Sensitive Periods And Factors In The Early Formation Of Food Preferences

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Introduction

Eating behavior is a complex, essentially learned activity critical for development and survival. It can be broken down into several components: when, how, what and how much to eat.[1,2] We will mainly describe in this chapter the important periods and factors associated with the development of "what" to eat, or in other words, food preferences and choice. Other aspects relevant to the early development of eating behavior have been previously reviewed.[2,3] Although it has previously been shown that food and flavor preference may be influenced by flavor exposure during the prenatal period[4-6], we will focus in this chapter on the acquisition of food preferences consecutive to direct exposure of the infant to foods. Detailed descriptions of prenatal influences may be found elsewhere.[7,8]

Food habits form early during childhood and are likely to track over childhood until the beginning of adulthood.[9,10] Understanding the determining factors of the acceptance of the very first foods other than milk, is therefore of particular importance, since these foods will form the basis of the child's future food repertoire. We will describe here how preferences are acquired during the first years of life, and how they can be modified in preschool children, until about the age of 5 years. We focused in particular on the acquisition of preference for fruits and vegetables, because these foods are generally not as consumed by children as it is recommended. The development of preference for other foods is described elsewhere.[11-13]

Milk feeding period

Milk is the first food consumed by the infant. The flavors of breast milk are likely to vary from one feeding episode to another.[14] The flavors of formula milks are also likely to differ according to their types, whether they are regular, antiallergic (with hydrolysed protein), antidiarrheic, fermented, etc.[15]

Some works focused on the impact of the timing of milk feeding on acceptance of specific formula; in particular, on the introduction of a specific milk formula, protein hydrolysate formula, which bears distinct, unpleasant flavour notes. Their results suggest that there may be a specific window to favour its acceptance: it is easily accepted at the age of 2 months but not at the age of 7 months.[16] At the age of 7 months, such a formula is accepted provided the infant had received previous exposure to this type of formula.[17] It was suggested that the earlier the exposure to protein hydrolysate formula, and the longer the exposure, the higher the acceptance of this food.[18]

The mode of milk feeding may be associated with a differential acceptance of food at the beginning of complementary feeding: breastfeeding leads to a higher acceptance of a new food when acceptance is evaluated during the first days of the complementary feeding period [19,20]_ENREF_19, or within one month after the beginning of complementary feeding.[21] However, this association is not observed when acceptance of new foods is averaged over a two-month period.[22] Moreover, after 2 weeks of exposure to a flavored food, breastfed and bottle fed infants do not differ in their acceptance of this food compared to an unflavored version._ENREF_21 The positive impact of breastfeeding on further food acceptance may be mediated by the variety of flavor exposure in the milk context, not to exposure to specific flavors.[4,21] This impact may be limited to the very beginning of complementary feeding.

The infant's taste experience in the milk feeding context may modify further food preferences. The longer

the breastfeeding duration, the higher the acceptance of a umami-tasting solution at the age of 6 months.[23] Exposure to hydrolyzed-protein formulas is associated to a different taste preference pattern later, up to the age of 5 years.[24,25]

Epidemiological studies also revealed some associations between breastfeeding practices and dietary habits at a later age. Breastfeeding duration is positively associated to food variety later: it is associated to variety of free food choices by 2-to-3-year-old children[26], to healthy eating habits at 2 years[27], to food variety at 2 years[28], to fruit consumption at 6-8 years[29] and to a healthy eating patterns (consumption of meat, fruits and vegetables) at 2-8 years.[30] A longer breastfeeding duration was consistently related to higher fruit and vegetable intake in 2–4-y-old children when taking into account data from 4 different European cohorts (the British Avon Longitudinal Study of Parents and Children (ALSPAC), the French Etude des Déterminants pré et post natals de la santé et du développement de l'Enfant (EDEN) study, the Portuguese Generation XXI Birth Cohort, and the Greek EuroPrevall study).[31] Exclusive breastfeeding for at least 3 months is associated with a higher consumption of vegetables at 4 years.[32]

Complementary feeding period

Several factors are now known to be involved in the acceptance of foods at complementary feeding, in particular factors related to practices of complementary feeding, i.e. timing of introduction to solid foods, repeated exposure, and variety of foods offered. The sensory properties of the foods offered at that moment are likely to modulate the effect of these factors.

