produced as 100 ± 2 g jar (Freshinov). Three purée recipes were developed according to the following constraints: the basic and sweet purées had equal energy densities, but the sweet purée had a sweeter taste; the basic and energy-dense purées had comparable tastes but different energy densities. To check whether these constraints were met, sensory descriptions were conducted by a trained panel (**Supplemental Table 1**) and the nutritional composition was analyzed by an accredited laboratory (INZO) according to standard methods (**Supplemental Table 2**).

To study whether the learning mechanisms would be generalized to homemade purées, for follow-up at 6 mo (FU6M), all parents were asked to cook basic artichoke and carrot purées according to defined recipes. One-third of the infants received both homemade and experimental purées and the remaining infants received only the homemade purées. Because all infants received the homemade purée and because no significant difference in acceptance between both purées was observed (paired t test; n = 32), analyses at the FU6M were performed on the homemade purée.

Experimental procedure

The study was designed in 6 periods: a preexposure test (pre), an exposure period, a test at postexposure (post), and tests at 2-wk (FU2W), 3-mo (FU3M), and 6-mo (FU6M) follow-ups (Fig. 1). At preexposure, postexposure, FU3M, and FU6M, one-half of the infants received a basic artichoke purée first and then a control carrot purée and inversely for the other one-half of the infants. Infants were randomly divided into 3 experimental groups, with the aim of matching groups according to age, gender, and mode of milk feeding. During the exposure period, infants were exposed 10 times to a basic (RE group), a sweet (FFL

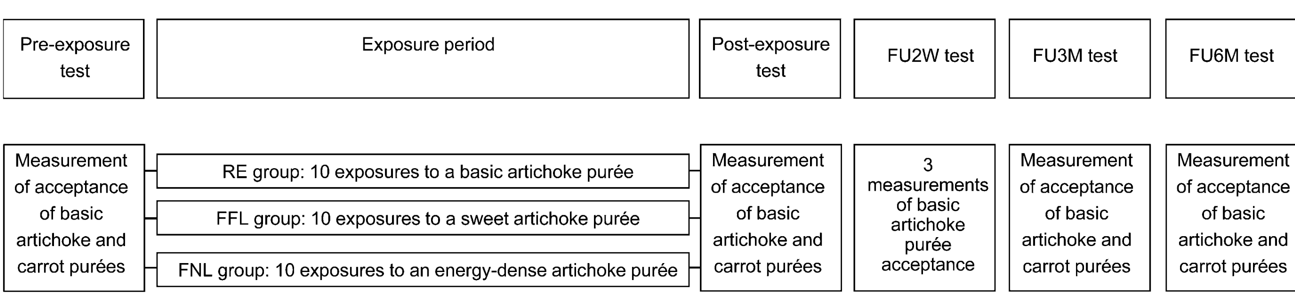

FIGURE 1 Experimental design. The study was designed in 6 periods: a preexposure test, an exposure period, a postexposure test, and tests at 2 wk, 3 mo, and 6 mo follow-ups. During the tests at preexposure, postexposure, 3 mo, and 6 mo, one-half of the infants received a basic artichoke purée first and then a control carrot purée and inversely for the other one-half of the infants. Infants were randomly divided into 3 experimental groups, with the aim of matching groups according to age, gender, and mode of milk feeding. During the exposure period, infants were exposed 10 times to a basic (RE), a sweet (FFL), or an energy-dense (FNL) artichoke purée. The test at 2 wk consisted in 3 measurements of the basic artichoke purée acceptance for all infants. FFL, flavor-flavor learning group; FNL, flavor-nutrient learning group; FU2W, measurement at the 2-wk follow-up; FU3M, measurement at the 3-mo follow-up; FU6M, measurement at the 6-mo follow-up; post, measurement at postexposure; pre, measurement at preexposure; RE, repeated exposure group.

group), or an energy-dense (FNL group) artichoke purée according to their group. The FU2W consisted of 3 measurements of the basic artichoke purée acceptance for all infants. A power calculation conducted using data from a previous study (23) revealed that 24 infants by group would be necessary to observe a significant difference in intake between pre- and post-measurements. We decided to recruit at least 30 infants by group to anticipate drop-out.

