SUPPLEMENT

Developmental and Environmental Influences on Young Children's Vegetable Preferences and Consumption[1–3]

Susan L Johnson*

University of Colorado Anschutz Medical Campus, Department of Pediatrics/Section of Nutrition, The Children's Eating Laboratory, Aurora, CO

ABSTRACT

Food intake patterns begin to be shaped at the earliest points in life. Early exposures and experiences are critical for the acceptance of some foods, particularly healthful foods such as vegetables, which often have a bitter component in their flavor profiles. In addition to repeated exposure to these foods, the quality and emotional tone of parent-child interactions are important in facilitating children's acceptance of vegetables. During early childhood, parents are challenged by children's developmental characteristics related to eating, such as the emergence of child neophobia, and by individual characteristics of the child that are more biologically based, including genetic predispositions to bitter taste and sensory sensitivities. Experimental studies consistently show that repeated exposure to novel and rejected familiar foods is the most powerful method to improve acceptance. However, the manner and persistence with which these exposures are performed are critical. Research investigating influences on children's vegetable acceptance and ingestion has focused on associations among availability, parent intakes, child neophobia, and the parental feeding response to children's reluctance to try and consume vegetables. Because young children's dietary intakes are low and below dietary recommendations, investigations have focused more on factors that impede children's vegetable acceptance, such as controlling feeding practices, than on positive influences. Research that addresses the multifaceted nature of these interactions among different levels of social-ecological environment, individual traits, parental feeding styles and practices, and socioeconomic influences and that uses longitudinal designs and complex statistical approaches is called for to ascertain more effective methods to improve children's vegetable acceptance. *Adv Nutr* 2016;7(Suppl):220S–31S.

Keywords: child, neophobia, food acceptance, feeding behavior, vegetables, parenting, obesity, growth and development

Introduction

Definition of the issue

In a world of readily available, highly palatable foods, caregivers report that it is particularly challenging to teach children to like and eat vegetables. Studies of children's food preferences indicate that foods that are most highly preferred are energy-dense items (particularly sweet and salty foods) and that vegetables are least liked (1). These reported food preferences are consonant with preschool-aged children's food intake patterns (2–4). Indicators from available data suggest that vegetable acceptance, as well as variety of vegetable intake, is at its peak during early infancy, declines after 1 y of age, and continues to fall through the preschool years (5).

In the United States, young children's vegetable intakes fall far short of dietary recommendations. Approximately 25–30% of young children do not ingest any vegetables on a given day and the variety of vegetables typically consumed by US preschool-aged children does not often include dark-green vegetables, which are rich sources of micronutrients (3). Data from large cohort studies indicate that preschool-aged childrens' average intakes of vegetables do not meet the standards in many countries (6–8).

Why this is important

The statistics of obesity and its related chronic diseases throughout the life course are clearly linked to worsening dietary intake patterns (9). The necessity to shift toward more healthful intakes to prevent these illnesses and to attain optimal health requires an understanding and integration of the research related to children's development of food

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*To whom correspondence should be addressed. E-mail: susan.johnson@ucdenver.edu.

preferences and intakes and the factors that influence children's eating. Early experience with foods, e.g., vegetables, has the potential for long-lasting effects on an individuals' diets because this period is a sensitive, if not critical, period for sensory, motor, and experiential learning (10). Development and learning occur across multiple and varied contexts and understanding the influences of environments and caregivers will help to identify modifiable factors for effective interventions to improve children's vegetable and overall dietary intakes.

This review summarizes the evidence for developmental and environmental influences on children's vegetable preferences and intakes. It integrates findings from epidemiologic, laboratory, and observational studies and concludes with suggestions for future research to support the development of effective interventions and public health messages. Of note, this review seeks to focus on vegetable acceptance and ingestion (instead of fruit or fruit and vegetables combined) because the trajectory of children's acceptance and intake of vegetables appears to differ from that of fruit. Where possible, data for vegetables, separated from fruit, are presented and discussed.