Introduction to complementary foods is a process which helps the transition between a single food, milk, toward a diversity of family foods. At the age when complementary feeding is generally conducted in developed countries (middle of the first year), the infant displays limited physiological capacities (i.e. intestinal maturity, renal functions and oral function development), and therefore family foods need to be adapted to infants' capacities. They are often adapted in terms of texture and are initially offered in the form of purées or soup. They are also adapted in terms of nutritional content.[33]

Role of the timing of complementary feeding

The recommended age for starting complementary feeding is set at 6 months by the World Health Organisation[34], but national recommendations may range from the age of 4 to 6 months.[2]

It may be possible that, because of physiological and/or psychological development, one or more specific time windows may lead to an easier acceptance of complementary foods at introduction, or would lead to more sustainable preference.[35-37] However, the consequences of timing of introduction to complementary foods in terms of eating behavior and acceptance are not very well documented[38], since most investigations focused on the nutritional consequences of the cessation of breastfeeding.

Concerning solid foods, a study showed that the acceptance of salty cereals compared to plain cereals was higher in infants aged 16-17 weeks than in infants aged 18-25 weeks.[39] In an observational study conducted in France with the OPALINE cohort (Observatory of food preferences in infants and children), it was showed that the earlier vegetables were introduced in the infant's diet (but after the age of 4

months), the higher their acceptance by infants.[22] This effect was not observed for other types of complementary foods (cereals, fruit, starchy foods, fish meat, dairy products, desserts, biscuits). Whether age of introduction to different categories of foods may impact their acceptance, on the short and longer run, deserves more attention in futures studies.

The consequences of an early introduction to fruit and vegetables have been analysed in different ways. One study reported a positive relationship between early consumption of fruit and measured fruit intake at the age of 18 months, and this relationship was mediated by the acceptance of the sour taste, which is pronounced in fruit.[40] Another study conducted in the UK and based on parental report revealed that early introduction to fruit or vegetables (with no indication of specific age) was associated with higher consumption of fruit or vegetables, respectively, at 2-5 years of age.[41] In this analysis, after adjustment for effects potentially influencing consumption, such as parental intake or parental neophobia, only fruit intake was significantly related to early introduction to fruit. A comparable finding was shown in a study conducted in the USA[42], suggesting that the early introduction to fruit has more impact on later consumption of fruit than the early introduction to vegetables. One might conclude that it is not necessary to introduce vegetables early in the infant's diet. However, vegetables are much less energy-dense than fruit and other foods[43], which does not favour their consumption in young children.[44] Previous studies indicate that vegetables are easily accepted at the beginning of complementary feeding, but not when the child has reached a more advanced age, around 2 to 4 years old[43,44], revealing a change in acceptance which might be related to their nutritional properties, their sensory properties (see section on sensory properties below), or to a competition from other more palatable foods introduced later on after the beginning of complementary feeding. For these reasons, it may be advised to introduce vegetables early in the complementary feeding process.

One study recently explored whether they may be a benefit of introducing vegetables before fruit; compared to the introduction to fruit before vegetables[45]. It showed that repeated exposure to fruit had no effect on the vegetable intake, and vice versa. However, because fruit intake was significantly higher than vegetable intake from the start, and because reported daily intake of vegetables at 12 months of age was 38 % higher in infants first fed with vegetables than in infants first fed with fruit, the authors suggest that complementary feeding should start with vegetables in order to promote vegetable acceptance in infants. However, reported daily intake of vegetables was similar for both groups at 23 months of age.[46]

Role of repeated exposures

The repetition of exposures to a food is one of the primary determinants of its acceptance. Several studies have shown that a food is consumed more and is judged by an adult (generally the mother) as more liked by the infant after several offers. The first study related to the effect of exposures in infants at the beginning of complementary feeding clearly demonstrated an increase in acceptance of a new green vegetable after 10 exposures to this food.[47] A further study also showed a similar exposure effect: after 8 exposures to a new fruit or vegetable intake increased.[48] The effect of repeated exposures was potent enough to increase the acceptance of foods which had been previously identified by the mother as being refused by her infant during the beginning of the complementary feeding process, which were most often green vegetables, but also pumpkin.[49] The repeated exposure effect is so consistent and powerful that it has become the "gold standard" against which any mechanism is studied.

However, despite the efficacy of repeated exposures to complementary foods to increase their acceptance, foods are most often only presented a limited number of times (in a majority of cases less than 5 times) before the parent(s) decide that the infant dislikes this food, as revealed by surveys conducted in different countries across the world.[50,51]

Repeated exposures may act through several mechanisms. Exposing an infant to an unknown food may generate fear, which is reduced by the safe ingestion of the food. This is called learned safety. Simply being exposed to a stimulus may enhance is acceptance through familiarisation.[52] Moreover, repeated ingestions may provide the infant with the opportunity to associate the taste of the food to its energy content; an associative conditioning phenomenon known as flavor-nutrient learning.[53] Associative conditioning may also help to increase the acceptance of a food with a new flavor, when it is associated with a liked flavor. This is described as flavor-flavor learning. In infants at the start of the complementary feeding period, it was shown that repeated exposures was as effective as associating a new vegetable with a liked flavor (the sweet taste) to increase its intake[54,55]; whereas associating it with a higher energy content (by adding oil) did not increase its intake, probably through learned satiation.[55] This suggests that the repeated exposure mechanism is as effective as and simpler to implement than flavor-flavor learning and more effective than flavor-nutrient learning for increasing vegetable acceptance at complementary feeding.