All measurements were conducted at home. Parents (mostly mothers) received the study instructions from a trained experimenter, during home visits, organized before the preexposure and the 3- and 6-mo follow-ups. Phone contact was also made several times during the experimental period. Parents were instructed to choose between lunch and dinner and then to conduct the observations always at the same time. Observations had to be conducted 2 or 3 times/wk, neither on multiple occasions within the same day nor on consecutive days. They could not skip weeks, except if their infant was sick. The period ranging from pre- to postexposure lasted a mean of 41 ± 1 d. The experimental purées had to be the first food of the meal offered to infants to make sure that they were hungry. Parents were asked to warm the two 100-g jars of the same food for 20 s in a microwave or 4 min in a water bath. It was specified that during each experimental meal the parents should not give another vegetable purée. Parents were also instructed not to give other artichoke-based foods between pre- and postexposure. To check compliance, parents were asked to record the time of feeding, report which foods they offered during each experimental meal, and record each feeding occasion after the postexposure when they fed the infant an artichoke-based food.

Intake and liking measurement

For each experimental meal, intake and liking of the study foods were measured. To measure intake, parents were asked to weigh each jar before and after consumption, using a digital kitchen scale (± 1 g, Soehnle) that we provided them with, and to record the weight in a notebook. To evaluate their infant's liking of the purée, parents were asked to use a 9-point scale ranging from 1 = dislikes very much to 9 = likes very much (23). They were instructed to tick the point of the scale that best reflected their infant's liking. Parents were instructed to present the food to their infant until s/he exhibited 3 consecutive refusal signs (keeping the mouth closed, turning his/her head away, turning the spoon away, etc.).

After each observation, parents were required to reseal the jar(s) of food, freeze them, and bring the used jars back to the laboratory to check compliance with the study procedure and data accuracy.

Background information and questionnaires

Questionnaires were completed at home by parents. They reported their education level and the height (cm), weight (kg), and feeding history of their infant. They were asked if the mother had breastfed the infant or not, and if so, the duration of exclusive breastfeeding and total breastfeeding duration. They were also asked when complementary feeding had started and the foods they had offered to their infant. The number of vegetables offered before the study was calculated to evaluate the effect of food variety before the start of the experimental exposure on artichoke acceptance.

Statistical analyses

We used the SAS System for Windows version 9.1 (SAS Institute) to perform the analyses. Results are expressed as means ± SEMs and as parameters ± SEs. Significance was set at $P < 0.05$ and marginal significance at $P < 0.10$.

The background characteristics of the infants were compared among the 3 experimental groups by ANOVA (quantitative variables) or chi-square test (qualitative variable).

Analyses were performed to study intake (in grams) and liking (1–9) separately at each measurement point, but these 2 variables are described in the following paragraphs using the term acceptance for the purpose of concision. Concerning the analysis of the FU2W, in each group, paired *t* tests were performed between the first, second, or third measurements for intake and liking. Because no significant difference was observed, individual mean acceptance across the 3 measurements was considered.

To evaluate the acceptance of the basic artichoke purée at each measurement point, an ANCOVA was run with "group" as a fixed effect and "number of vegetables eaten before the study" as a covariate. Other covariates were considered: age at complementary feeding, age at the beginning of the study, number of days between the start of complementary feeding and the beginning of the study, duration of exclusive breastfeeding, Z-score of BMI, and infant's weight at each period of the study (27). Because the effects of these covariates were never significant, they were removed from the final model. A post-hoc comparison (Student's *t* tests) was used to compare means across groups.

The change in acceptance of each artichoke purée during the 10-exposure period was analyzed with a mixed linear model. The "infant" effect was considered random. The model was as follows: acceptance = group + exposure number + number of vegetables eaten before the study + (group × exposure number) + (group × number of vegetables eaten before the study) + (group × exposure number × number of vegetables eaten before the study) + error, with the number of vegetables eaten before the study and exposure number being regressors in this model.

