

# Early Origins of Overeating: Early Habit Formation and Implications for Obesity in Later Life

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**Abstract** Excessive eating is a major determinant of the present obesity epidemic. Early infancy is a critical period in food preference formation and habits established in this period track into adulthood. This behavior is learned through repeated experiences with foods. Many mechanisms influence children's eating patterns and overall energy intake. In this review we focus on food preference formation, the food itself, and environmental factors related to the eating situation. We will highlight some of the many possible actions that are available to parents and practitioners to facilitate eating behavior supporting healthy diets in children. The plasticity of food preferences underlines the importance of parents' and caregivers' continuous efforts in helping children develop healthy eating patterns. It is never too late, but starting in early infancy holds many advantages.

**Keywords** Preference formation · Eating habits · Children · Sensitive periods · Food neophobia · Learning mechanisms · Exposure · Compensation · Energy intake · Portion size · Serving style · Variety · Energy density · Sensory specific satiety · Habituation · Obesity · Overeating

## Introduction

A surplus of energy intake leads to an increasing risk of overweight in infants, toddlers and preschool children [1], so food habits and eating behavior can be important causes for energy imbalance and weight gain. Intervention practises targeting specific aspects of children's eating behavior (such

as preference or intake) appear to be effective during childhood where the child forms its food acceptance patterns and is highly influenced by its environment. Several studies have shown the critical importance of the first years of life for this learning [e.g., 2].

Generally children's eating habits can be influenced by changing their food preferences (intervention/learning strategies), changing the food (e.g., make it more appealing or aligned with the children's preferences), and/or influencing the eating situation (e.g., peer influence, role modeling etc). These will all be dealt with in this review which will focus on establishment and tracking of food preferences, strategies to change food acceptance, energy balance and other factors promoting overeating in children.

## Innate Preferences

Human infants have predispositions for energy-rich foods and basic tastes, i.e., innate acceptance of sweet taste and rejection of bitter taste [3]. These predispositions probably evolved and served an adaptive function. They promoted the ingestion of edible substances as a source of nutrients (i.e., liking for sweet), but also served as a warning signal for potentially poisonous food items (i.e., dislike of bitter) [4]. Accordingly, these predispositions influence acceptance of foods with such taste properties [5, 6], including many dark green vegetables containing bitter compounds [7].

There appears to be very few inborn olfactory mechanisms [8] among them an aversive reaction to the smell of decay [9]. As Köster points out not having innate olfactory preferences – or preference restrictions – is advantageous for human omnivores, and permits humans to live in any food culture around the world. Following this suggestion, infants should learn to distinguish between edible and non-edible food items, from early on, in relation to their odor

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profile. There is evidence of prenatally acquired odor preferences through repeated experiences [e.g., 8, 10, 11] and some indication of flavor learning via mother's milk [11], although probably not specific for single flavor compounds [12]. Hence, children seem to be guided by their innate taste preferences and learn to accept a wide range of odorants as well as bitter tasting foods through experiences, starting early on.

### Critical Periods in Habit Formation

Infants and young children generally show high acceptance of novel foods until the age of 18 months to 2 years [13, 14], where a phase with low dietary variety [15] and many food refusals sets in. This phenomenon is called *food neophobia* meaning fear of novel foods [16]. Food neophobia emerges at the time when a child's cognitive development allows the formation of a "concept" of food [17]. The child comes to realize that novel foods are either safe or dangerous. The neophobic phase peaks around the age of 2-5 years [13] possibly from 2-3 years [14], and continues to decline throughout childhood [18]. Early infancy is therefore often characterized as a *sensitive period* where infants learn about foods and eating [13]. There is evidence of tracking of food preferences established in infancy into early adulthood [2]. However, a child's preferences will change across the entire childhood as a result of exposure, influence from peers and social/imitation learning.