Role of the variety of foods offered

As described previously, repeated offerings of a given food may enhance its acceptance. Moreover, repeated offerings of a variety of foods may also promote the acceptance of an unknown food. Infants aged ~6 months were shown to better accept carrot, a new food, either if they had been repeatedly exposed to carrot (repeated exposure effect) or to a variety of foods differing from one day to the next, but not if they had been repeatedly exposed to potato.[56] Moreover, infants in the variety group better accepted chicken than children in the two other groups. Further studies showed that this "exposure to food variety" effect might enhance the acceptance of a less liked food than carrot, such as green bean, only if the exposure to variety is higher than the variety necessary to increase acceptance of carrot.[57] Green bean acceptance increased only if in the variety condition, pairs of different foods were presented over several days, not if different foods were presented over several days.[57] This suggests that exposure to variety might be interpreted at the day level or at the meal level. A practical consequence of this observation is that introducing more than one food per eating occasion might be a way to enhance exposure to variety, and therefore acceptance of new foods.

The role of timing of exposure to variety at around the beginning of complementary feeding was further explored. A study revealed that offering three different foods three times by alternating foods from one day to the next resulted in a higher acceptance of new foods than offering each of the three different foods for a period of three days.[20] This effect was observed for several new foods (zucchini-tomato, peas, meat and fish). Furthermore, a recent study suggested that the efficiency of the exposure to variety effect may depend on the age of the infant at the beginning of complementary feeding.[58] This study showed that among children introduced to complementary foods after 5.5 months, the acceptance of a new food, pea, was higher in infants previously exposed to a variety of tastes than in infants previously exposed to a single taste (but there was not difference between exposure groups when infants were weaned before 5.5

months). Altogether, these findings suggest that exposure to variety is a robust mechanism favouring the acceptance of new foods.

A randomized controlled trial named 'TASTE' was conducted in UK, Greece and Portugal to specifically investigate whether exposure to a wide variety of vegetables early in the complementary feeding process would prevent the observed decline in liking and intake at a later age.[59] Parents of 4-6 month old infants were recruited and randomized to receive shortly before the start of complementary feeding either (i) guidance on introducing a variety of culturally appropriate vegetables as first complementary foods or (ii) usual care. Infants in the intervention groups showed increased consumption and liking of an unfamiliar vegetable in the short term, but only in countries where single vegetables are not already amongst the common first foods offered to infants (UK and Greece). Beneficial effects of the intervention were not maintained at the 6 or 9 months follow-up, although results from the Greek sample suggest that there may be a positive effect of the intervention on vegetable variety and general vegetable acceptance.

Impact of the sensory properties of foods on their acceptance

The sensory properties of foods are important determinants of their initial acceptance by infants. In particular, texture, taste and aromatic properties play an important role in modulating their initial acceptance.

Due to the limited oral skills of the infant, texture is one of the food properties that requires the most adaptation to enable the infant to 'process' and swallow the food.[60] A significant proportion of infants (23%) have difficulties with foods containing pieces.[61] However, these difficulties should not be interpreted by parents as a reason to delay the introduction to solid foods. Delayed introduction is indeed associated with further problems of texture acceptance, in the extreme as observed in infants who have received tube feeding.[37] In healthy infants, offering new and varied textures before or at 9 months is associated with less food refusals and a better acceptance of complementary feeding foods later on.[62] The best predictor of acceptance of chopped carrots in 12-month-old infants was shown to be the infant's previous experience with carrots presented under a variety of textures.[63] Introduction to lumpy foods before the age of 6 months was associated with fewer food refusals at the age of 7 years, and a higher consumption of a number of fruits and vegetables.[64] The observation of the absence of the transfer of the effect of exposure between an industrially-processed baby food and a home-made food might be related to the texture differences related to each type of food.[48]

Taste may also impact acceptance of new foods at the beginning of complementary feeding. By analysing foods offered to infants aged 5-7 months, it was shown that reactions to new vegetables were more positive if the vegetable was salted or contained a salty ingredient.[65]

The contribution of flavor as a whole to the initial acceptance of vegetables can be interpreted by comparing the effect of exposure to a variety of vegetables on the acceptance of carrot[56] or of green beans.[57] Acceptance of green bean appears more difficult to promote than that of carrot, no doubt in part due to the difference in tastes of the two vegetables with one being sweeter than the other. In some repeated exposure studies, different vegetables were used: it showed for instance that the acceptance of green beans is easier to enhance through repeated exposure than the acceptance of artichoke.[45]