To compare the efficacy of the 3 learning mechanisms, the difference in basic artichoke purée acceptance from pre- to postexposure was calculated [Δ(post − pre)]. To study short- and long-term effects, the differences in basic artichoke purée acceptance between postexposure and the 2-wk follow-up [Δ(FU2W − post)], the 3-mo follow-up [Δ(FU3M − post)], and the 6-mo follow-up [Δ(FU6M − post)] were calculated. These differences were analyzed by an ANCOVA, with group as factor and number of vegetables eaten before the study as a covariate. Moreover, for each group, these differences were analyzed by paired *t* tests between 2 times.

To test the significance of the difference of acceptance between the preexposure and the first exposure [Δ(E1 − pre)] or between the 10th exposure and postexposure [Δ(post − E10)], a paired *t* test was calculated for each group. At pre- and postexposure, acceptance of artichoke was compared with acceptance of carrot using a paired *t* test.

Results

Participants

Recruitment took place between October 2010 and May 2011. During this period, 123 families expressed interest in participating in this study, but 23 of these families did not meet the inclusion criteria and were excluded. Five families dropped out during the exposure period. As a result, the data reported here are restricted to infants who completed the entire exposure period ($n = 95$). All of them completed the study until the FU2W; 93 completed the FU3M and 92 completed the FU6M (**Supplemental Fig. 1**).

The characteristics of the infants who completed the period from pre- to postexposure are presented in **Table 1**. The groups differed significantly only in that infants in the FFL group were weaned 2 wk later than those in the other groups. Parental education did not differ across groups.

Artichoke acceptance at preexposure and impact of infant feeding history

At preexposure (**Fig. 2**), no significant differences in basic artichoke purée intake were observed between the experimental groups, but liking in the FFL group was greater than in the FNL and RE groups ($P = 0.026$).

Among the participating infants, 19 were bottle-fed and the others were exclusively breastfed for a mean 93 ± 7 d. Duration of exclusive breastfeeding was related neither to initial intake nor to initial liking of artichoke purée.

Sixteen infants had been exposed to artichoke purée at least once before starting the study; for 15 of them, it was a commercial artichoke purée. This purée contained only 21% artichoke and the artichoke taste was hardly perceptible compared with the experimental artichoke purées. Infants had eaten a mean of 6

TABLE 1 Characteristics of infants by experimental group exposed 10 times to a basic (RE group), a sweet (FFL group), or an energy-dense (FNL group) artichoke purée[1]

	RE group	FFL group	FNL group
Infants, *n*	32	31	32
Female/male, *n*	15/17	11/20	12/20
Age at preexposure, *mo*	6.3 ± 0.1	6.6 ± 0.1	6.2 ± 0.2
Age at the start of complementary feeding, *mo*	5.1 ± 0.2[b]	5.6 ± 0.1[a]	5.0 ± 0.1[b]
BMI Z-score	0.7 ± 0.2	0.7 ± 0.2	0.9 ± 0.3
Bottle fed, *n*	6	7	6
Duration of exclusive breastfeeding, *d*	79 ± 11	78 ± 13	60 ± 10
Duration of total breastfeeding, *d*	91 ± 15	118 ± 18	117 ± 21

[1] Values are frequency or means ± SEMs. Means without a common letter differ, $P < 0.05$. FFL, flavor-flavor learning; FNL, flavor-nutrient learning; RE, repeated exposure.

different vegetables before starting the study and no differences in the number of vegetables eaten previously were observed between groups. The more vegetables infants had eaten before starting the study, the greater the artichoke intake at preexposure (+8 ± 2 g/vegetable previously eaten; P = 0.0001). No effect of number of vegetables eaten before starting the study was observed on artichoke liking at preexposure.

Change in artichoke acceptance during the exposure period

The intake of artichoke purée was greater in the FFL group (141 ± 8 g, 302 ± 71 kJ) than in the RE (123 ± 7 g, 248 ± 55 kJ) and FNL (107 ± 8 g, 646 ± 50 kJ) groups. Moreover, the number of exposures affected artichoke purée intake (4 ± 1 g/exposure; P = 0.0005) (**Supplemental Fig. 2***A*). Liking of artichoke purée was greater in the FFL (7.3 ± 0.2) and RE (7.0 ± 0.2) groups than in the FNL (6.1 ± 0.3) group. The number of exposures did not affect liking of the purée (Supplemental Fig. 2*B*). The group × exposure number interactions in the models analyzing intake or liking were not significant.