### Influence of Taste Sensitivity on Food Acceptance

Young children tend to prefer more intense solutions of sweet [19], sour [20], and salty taste [21] than adults. They appear also to be guided by their taste sensitivity to a greater extent than adults [22]. Children's taste sensitivity accounts for some of the variation in their food preferences, in particular in relation to bitter taste sensitivity that seems to influence children's food choices and intake [23]. In studies with pre-school children using the bitter compound 6-*n*-propylthiouracil (PROP) to characterize the children's bitter taster status, highly sensitive children were observed to have lower acceptance of raw broccoli [24] and spinach [5] than less sensitive children. Both vegetables contain the bitter-tasting thiocyanate compound (N-C=S), which is also responsible for the bitter taste of PROP [7]. The compound is heat labile and differences in intake of broccoli and spinach are not present when serving the cooked vegetables. In one study serving broccoli with dip increased intake among bitter sensitive children, although all children had positive effects of repeated exposure to broccoli regardless of taster status [25]. Highly bitter-sensitive children thus tend to dislike and avoid bitter foods [23, 24], while at the

same time prefer [7] and consume more of sweet foods than less sensitive children [22].

### Establishment and Directed Changes in Food Preferences

#### Weaning Strategies and Food Acceptance

The transition from an exclusively milk-based diet to solid foods is a critical stage in the development of food behavior and also for the infant's growth [26] and long-term health [27]. The establishment of eating habits during *weaning* seems to be influenced by breastfeeding, weaning practices and repeated exposure. At this stage infants appear to accept most foods on a first encounter, however. In a sample of 74 French children 867 different weaning foods were introduced between the age of 5 and 7 months [6]. The majority of these foods were well accepted on a first exposure (88 %); particularly salty foods. Interestingly, bland foods with no salient taste were least well accepted (e.g., potatoes, unseasoned meat). Although infants display high acceptance of weaning foods differences exist depending on feeding history and food groups.

Breastfeeding seems to promote the immediate acceptance of weaning food [28, 29] regardless of exposure to the particular taste or flavor compound [12]. The positive effect of breastfeeding seems to diminish with repeated exposure and possibly introduction to a broader food repertoire. Formula-fed infants reach the same level of food acceptance after 8 to 10 exposures to the particular food [12, 30, 31]. Also breastfed infants learn to accept foods they dislike - typically characterized by bitter and sour taste or a disliked texture - after repeated exposures [28, 30].

Variety in the presentation of weaning foods appears also to have a general positive influence on infants' acceptance of novel foods. This effect was first studied in formula-fed infants divided into three study groups with a daily exposure to carrots, potatoes or peas/potatoes/squash alternatively for nine days [32]. Both carrot and variety groups increased intake of carrots post intervention, while the potato group did not. The variety group also consumed significantly more of a novel food (chicken) than the other groups. The frequency of change in exposure rather than number of exposure foods seem to drive this positive learning [29]. Offering three different foods alternately results in higher acceptance of novel foods over a period of two months than the strategy of giving the same three foods for three consecutive days at a time [29]. Presenting more than one food in a meal appears also to increase infants' acceptance of the exposure foods [33], although acceptance of each food item appears to be learned independently [31]. Dietary variety (with regards to flavor, texture and color) appears thus to be the key to successful acceptance of weaning foods.

## Strategies to Change Food Preferences in Young Children

As described above the *repetition of exposure* to a food is a primary determinant of its acceptance. This strategy has been successful in changing not only infants' (4–7 months) [28, 30], but also toddlers' [34, 35], and children's [36, 37] acceptance of novel foods. Foods with bitter taste profiles such as vegetables may require 5 to 10 exposures before a stable acceptance is achieved [e.g., 35, 37, 38], while one or two exposures can be sufficient for sweet foods [39]. Timing and duration of exposures may also influence this type of acceptance learning. Daily exposure or high frequency of exposures may result in boredom with the exposure food or test regime, expressed as decreased liking and consumption [40, 41]. The optimal frequency of exposures is not known at present [42], but several studies have successfully applied two to three weekly exposures in naturalistic settings with the aim of increasing acceptance of less liked foods [25, 35].