Individual differences in new food acceptance

The effects of the factors or mechanisms previously described are those observed for a majority of children, on the basis of mean observations. However, infants (or children) who are less enthusiastic eaters may need more exposures to accept a novel vegetable.[66] The eating temperament of infants or children may be characterised with the baby eating behaviour[67] and the child eating behaviour questionnaire[68], respectively. The general temperament of the infant may also be related to how much a new food is accepted; as was revealed by a recent study showing that the infants rated low in the "approach" dimension were less accepting a novel food compared to infants rated high in approach.[69]

Individual differences in reactivity to tastes may explain differential acceptance of new foods at the beginning of complementary feeding .[65] This work revealed in particular that at the age of 6 months, infants who accepted more easily the sour, umami and sweet tastes in water solutions also displayed more positive reactions toward sour-, umami- and sweet-tasting complementary foods, respectively. In a similar fashion, individual differences in reactivity to food odours were shown to explain differences in reactions towards new foods.[70] At the age of 12 months, the more toddlers liked the odour of trimethylamine (fish odour), the more they were reported by their parents to like fish, and the more they liked the odour of dimethyl disulphide (sulphurous odour of some cheeses and of some vegetables), the more they were reported to like cheese with a sulphurous flavour note and the more they tend to like vegetables with a sulphurous flavour note.

Pre-school children

A period of development of eating difficulties

As mentioned previously, the beginning of complementary feeding seems a favourable period for the introduction to a large diversity of foods. However, as children grow older, they may become more and more difficult to feed. Different behaviors related to children's eating difficulties have been distinguished. The first one, generally described as food fussiness, refers to two constructs which are distinct but linked: "food neophobia" and "pickiness".[71,72] Food neophobia corresponds to the reluctance to eat or the avoidance of new foods[73] while pickiness is the rejection of a substantial number of familiar foods. Another dimension related to children's eating difficulties has been described as a "low drive-to-eat'', corresponding to two distinct but correlated constructs, "low appetite "and "low enjoyment of food".[72]

Food neophobia rises rapidly around the age of 2 years.[74-76] This behavior is described as an evolutionary advantage, avoiding toddlers to ingest harmful substances at a stage where they become autonomous. Thus, food neophobia is considered as a normal stage in child's development. However, the development of neophobia might not be specific to food and also corresponds to the 'refusal' phase when the child's own personality develops, partly by standing against adults' attitude. This could explain why, during this stage, most children become also "picky eaters", refusing foods they previously consumed.

It has been observed with a sample of 332 children aged 4 to 38 months, that food fussiness and satiety responsiveness - a dimension close to the appetite dimension since four items used to measure this

individual characteristic refer to the development of satiety over the course of the meal[68] - were positively correlated with age.[66] On the contrary, but to a lesser extent enjoyment of food was negatively correlated with age.[66] In the Longitudinal Study of Child Development in Québec, the proportion of children reported by their mother as being picky eaters remained quite stable from 2.5 to 4.5 years.[77] In another longitudinal study following children's eating behaviors from 3 to 7 years[78], the percentage of picky eaters was 40% at baseline, increased up to 49% at 5 years and then decreased to 30% at 7 years. Moreover, the children were reported to try more unfamiliar foods at 7 years than at 3 years of age. However, food neophobia levels off clearly after the age of 8-9 years.[10,79]

In conclusion, pre-school age is the period of life where food fussiness peaks for most children.

Links between food fussiness, and eating behavior, quality of the diet, or weight status

In experiments conducted with 4 to 38 month-old children, a multiple linear regression revealed that the intake of a novel vegetable, artichoke purée, was predicted by age and satiety responsiveness: the younger and the children with lower satiety responsiveness score had the higher intake of the artichoke purée when offered for the first time.[66] The other individual characteristics, i.e. total breastfeeding duration, age at the introduction to solid foods, BMI z-score, food fussiness and food responsiveness did not significantly impact first intake of artichoke purée. The absence of effect of food fussiness could be due to the fact that fussiness was positively related to age.[66] Correlations of intake of a familiar vegetable by 2-6 year-old children with different child characteristics revealed negative significant links with food fussiness and food neophobia.[80]

The food neophobia and pickiness phase is associated with consequences on children's food choice. The variety of free food choices decreases between 2 and 3 years old.[26] The diversity of intake lowers between 2 and 5 years old[81] and picky children have a less varied diet. [82,83] Between 2 and 9 years old, neophobic children eat less fruit and especially less vegetables.[71,84-86]