Artichoke acceptance at postexposure

Between pre- and postexposure [Δ(post − pre)], the increase of artichoke acceptance was significant for the RE group for intake (+63%; P = 0.0001) and liking (+21%; P = 0.007), for intake only in the FFL group (+39%; P = 0.005), and for neither intake nor liking in the FNL group (**Supplemental Table 3**). Consequently, at postexposure, intake and liking in the FFL and RE groups did not significantly differ from each other and were greater than in the FNL group (Fig. 2).

Artichoke acceptance at follow-ups

For each group, no significant change in basic artichoke purée intake was observed between postexposure and the different follow-ups [Δ(FU2W − post); Δ(FU3M − post); Δ(FU6M − post)] (Supplemental Table 3). Nevertheless, because the intake of basic artichoke purée decreased significantly in the RE group between the FU3M and FU6M, the group effect on intake of basic artichoke purée was no longer significant at the FU6M (Fig. 2). Compared with liking of basic artichoke purée at postexposure (Supplemental Table 3), liking at the FU3M decreased [Δ(FU3M − post)] only in the FFL group; at the FU6M, it decreased [Δ(FU6M − post)] for all 3 groups. Consequent to the different decreases in liking across groups, liking ratings at the FU3M did not differ in the FFL and RE groups and were greater than those in the FNL group (P = 0.0046). No significant group effect was observed at the FU2W or the FU6M.

Difference in artichoke acceptance between preexposure and the first exposure and between the 10th exposure and postexposure

Neither intake nor liking differed for the RE group, which always received the basic artichoke purée, between preexposure and the first exposure and between the 10th exposure and post exposure. In the FFL and FNL groups, when the artichoke purée was changed first from the basic to a sweet or energy-dense

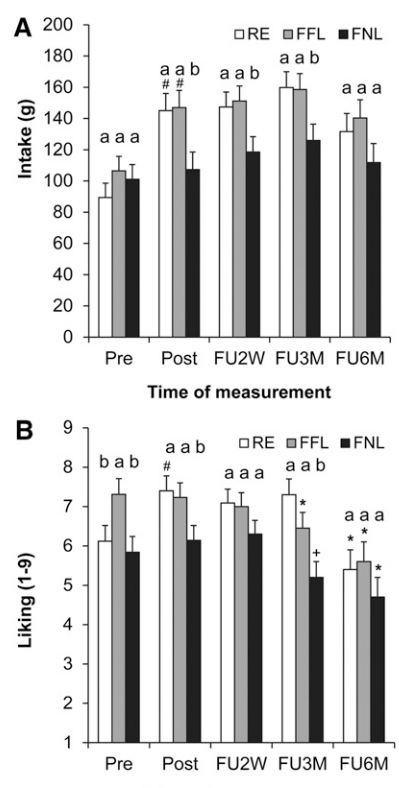

FIGURE 2 Intake (*A*) and liking (*B*) of a basic artichoke purée measured before, immediately after, and 2 wk, 3 mo, and 6 mo after infants were exposed 10 times to a basic (RE), a sweet (FFL), or an energy-dense (FNL) artichoke purée. Values are means ± SEMs, n = 30–34. Means at a time without a common letter differ, $P < 0.05$. #Pre and post differ, $P < 0.05$; *post and follow-up at that time differ, $P < 0.05$. +post and FU3M tend to differ, P = 0.06. FFL, flavor-flavor learning group; FNL, flavor-nutrient learning group; FU2W, measurement at the 2-wk follow-up; FU3M, measurement at the 3-mo follow-up; FU6M, measurement at the 6-mo follow-up; post, measurement at postexposure; pre, measurement at preexposure; RE, repeated exposure group.

recipe, and second from a sweet or energy-dense to the basic recipe, neither intake nor liking differed.