Associative conditioning strategies where modifications of the target food results in increased liking and intake of the exposure food have also been successfully applied in children. *Flavor-flavor* and *flavor-nutrient* learning are the two main learning strategies. The principle behind these types of learning is that repeated pairing of a neutral or disliked flavor with a liked flavor (flavor-flavor) or nutrient (flavor-nutrient) will result in a positive shift in liking of the initially neutral or disliked flavor [43]. Flavor-nutrient learning has been effective in changing 2–5 year-old children's flavor preferences by pairing unfamiliar drink flavors with carbohydrates [44] or flavored yoghurts with dietary fats [45]. This approach has not been successful with vegetables, however [35]. There is good indication of changing young children's acceptance of vegetables using flavor-flavor learning strategies that pairs the novel vegetable with sweet taste or a liked dip. Positive results have been obtained in 1–3 [35, 38], 3–6 [37, 46] and 8–10 year-old children [unpublished data in 43]. In one study with 11–13 year-old children pairing vegetables with peanut butter increased consumption of vegetables as well as variety of eaten vegetables over a 4 month period, while children exposed repeatedly to the vegetables alone decreased consumption [47]. The study was part of a larger weight-loss study, but possible long-term effects of the increased vegetable consumption remain to be determined, as adding peanut butter will inevitable add substantial calories and may thus counteract or challenge weight loss.

Few studies have investigated the relative effectiveness of different learning strategies in children. Tangible rewards linked with repeated taste exposure appear to be an effective strategy for increasing liking and intake of disliked vegetables in pre-schools/schools [48] and homes [49]. Sometimes exposure alone can be more effective in changing children's

liking and intake of an exposure food [50]. When directly compared, repeated exposure appears to be the most effective at increasing children's acceptance of a novel food [35, 38], and the simplicity of this strategy is a clear advantage [50]. However, offering a familiar liked flavor with the novel food may promote tasting in children with high neophobia, and is also an effective way of changing children's acceptance of novel foods.

## Changing the Food

Foods can be changed in many different ways, most notably by directly manipulating the composition of foods, or changing their serving style. Food composition is typically altered either in accordance with metabolic needs by increasing or decreasing energy density [e.g., 51, 52], or to make it more palatable by, e.g., adding sugar, ketchup or other well-liked flavors [53, 54]. Simply mixing or serving a target food with more liked foods may also be an option by means of conditioning as discussed above [40, 55].

Serving style has not received much attention in the literature, although the visual appearance of food is important for determining our interest in it [56]. This is particularly expressed in children, who pay more attention to various visual inputs as drivers of liking than adults do – such as appearance, color and amount [57]. Such factors can influence our perception of foods [56], as well as amounts of consumption [58], but few studies have addressed children's specific preferences: In comparison to adults, children preferred more diverse arrangements of food on their plates, and they liked having a variety of foods and colors displayed [59]. Children also expressed distinct preferences for certain shapes (stars) of snack vegetables [60], and smaller sized snacks were more liked than their larger counterparts – also over repeated exposures [61]. These findings indicate that children's serving style preferences differ from those of adults and should receive more attention. Additionally, adult studies suggest plate color, plate shape as well as plate and cutlery material etc. as other potential determinants [62]. As special eating equipment is often used for children, more systematic research of this area is welcomed.

## Energy Balance

Most healthy children are remarkably good at balancing energy intake and energy expenditure. This is very fortunate as imbalances down to just 100 kJ/day (equivalent to just 2 % of the total daily energy flux) can eventually lead to obesity [63]. Actually, 2–5 year old children's daily energy intake is rather stable (10.4 % variation), although the intake

at individual meals varies considerably (33.6 %), because intake between successive meals are interdependent [64].