In Generation XXI, ALSPAC and EDEN cohorts, children with eating difficulties (poor eating, food refusal, unable to get into a routine), as described by their parents at 2 years, were likely to have lower fruit and vegetable intake, as well as a lower variety score at 3-5 years than those with no difficulty. This suggests that the presence of eating difficulties could be an early indicator of a worse dietary profile later in life.[87] The Longitudinal Study of Child Development in Québec also revealed that picky eaters were twice more likely to be underweight at 4.5 years than children who had never been picky eaters.[77]

In conclusion, child's eating difficulties and, in particular food fussiness, is likely to impact the quality of the diet at least during the pre-school years. A better understanding of the determinants of food fussiness, and on the way parents respond to their child's eating difficulties is important in order to design effective interventions to improve diets of children with eating difficulties.[88]

Children's characteristics related to eating difficulties

A study conducted with twins aged 8-11 years in the UK showed that three quarters of the variation in reported food neophobia was accounted for by heritability.[89] The remaining quarter was explained by

non-shared environmental factors; this means that twins were more different from what would be expected by their shared genes. A recent longitudinal twin study reported the contribution of genetic and environmental factors to variations in different eating behaviors when children were 2.5 and 9 years old.[90] In 9-year-old children, 85% of variation in fussiness was accounted for by heritability, while in 2.5 year-old children, the shared environment contributed to 70% of variation in fussiness. Genetic predispositions explained about 88% of the variations in scores for questions related to appetite in 2.5 year-old children but only 55% in 9-year-old children (the remaining 45% being accounted for by non-shared environmental factors). Thus, despite the importance of heritability, environmental factors are likely to play an important role on eating behavior during childhood. However, this importance may differ according to age and the considered eating behavior. The influence of familial environment on fussiness could be important in early childhood and, when children get older, appetite-related behaviors become more sensitive to environmental influences outside the home.

Sensory characteristics of the foods are key factors driving food liking and consequently food consumption in young children. The taste of foods in particular is likely to influence their acceptance by children. Children reject bitter taste. As bitter taste intensity is above the 3rd quartile for many vegetables amongst 590 different foods/dishes[91], this could explain the low level of acceptance of vegetables by young children. One can suppose that the more children are sensitive to bitterness, the lower their liking for vegetables. Phenotypic differences in sensitivity to two bitter-tasting compounds; phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP), have been related to genetic differences in the TAS2R38 gene. PROP has been used to categorise individuals according to their sensitivity to bitterness into tasters and non-tasters. PTC and PROP do not occur in foods but contain the N-C=S moiety as isothiocyanates which occur in Brassica vegetables, such as broccoli and Brussel sprouts. Several studies have been conducted to investigate the link between sensitivity to PTC or PROP and the liking or consumption of bitter vegetables. Some studies found, as expected, that non-tasters gave a higher liking score for some bitter vegetables, but such an effect was not found systematically for all bitter vegetables even within the same study (e.g.,[92]). These discrepancies could be due to the difference in the bitterness intensity of the vegetables used in the tasting sessions, and to the previous experience of the children with some of the tasted vegetables. Other children's characteristics could interfere with taste sensitivity to drive liking as suggested by one recent study[93] which investigated the link between sensitivity to PROP and food neophobia on intake of fruit and vegetables in a large sample (n=323) of 4-6 year-old Japanese children. High neophobic boys had a lower intake of vegetable (controlled for total energy intake) whatever their PROP status. No effect of neophobia or PROP status was observed in the girls. Although several potential confounders, including parental control index, were taken into account in the data analysis, an effect of other unmeasured factors cannot be excluded for explaining the difference observed between boys and girls. As previous studies did not report separate analyses for boys and girls, it is difficult to conclude if this result is specific to this study.

It is also clear that food liking results not only from genetically-determined taste sensitivity but also from environmental components. Burd et al.[94] found, as expected, that non-taster children had a greater vegetable acceptance than tasters if they live in healthy food environments but no effect of PROP sensitivity was found for children living in non-healthy food environments. A recent study on a large group of Irish children concluded that the only significant predictors of vegetable liking were socio-economic status and gender; liking being higher in the low socio-economic status which was

unexpected.[95]

Even if the question of innate likes and dislikes for odours is not fully resolved, it appears that hedonic answers towards odorants are in agreement with those from adults at least from 8 months of age.[70] Thus, one can wonder the importance of the olfactory signals in food dislike. However, there is a very limited number of studies aiming at answering this question, probably due to the huge number of possible odorants to be tested, and also to the difficulty to conduct measurements of olfactory sensitivity in young children. The only study conducted with children did not show a significant association between sensitivity to trimethylamine, a compound responsible for fishy odour, and liking and consumption of fish.[96]