Carrot vs. artichoke: intake and liking

Carrot intake at preexposure was greater than artichoke intake in the RE group (115 ± 10 vs. 92 ± 9 g; $P = 0.01$), but not in the FNL (114 ± 10 vs. 98 ± 12 g) or FFL (122 ± 10 vs. 107 ± 8 g) groups. Infants liked carrot more than artichoke in the RE (7.1 ± 0.3 vs. 6.1 ± 0.4; $P = 0.03$) and the FNL groups (7.2 ± 0.4 vs. 5.8 ± 0.5; $P = 0.005$) groups, but not in the FFL group (7.1 ± 0.4 for carrot vs. 7.3 ± 0.3 for artichoke).

At postexposure, carrot and artichoke intakes were not significantly different in the RE group (159 ± 13 of carrot vs. 145 ± 10 g of artichoke). Carrot intake was greater than artichoke intake in the FFL (178 ± 13 of carrot vs. 147 ± 11 g of artichoke; $P = 0.007$) and FNL groups (166 ± 14 g of carrot vs. 107 ± 12 g of artichoke; $P = 0.0001$). At postexposure, carrot and artichoke likings did not differ in the RE (7.4 ± 0.4 for carrot vs. 7.3 ± 0.3 for artichoke) or FFL (7.3 ± 0.3 for carrot vs. 7.2 ± 0.4 for artichoke) groups. Carrot liking (7.5 ± 0.3) was greater than artichoke liking (6.2 ± 0.5) in the FNL group ($P = 0.01$).

Discussion

The aim of this study was to investigate the effect of 3 learning mechanisms, RE, FFL, and FNL, on the acceptance (intake and liking) of a new vegetable in infants at the beginning of complementary feeding. Overall, the results show that RE and FFL were as effective at increasing intake of the basic artichoke purée in the short term. Only RE appeared to increase liking. However, liking of carrot and basic artichoke were similar after exposure in the RE and FFL groups; intake of artichoke was equivalent to intake of carrot only for the RE group. On the contrary, FNL was not effective: neither intake nor liking of the basic artichoke increased in the FNL group. After the 3-mo follow-up, artichoke intake in the RE group and liking in the FFL and FNL groups decreased, leading to equivalent acceptance across the 3 groups at the 6-mo follow-up. This suggests stability of the learning effect for at least 3 mo postexposure. In fact, at the FU6M, infants were 1 y old. This age corresponds with the widening of the food repertoire (28) and the onset of food neophobia (29,30). The transition toward a more varied diet may be accompanied by a decrease in the appeal of vegetables compared with other food categories (31) and may explain the decrease in artichoke acceptance.

Thus, altogether, these results revealed for the first time that at the beginning of complementary feeding, RE and, to a lesser extent, FFL, are effective mechanisms for increasing vegetable acceptance and that the learning effect can still be observed 3 mo after the exposure period. This study lends further weight to experimental evidence of the efficacy of RE (17,22,32–34) and FFL (16,20,35) in increasing food acceptance in children.

On the contrary, although the efficacy of FNL to condition flavor preference has been demonstrated by other studies in older children (12–14), the effect of flavor-nutrient conditioning to increase vegetable liking was not shown in this study. The absence of a flavor-nutrient conditioning effect on intake in the present study is in agreement with results obtained with similar foods in older children (19,20). Several hypotheses may account for this stability in artichoke intake after exposure to the energy-dense purée. The first hypothesis is that infants may have disliked the specific flavor of the energy-dense purée. This was not the case in this study, because infants ate ~100 g of this purée. Moreover, intake in the FNL group did not vary when infants switched from the basic to the energy-dense purée at pre- and postexposure. The second hypothesis is that one jar of the energy-dense artichoke purée may have been sufficient to cover the infants' energy needs. During the exposure period, the energy intake related to the ingestion of the energy-dense purée (~650 kJ) was greater than those related to the other artichoke purées (~300 kJ for the sweet purée and 250 kJ for the basic purée). At 6–7 mo, infants require ~2700 kJ/d to cover their needs for metabolism and growth (36), which is generally covered by 5 meals/d, including milk feedings (31). If infants ate until meeting their energy needs, one may wonder why infants in the 2 other groups did not eat more. In these groups, ingested volume (37–39) and sensory-specific satiation (40–42) may explain meal termination. The third hypothesis is that the lower intake in the FNL group may be related to expected satiation, which is described as the extent to which a food is expected to deliver fullness (43). In this study, infants in the FNL group learned through exposure to associate the artichoke flavor with a feeling of fullness, resulting in a lower intake compared with the other groups at the postexposure test. Moreover, the intake of the basic purée for infants of the FNL group was stable at all follow-ups (FU2W, FU3M, and FU6M), this suggests that the flavor-nutrient association formed during the exposure period was robust over time. Altogether, this result indicates that the effect of flavor-nutrient conditioning was not an increase in the affective value of artichoke but a learned satiation.