### Energy Density

To some extent, children consume fixed amounts of food based on weight – regardless of energy density or portion size [65, 66]. The energy density, and thus energy loads vary enormously between different types of food. As many children in Western countries are at risk of becoming overweight, reducing the energy density of foods might be a way of lowering the total energy intake. Leahy and coworkers [66] have shown how reducing energy density is associated with reduced energy intake both within meals and over successive meals. Results from cross-sectional data on children have suggested positive associations between energy density and total energy intake [67]. However, long-term effects are unclear. Results range from no effects [68] to positive associations between energy density and adiposity [69].

### Compensation

Under many circumstances, children do express some degree of *compensation ability*; i.e., consume more or less of a given food depending on the total energy intake and previous preloads. This ability to compensate has been demonstrated in both natural surroundings [70], and in the laboratory [71].

Age seems to be an important determinant for one's ability to compensate. Generally, children are much better at compensating than adults, who compensate very inaccurately [72]. As children grow older, their ability to compensate seems to diminish [73] – possibly as they transition from unlearned internal cues to becoming influenced by external cues and learning [74].

Even among children, age is a factor; young children compensate more accurately and are also sensitive to the macronutrient content of preloads compared to slightly older peers [74]. In another study, 2-5 year-old children compensated for energy, but the compensation was not nutrient-specific. Importantly, however, most children do not compensate completely, rather they *adjust* [73, 75].

Compensation ability is subject to large individual variation [71]. Results from 5-12 year-old children [76] suggest that ability to compensate is influenced by weight status, with overweight children being less likely to compensate than their leaner counterparts. The mechanisms are not known, but genetic interactions may play a role [77]. Finally, it should be noted that in adults compensation is more easily achieved for missing energy, in contrast to added energy [72] – the same may be the case for children.

### Portion Size

*Portion size*, i.e., the amount of served food, has been identified as the most powerful determinant of amount consumed at meals in 4-6 year-olds [78]. Increasing portion size increases children's intake [79], although this may also depend upon the attractiveness of what is being served [80], how much the portion size is increased [81], and age of the child; younger children are least influenced by portion sizes [82].

Altogether, in order to lower risk of weight gain and obesity care should be taken regarding both the energy density in food, which for many recipes can easily be lowered (e.g., by integrating water, air, or vegetables), and the portion size, which should not be too large. This is important for children of all ages, but particularly as children grow older and their ability to compensate diminishes.

### Factors Promoting Overeating in Children

Overeating can come about as a result of many causes. Genetic and biological factors are hard to modify and will not be discussed here. In the following we will provide examples of dietary factors, i.e., determinants related to the foods, and of behavioral and environmental factors which can promote overeating.

### Consumption Patterns

In a recent investigation of food consumption patterns of infants and toddlers [83•] it was found that high-caloric dessert foods were eaten by almost 20 % of the 6-9 month old infants. The percentage of children eating these foods increased with age and by 15 months of age 67 % of toddlers consumed desserts, sweets or sweetened beverages on the survey day. Studies of effects of intake of sugar sweetened beverages have found positive correlations with risk of overweight and obesity in toddlers and preschool age children [84]. Since children who have a high consumption of fruit and vegetables consume less total energy [66] actions to facilitate an increase in the consumption of fruit and vegetables are desirable. Unfortunately the feeding infants and toddlers studies conducted in the US have found that about one third of infants and toddlers did not consume any vegetable on a given day, whereas one third of toddlers aged 1-2 years ate snacks or meals at a fast-food restaurant on a given study day [85].

Based on these data there seems to be ample opportunity for significant reductions in intake of sweetened beverages and other high energy density foods to lower the risk of excess energy intake and obesity development.

## The Influence of Food Variety

Variety within a meal is known to increase intake [86]. A possible explanation is *sensory specific satiety (SSS)*, which can be described as satiation that is specific to the food just eaten, but not necessarily to other foods that have not been eaten [87]. SSS is expressed in both children and adults [88], but children tend to be more product specific [89], while SSS in adults may generalize to non-eaten foods sharing sensory characteristics with the eaten food [86]. This could mean that children can eat several different types of foods consecutively even if they share sensory characteristics with each other.