In a recent study some relationships were found between hedonic responses to two unpleasant odors and food liking at the age of 12 months.[70] The more toddlers liked the odor of trimethylamine, the more they were reported by their parents to like fish, and the more the liked the odor of dimethyl disulphide, the more they were reported to like cheese with a sulphurous flavor note and the more they tend to like vegetables with a sulphurous flavor note. However, these relationships were not further observed at 22 months of age, and only one tendency was observed: the more children liked the odor of 2-iso-butyl-3-methoxypyrazine, the more they tend to like vegetables bearing such a green flavor note, i.e. green pepper, green bean, green salad and green peas. In a study where taste and olfactory sensitivities were not measured experimentally but reported by the parents thanks to a questionnaire, a higher 'taste/smell sensitivity' was found to be associated with lower fruit and vegetable consumption, lower variety of liked fruit and vegetable, and higher food neophobia in 2-5 year-old children.[97] However, it must be noted that such a questionnaire could not allow an evaluation of the 'true' sensitivity but only gives an indication of avoidance of different types of stimulations.

Foods, and in particular vegetables, present not only a diversity of flavours but also a diversity of textural characteristics. Szczesniak reported children's likes and dislikes for different textures and underlined the parallelism between these likes/dislikes and the development of oral function. It is clear that "children reject textures which are difficult to manipulate in the mouth". Children disliked also the contrast of texture within a food such as pulp in a fruit juice or seeds in a jam, certainly because contrasting textures are less easy to manipulate. The oral development is of course function of the child age but would also depend on previous experience with different textures. A higher tactile sensitivity was associated with lower fruit and vegetable consumption and higher food neophobia.[97]

Possible strategies for increasing vegetable acceptance

A number of experiments have been conducted in order to test the effectiveness of different learning strategies or to test the impact of a modification of the sensory characteristics of the foods on vegetable accpetance. The text below is not a systematic literature review but will provide some insights into the main different strategies that have been tested in order to increase liking or intake of novel or familiar non-well liked vegetables.

Learning by experience

Despite the high food neophobia characterising the pre-school age period, it remains possible to induce preference for a novel food with repeated exposures during this period. In children aged 2-5½ years, a visual exposure is not sufficient to increase gustatory preference.[98] In an experiment conducted in UK nurseries with children aged between 9 and 38 months, it was found that intake of a novel vegetable, artichoke, increased to the same extent after repeated exposure than after an association of artichoke with sweet taste (flavor-flavor learning) or with energy (flavor-nutrient learning).[99] Moreover, 5 exposures were sufficient to significantly increase intake. In a similar experiment conducted in Danish nurseries with children aged 2-3 years the sweet artichoke purée seems to be preferred as eaten in a greater quantity than the plain version.[100] Nevertheless, repeated exposure was as effective as flavor-flavor learning. Moreover, intake of purée was unchanged in the flavor–nutrient condition. With French toddlers aged 2-3 years, repeated exposure to a new vegetable, salsify, with a pinch of salt (0.2% w/w NaCl) led to a higher increase in intake of this vegetable than flavor-flavor learning with a higher salt content (0.5% w/w NaCl) or with nutmeg.[101] In children aged 5-7 years, eight exposures to red pepper led to an increase in liking and intake; but an increase in intake, not in liking, was observed after only one exposure.[102] This suggests that the affective reaction (liking) would be more difficult to modify than the behavioral reaction (intake). In a recent study with toddlers aged 1.5 to 4 years a significant increase in intake was observed after 7 exposures to vegetable crisps being offered with a liked dip (flavour-flavour learning) or with a neutral dip (simple repeated strategy). This reveals an effect of repeated exposure which was moreover quite persistent as still observed 6 months after the intervention.[103] Another study conducted with toddlers (21-46 months) showed a significant increase in intake and liking after 7 exposures to two novel vegetable soups, whatever the soup was paired or not with a high level of energy during the intervention period. This effect was still observed six months after the intervention. However, a significant increase in liking was observed only for the soup paired with a high energy level. This seems to indicate that flavor-nutrient learning has no superiority for increasing intake but would be more effective for increasing the affective response.[104]

If repeated exposure seems effective for increasing acceptance of a novel vegetable, one can wonder if it is also effective for increasing acceptance of a familiar neutral or disliked vegetable. In a study where parents of 34-82 month-old children were asked to offer their child a taste of a target disliked vegetable daily for 14 days while being encouraging but not using reward, a significant increase of liking and intake was observed. Nevertheless, the increase in intake was really small (from 4 to 9 g) and 14 out of 48 parents failed to complete more than nine tasting sessions and many more expressed the opinion that 2 weeks was too long.[105] These results confirm previous data reporting that most parents did not persist sufficiently in offering a disliked food.[50,51] A recent study failed to demonstrate an increase in carrot intake with 4-6 year-old Dutch children who received, ten times over five weeks, carrot during their morning snack break. It is possible that a two frequent presentation of a familiar not well liked vegetable induces boredom and thus has a negative effect counteracting the positive effect of repeated exposure.