Besides, because of the fat taste of the energy-dense artichoke purée, the flavor-nutrient association could also have resulted in a flavor-flavor association. Consequently, the results suggest that FFL could be more effective with the sweet taste than with the fat taste. However, when food ingestion is considered, it is difficult to completely separate the flavor effects from the postingestive effects. Here, for ethical and regulatory reasons, it was not possible to use certain ingredients, such as sweeteners that bring sweet taste without energy or ingredients that add energy without modifying the sensory properties.

Another highlight of this study is that, at the beginning of complementary feeding, although intake and liking were lower for artichoke compared with carrot, the amount of artichoke purée eaten was high, ~100 g. This is consistent with a previous observation that infants accepted most unknown foods they were offered at complementary feeding (11). This high intake at the first exposure could explain the fact that the increase in intake over the subsequent exposures was less pronounced than in similar studies conducted with older children (19,20).

Different factors have been previously described to influence vegetable acceptance at complementary feeding, such as the milk-feeding mode (17,18,21) and the variety of vegetables eaten at the start of complementary feeding (18,22,23). In this study, duration of breastfeeding was not related to artichoke acceptance. This absence of a breastfeeding duration impact could be due to the fact that 75% of the infants had been breastfed for only a short period (~3 mo). However, the variety of vegetables eaten before the study began had a positive impact on the initial acceptance of artichoke. This result confirms that variety at the beginning of complementary feeding is particularly important for increasing acceptance of a new food (22–24).

At the 6-mo follow-up, the intake of the experimental artichoke purée did not significantly differ from the intake of the homemade artichoke purée, regardless of the group. This result supports previous results, indicating that experience with a given food can attenuate the neophobic response to other similar foods (44).

Two types of measurement were used in this study to evaluate the infants' acceptance: intake and liking. The impact of learning differed for these 2 variables; during the exposure period, artichoke intake increased while liking was stable. Despite the fact that FFL or FNL were supposed to induce an increase in the affective value of foods, it was not the case in this study. The present results suggest that change in intake could occur without any observable change in infants' facial or body behavior. Liking may be a less sensitive variable than intake to evaluate the effect of learning in infants. Here, liking was assessed by the parent's subjective evaluation, because they were in the best position for reporting their infant's reactions and they could compare these feeding situations with other ones.

The results of this study should be interpreted in the light of its limitations and strength. In any study conducted with infants in a natural context, at home, parents are the best intermediate, but it is difficult to completely control their practices. However, parents were given precise instructions, and data collected in the notebook revealed that they complied with the instructions.

In summary, these results highlight the plasticity of food acceptance at the moment of the transition from a milk diet to a diversified diet (21,23), revealing that conducting complementary feeding around the age of 6 mo is a favorable period for learning what and how much to eat. Moreover, this study demonstrated that repeated exposure to a basic purée is an effective and simple way to increase intake and liking not only in the short term but at least until 3 mo after exposure. This study also demonstrated that, at the beginning of complementary feeding, it is not necessary to add an ingredient with a liked taste or an energy-dense ingredient to induce learning for a novel vegetable. This is an important practical finding, as it is easier to recommend to simply repeat exposure than to add an ingredient for first food exposures. This study also confirms that at the beginning of complementary feeding, early exposure to a variety of vegetables increased acceptance for an unfamiliar vegetable.

Acknowledgments

The authors thank Vincent De Anfrasio and Isabelle Grangé for their involvement in the data collection, Dr. Vincent Boggio for his advice, and Christophe Martin (ChemoSens Plateform) for his help in conducting the sensory description. E.R., S.I., and S.N. designed the research project, analyzed data, wrote the paper, and had primary responsibility for the final content; E.R. conducted the research; and C.C. analyzed the data and edited the manuscript. All authors read and approved the final manuscript.