A different effect than SSS but with the same end result is referred to as habituation. *Habituation* means that a physiological or behavioral response decreases after many presentations of the same stimulus and increases when the organism is presented with a new stimulus. Epstein and colleagues have argued that habituation processes are related to food intake, such that rapid habituation to a food means that less of it will be consumed. They found that overweight 8-12 year-old children habituate slower to food than non-overweight children, and that dietary variety impaired habituation in children. A recent paper [90] provided data suggesting that slow rates of habituation predicted greater weight gains over 12 months in lean children. Whether similar effects would be found for younger children is unknown.

Altogether these results suggest that there are two effects of variety to balance: If one wants to limit intake of food, variety should be minimized. However, one should still ensure that variety is kept high enough to ensure that children are exposed to a wide variety of different healthy foods. For instance, this could be done by providing variety between meals rather than within meals.

## Peers and Role Models

Social influences are very important for shaping food preferences, particularly in infants and children, where eating is usually a social event [34]. Children are influenced by preferences and eating behavior of fellow eaters, such as peers, siblings, role models, teachers, parents, or other adults [91]. This is termed *social facilitation* [92]. As an example, it was found that when grouping 3-5 year-old children according to their preferences for vegetables, a target child seated with other children, who all liked a particular vegetable more than him/herself, increased preference for this specific vegetable [93]. Peer influence is sensitive to age, and a target child is more easily influenced, if younger than his/her peers [93]. Children's mutual relationship also plays a role [94].

It should be emphasized that social influences can facilitate increased intake of healthy as well as unhealthy foods.

It is therefore important that parents are encouraged to eat healthy foods together with their children at regular meals.

## Television

Children spend a substantial amount of time watching television, and this behavior is associated with obesity [95]. Watching television is typically an inactive and sedentary behavior, and it influences children's food preferences and eating behavior [91] by means of programs and particularly during commercials. Children are exposed to numerous adverts through television [96], and foods are among the most heavily advertised items on television programs for children [97]. Unfortunately, the majority of foods advertised for children (97.8 %) are of low nutritional value [98]. In addition to the direct effect of advertising, watching television *per se* has been shown to increase intake of snacks in 5-7 year-old children [99]. Possibly because it serves as a distractor and removes focus from what is eaten, which can lead to excessive eating. As 7-11 year-old children actually consume a rather large amount of their daily energy intake in front of a television (17-18 % on weekdays and 26 % in weekends) [100], this might be a good place to intervene in children wishing to lower their energy intake.

Altogether, watching television is associated with obesity as it promotes sedentary behavior, increases snacking, and advertises prime children to eat unhealthy foods. Accordingly, reducing and/or carefully paying attention to the amount of time children spend watching television is recommendable.

## Conclusion

The many topics touched upon in this review suggest that factors leading to overeating in children are widespread; the food provided in the home, the child's eating habits, and the eating situation contribute. In particular, we would like to stress the importance of early habit formation via varied exposure and how important it is to give children more opportunities to try new foods during weaning. Effective strategies to change children's acceptance of novel or disliked foods exist, many of which are simple to use and can easily be applied at home. Concerning the food, reducing energy density, portion size, and trying to identify serving styles children find attractive may facilitate energy intake appropriate to the child's needs. Variety can lead to overeating, but may also be used actively to influence intake of particular foods. Social facilitation can help children develop more appropriate eating habits, e.g., at family dinners where parents serve as role models for their children. Finally, watching television influences children's eating behavior in multiple ways and is associated with obesity. Taken

together the plasticity of food preferences suggests that parents and caregivers can facilitate healthy eating in children. It is never too late, but starting in early infancy offers particular advantages in establishing healthy eating patterns.

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- Of major importance

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