A recent study with 3-5 year-old children showed that associative conditioning (combined effect of flavor-flavor and flavor-nutrient learning) was more effective than repeated exposure in increasing liking for a novel bitter vegetable - Brussels sprouts - whereas repeated exposure alone was effective for a more

familiar non-bitter vegetable – cauliflower.[106] A flavor-flavor conditioning with sucrose added in grapefruit juice induced an increase of liking for the unsweetened juice in 2- to 5-year children who, initially rated it as neutral or not liked.[107] However, this strategy was not compared with repeated exposure. With children of about 5 years of age, associating dextrose to a mashed vegetable during six trials across 2 consecutive days increased preference for the unsweetened version.[108] Similar six trials with an unsweetened vegetable did not lead to an increased preference. Taking several times per day a sip could not be sufficient for observing a repeated exposure effect.

Overall, it seems that repeated exposure is an effective strategy to increase intake of a novel vegetable. The effectiveness of this mechanism is less conclusive for previously known and not liked vegetables. For bitter vegetables pairing them with a liked and/or energy-dense ingredient could be a good strategy to increase the liking of their flavor in particular for children with a high sensitivity to bitterness.[109]

Learning with reward

As nicely written by Birch et Marlin[110] "eating is a social occasion and early exposure to food does not occur in a vacuum"; parents used different practices and strategies to make them child eating a novel or a disliked food. In a survey conducted in the Netherlands with 259 children between 4 and 12 years and their parents, it was found that the impact of the eating context was more negative for vegetable than for fruit. If this negative context could be the result of the higher children's dislike for vegetables than for fruit, is seems very plausible that a negative context makes the situation worse. On the contrary, it is interesting to examine the impact of *a priori* more positive contexts.

One strategy often used by the parents is to praise their children or to offer them a reward to encourage them to eat a refused food. Such a strategy is referred as a contingent strategy since the access to a reward (e.g. watching T.V.) is contingent upon consumption of the refused food. In an experiment conducted by Birch et al.[111], two types of reward were used: a verbal praise and a tangible reward (a ticket giving access to a movie). Results showed a significant decrease in preference for the target novel juice whatever the experimental condition. However, some recent studies indicate that encouraging children by offering them a small non-food reward could be an effective strategy. Parents in the treatment groups were asked to offer 12 daily tastes of the target vegetable giving either praise or a tangible reward (i.e. a sticker). Parents of a control group were not asked to offer any tasting of the target vegetable. Children who received tangible rewards during exposure increased their intake and liking of the target vegetable significantly more than did children in the control group, and the effect was still observed 3 months after the intervention. Increases in intake and liking in the social reward group were not significantly different from the control group.[112] The same strategy, i.e. giving a small non-food tangible reward (a sticker) if the child complied, was tested in an experiment in which instructions to parents were mailed; thus, there was no direct contact with researchers or professionals for the implementation of the procedure. Over the intervention period intake and liking of the target vegetable increased significantly more in the intervention group than in a control group.[113]

Learning by observation: modelling

As we eat in presence of others, learning by modelling could be a way to learn to eat some foods that are

novel and/or not initially liked. Different studies have found a positive effect of modelling. An increase in preference for an initially neutral or disliked food was observed when children ate in a presence of a peer who had a high preference for this target food.[114] Moreover, initial preference of younger children (aged 3 years and 4 months) was more affected by peer modelling than of older children (4 years and 5 months). However, the effectiveness of trained peer models to encourage food acceptance of novel fruits did not last when the model was not present anymore.[115] Harper and Sanders[116] observed that more children tasted two novel foods when adults were eating also the target food than when adults simply offered the food. Children were more willing to taste the food if the adult was their mother than a visitor. A better acceptance of a novel food was found with enthusiastic teacher modelling but not with a silent teacher modelling.[117] According to these authors, it seems important that the model displays a real enthusiasm. This would mean that parents could play a modelling role if they really like the target food they want to be eaten by their child.

Freedom of choice

Offering children a choice between several vegetables could be an effective way for increasing intake. However, even if 4 to 6 year-old Dutch children appreciated being able to choose between two vegetables the vegetable they would eat for their dinner, their vegetable liking and intake did not increase in this condition.[118] A similar study conducted in Spain demonstrated that a choice between two vegetables either before or during a lunch was associated with higher vegetable intake, in comparison to a no-choice control condition [119]. It was hypothesized that offering choice would increase the sense of personal control and consequently would increase the level of intrinsic motivation for eating vegetable.