Literature Cited

1. WHO. Diet, nutrition and prevention of chronic diseases. Technical Report Series. Geneva: FAO/WHO Expert Consultation; 2003. Report No.: 916.
2. ANSES. Etude individuelle Nationale sur les Consommations Alimentaires (INCA2, 2006–2007). Paris: Agence Nationale de Sécurité Sanitaire; 2009.
3. USDA. Diet quality of low-income and higher-income Americans in 2003–04 as measured by the Healthy Eating Index. Washington: USDA; 2008. Report No.: 42.
4. Diethelm K, Jankovic N, Moreno LA, Huybrechts I, De Henauw S, De Vriendt T, Gonzalez-Gross M, Leclercq C, Gottrand F, Gilbert CC, et al. Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public Health Nutr. 2012;15:386–98.
5. Fernandez-Alvira JM, Mouratidou T, Bammann K, Hebestreit A, Barba G, Sieri S, Reisch L, Eiben G, Hadjigeorgiou C, Kovacs E, et al. Parental education and frequency of food consumption in European children: the IDEFICS study. Public Health Nutr. 2013;16:487–98.
6. Nicklaus S, Boggio V, Chabanet C, Issanchou S. A prospective study of food preferences in childhood. Food Qual Prefer. 2004;15:805–18.
7. Skinner JD, Carruth BR, Bounds W, Ziegler P, Reidy K. Do food-related experiences in the first 2 years of life predict dietary variety in school-aged children? J Nutr Educ Behav. 2002;34:310–5.
8. Nicklaus S, Boggio V, Chabanet C, Issanchou S. A prospective study of food variety seeking in childhood, adolescence and early adult life. Appetite. 2005;44:289–97.
9. Gibson EL, Wardle J. Energy density predicts preferences for fruit and vegetables in 4-year-old children. Appetite. 2003;41:97–8.
10. Nicklaus S. Children's acceptance of new foods at weaning. Role of practices of weaning and of food sensory properties. Appetite. 2011;57:812–5.
11. Schwartz C, Chabanet C, Lange C, Issanchou S, Nicklaus S. The role of taste in food acceptance at the beginning of complementary feeding. Physiol Behav. 2011;104:646–52.
12. Birch LL, McPhee L, Steinberg L, Sullivan S. Conditioned flavor preferences in young children. Physiol Behav. 1990;47:501–5.
13. Johnson SL, McPhee L, Birch LL. Conditioned preferences: young children prefer flavors associated with high dietary fat. Physiol Behav. 1991;50:1245–51.
14. Kern DL, McPhee L, Fisher J, Johnson S, Birch LL. The postingestive consequences of fat condition preferences for flavors associated with high dietary fat. Physiol Behav. 1993;54:71–6.
15. Zeinstra GG, Koelen MA, Kok FJ, de Graaf C. Children's hard-wired aversion to pure vegetable tastes. A 'failed' flavour-nutrient learning study. Appetite. 2009;52:528–30.
16. Havermans RC, Jansen A. Increasing children's liking of vegetables through flavour-flavour learning. Appetite. 2007;48:259–62.
17. Sullivan SA, Birch LL. Infant dietary experience and acceptance of solid foods. Pediatrics. 1994;93:271–7.
18. Maier A, Chabanet C, Schaal B, Issanchou S, Leathwood P. Effects of repeated exposure on acceptance of initially disliked vegetables in 7-month old infants. Food Qual Prefer. 2007;18:1023–32.
19. Caton SJ, Ahern SM, Remy E, Nicklaus S, Blundell P, Hetherington MM. Repetition counts: repeated exposure increases intake of a novel vegetable in UK pre-school children compared to flavour-flavour and flavour-nutrient learning. Br J Nutr. Epub 2012 Oct 30.
20. Hausner H, Olsen A, Møller P. Mere exposure and flavour-flavour learning increase 2–3 year-old children's acceptance of a novel vegetable. Appetite. 2012;58:1152–9.
21. Hausner H, Nicklaus S, Issanchou S, Mølgaard C, Møller P. Breastfeeding facilitates acceptance of a novel dietary flavour compound. Clin Nutr. 2010;29:141–8.
22. Gerrish CJ, Mennella JA. Flavor variety enhances food acceptance in formula-fed infants. Am J Clin Nutr. 2001;73:1080–5.
23. Mennella JA, Nicklaus S, Jagolino AL, Yourshaw LM. Variety is the spice of life: Strategies for promoting fruit and vegetable acceptance during infancy. Physiol Behav. 2008;94:29–38.
24. Maier AS, Chabanet C, Schaal B, Leathwood PD, Issanchou SN. Breastfeeding and experience with variety early in weaning increase infants' acceptance of new foods for up to two months. Clin Nutr. 2008;27:849–57.
25. Ahern SM, Caton SJ, Bouhlal S, Olsen A, Nicklaus S, Moller P, Hetherington MM. Vegetable intake and liking in pre-school children: a cross cultural comparison of three European countries. Brighton (UK): British Feeding and Drinking Conference; 2012.
26. Commission Directive. 2006/125/EC of 5 December 2006 on processed cereal-based foods and baby foods for infants and young children. Off J Eur Union. 2006;49:16–35.
27. Rolland-Cachera MF, Cole TJ, Sempe M, Tichet J, Rossignol C, Charraud A. Body mass index variations: centiles from birth to 87 years. Eur J Clin Nutr. 1991;45:13–21.
28. Skinner JD, Carruth BR, Houck K, Moran J III, Coletta F, Cotter R, Ott D, McLeod M. Transitions in infant feeding during the first year of life. J Am Coll Nutr. 1997;16:209–15.
29. Dovey TM, Staples PA, Gibson EL, Halford JCG. Food neophobia and 'picky/fussy' eating in children: a review. Appetite. 2008;50:181–93.