Increasing acceptance by modifying the sensory properties

The way used to prepare foods can affect flavor and texture and thus can modify immediate acceptance. However, due to methodological difficulties to conduct hedonic measurements with very young children, there was a very limited number of studies aiming at studying the impact of sensory modifications on liking. Nevertheless, there was some studies reporting the effect of sensory modifications on intake.
Sweetness is an important sensory parameter for food preference in children, Using pair preference tests, it was found that children aged 4-5 years were significantly more likely to prefer apple juices with added sugar.[25] In another study[120], it was found that the 5-year-old children's preference for sugar concentration in orangeade was affected by the fact that children were highly or little restricted for consuming mono- and disaccharides. Indeed, 55% of the children who were highly restricted preferred the beverage with the highest concentration versus only 33% of those little restricted. On the contrary, none of the highly restricted children preferred the orangeade with the lowest concentration of sucrose whereas 19% of the little restricted children preferred it. The generally higher preference for the highest concentration could be due to the methodology used based on comparison but would not necessarily mean that the lowest concentrations are not well accepted. Indeed, the added sugar content did not affect intake of a fruit purée in 2- to 3-year-old children.[121] Thus, it seems that an unsweetened fruit purée could be sweet enough for children to consume it due to the natural sweet taste of fruits. On the contrary, the absence of sweet taste, or the higher sourness and dryness of an unsweetened cream cheese could explain why it was less consumed by 2- to 3-year-old children compared to sweetened variants.[122] However, the three sweetened variants (5, 10 and 15% added sucrose) were consumed in a same amount revealing that a sugar content

maximizing liking without affecting intake, may exist between the 0% and the 5% added sucrose level and that the current observed level of added sugar in commercial dairy products (observed higher value in French products of about 14 %) could be lowered without reducing children's food intake.

Saltiness can impact food acceptance in young children. A majority of 3-6-year-old children preferred the highest salted soup to either the unsalted or even the moderately salted versions.[123] When they were told to consume as much as they want of 3 variants of soups during a 30 sec. period, they consumed in a greater quantity the two salted versions (0.17M and 0.34M NaCl) than the plain version with no added salt. Another study conducted with 24-month-old children with the same procedure and the same levels of NaCl did not reveal any significant difference in intake of soups whatever the NaCl content. However, these children consumed salted carrots in greater amount than plain carrots when during a 5-minute test, they were free to eat as many pieces of each variant of carrots.[124] In another study conducted with 2- to 3-year children aiming at comparing the intake of two foods, i.e. green beans and pasta, presented either with no added salt, with the usual amount (0.6% NaCl) or a higher amount than usual (1.2% NaCl), it was found that the suppression of salt induced a decrease of intake for green beans but not for pasta, whereas a higher salt content induced an increase of intake for pasta but not for green beans.[121] These results suggest that salt suppression in vegetables could be detrimental for vegetable consumption. A pinch of salt (possibly a lower content than 0.6% NaCl) could be helpful for increasing acceptance of vegetables, in particular of bitter vegetables as perceived bitterness can be lowered by salt addition.[125]

The impact of fat level has been mostly studied in the objective to evaluate if reducing fat content could be a possible strategy for moderating children's energy intake. A higher energy density obtained by adding butter did not affect intake of a macaroni and cheese entrée served at a dinner meal to 5- to 6-year-old children, but consequently total meal energy intake was 18% higher when the more energy dense variant was served in comparison to the low energy dense variant.[126] Similarly, weight-based food intake did not differ between high-fat and low-fat versions of familiar foods, i.e. macaroni and cheese, pudding, chocolate milk and regular milk, served to 4–6-year-old children in a meal.[127] In this experiment, liking ratings were collected but did not differ according to the fat content. In a study with younger children (2- to 3-year-old) it was observed that weight-based intake of green beans and pasta did not differ whatever the fat content, i.e. with 0, 2.5 or 5% added butter.[121] All these studies seem to indicate that adding fat to a food does not seem to increase its acceptance.

In conclusion, based on theoretical grounds, it seems that different strategies could be effective to promote vegetable consumption but their effectiveness was not always proven and thus children are probably sensitive to other non-controlled factors. In a familial context, parents use generally different practices and strategies and only observational studies allow determining the positive or negative relationships with children's eating difficulties. In a survey conducted with 502 French mothers with a child aged 20-36 months, it was found that the factors associated positively with children's eating difficulties were on the one hand permissive style and practices to fulfil child's desires, and on the other hand authoritarian style, contingent and coercive practices aimed at forcing children to taste rejected foods. In contrast, the more the mothers' motivations when buying foods for their child was focused on the quality of the food, the less their child was difficult to feed.[72]

All results listed in this chapter may lead to practical recommendations that may lead to a higher

acceptance of vegetables in children. A EU-funded project was recently conducted which provided some of the results presented above. Among its dissemination activities, it created several free brochures summarizing some of the main findings presented in this chapter, in a suitable form for anyone interested in feeding young children, including parents (http://www.habeat.eu/).

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