30. Nicklaus S. Development of food variety in children. Appetite. 2009; 52:253–5.
31. Le Heuzey MF, Turberg-Romain C, Lelièvre B. Comportement alimentaire des nourrissons et jeunes enfants de 0 a 36 mois: comparaison des habitudes des mères. Arch Pediatr. 2007;14:1379–88.
32. 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;3:353–60.
33. Sullivan SA, Birch LL. Pass the sugar, pass the salt: experience dictates preference. Dev Psychol. 1990;26:546–51.
34. Wardle J, Cooke LJ, Gibson EL, Sapochnik M, Sheiham A, Lawson M. Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. Appetite. 2003;40:155–62.
35. Capaldi ED, Privitera GJ. Decreasing dislike for sour and bitter in children and adults. Appetite. 2008;50:139–45.
36. Butte NF. Energy requirement of infants. Eur J Clin Nutr. 1996;50:24–36.
37. Rolls BJ, Castellanos VH, Halford JC, Kilara A, Panyam D, Pelkman CL, Smith J, Thorwart ML. Effect of volume on satiety. Appetite. 1997;29:412.
38. Brunstrom JM, Collingwood J, Rogers PJ. Perceived volume, expected satiation, and the energy content of self-selected meals. Appetite. 2010;55:25–9.
39. Kral TV, Rolls BJ. Energy density and portion size: their independent and combined effects on energy intake. Physiol Behav. 2004;82: 131–8.
40. Rolls BJ, Rolls ET, Rowe EA, Sweeney K. Sensory specific satiety in man. Physiol Behav. 1981;27:137–42.
41. Weijzen PLG, Liem DG, Zandstra EH, de Graaf C. Sensory specific satiety and intake: The difference between nibble- and bar-size snacks. Appetite. 2008;50:435–42.
42. Booth DA. Sensory, digestive and metabolic influences on preference and intake. Appetite. 2001;36:63–9.
43. Brunstrom JM, Scott-Samuel NE, Shakeshaft NG. Exploring expectations about the satiating quality of foods. Appetite. 2008;50:556–4.
44. Birch LL, Gunder L, Grimm-Thomas K, Laing DG. Infants' consumption of a new food enhance acceptance of similar foods. Appetite. 1998;30:283–95.