Current Status of Knowledge

Developmental influences, early experiences, and children's vegetable preference and consumption

Biological and developmental influences. Children's taste preferences change with age and development (11, 12). Preferences for sweet and salty tastes are highest during early childhood and decline somewhat with age (13). Children are known to prefer higher intensities of salt and sugar than adults. These preferences are innate as is the inborn distaste for bitter. However, this is not to suggest that individuals cannot learn to acquire preferences for foods (such as vegetables) that have bitter components in their taste profiles. Children's food preferences are predicted by early intake patterns but can change with learning and exposure (5, 10).

Ultimately, vegetable intake is influenced by early exposures that increase the likelihood that children will learn to like and consume healthful foods. Indeed, the few longitudinal studies that assess children's food preferences suggest that food preferences acquired during early childhood carry on into adolescence and predict the quality of the diet in adult years (14). The case for focusing on improvements in early childhood eating behaviors, with the aim of achieving optimal health and mitigating later chronic disease, is strongly made in the Scientific Report of the 2015 Dietary Guidelines for Americans (15).

The role of early experience. Early experiences in utero and during breastfeeding provide opportunities for exposure to and learning about flavors and are posited to increase familiarity with a variety of flavors. These early experiences are positively associated with infants' and young children's general food acceptance and specifically with vegetable acceptance and intakes (16). Breastfeeding and longer duration of breastfeeding have been associated with greater fruit and vegetable consumption in infancy (2, 17). The timing of introduction of fruit and vegetables has been reported to be important for later consumption of fruit and vegetables and seems to be related to a sensitive period for the introduction and acceptance of foods of varied texture (18, 19). The reader is referred to the article by Mennella et al. (20) in this supplement for more detailed information related to early learning experiences and their impact of food preference development.

Coulthard et al. (21) examined the relation between timing and frequency of introduction of fruit and vegetables and fruit and vegetable consumption at age 7 in UK children ($n = 7821$). Children who had not been introduced to home-prepared vegetables by 6 mo of age consumed fewer vegetables at age 7 y (21). However, the frequency of consumption moderated this effect such that children who were introduced to vegetables at a later age, but at a higher frequency, consumed amounts of vegetables at age 7 comparable to those who had experienced earlier introduction. In the study by Coulthard et al. most infants had been introduced to vegetables before 3 mo of age. A report in a small sample in the United States ($n = 129$) reported that early introduction of complementary foods (before age 4–6 mo) increased the odds of children's picky eating and was associated with reduced dietary variety (22). Therefore, more research is required to ascertain the optimal timing and method of introduction of vegetables (i.e., textures) and other complementary foods during the weaning period.

Not only is timing of introduction of complementary foods important but the variety of vegetables introduced during the weaning period sets the stage for future vegetable acceptance (23). The few studies that focused on introduction of variety suggest that exposure to a variety (across and within meals) during infancy results in greater generalized acceptance of vegetables (24). Throughout the weaning period, infants' diets become more varied as the development of eating skills progresses and as they gain more experience with food and eating. Food preferences from infancy track into later childhood such that infants who accept greater variety in the first year of life tend to do so in the second year (25). However, by the end of the second year of life, neophobia and food refusal become common and difficulty in children's feeding and eating is reported by the majority of mothers (26). During the toddler and preschool years, when neophobia is at its height, the variety of vegetable intake diminishes (25, 27).

The role of sensory learning. Children overcome neophobia and learn about novel foods in a number of ways including experiential learning. When presented with novel foods, preschool-aged children display a number of sensory-based exploratory behaviors [smelling, licking, chewing, spitting, and swallowing (28)]. Engaging in these behaviors is thought to provide experience with foods that facilitates acceptance and consumption. These behaviors are often discouraged by caregivers because they are perceived to fall in

the realm of poor table manners (26, 29, 30). A focus on etiquette may impede acquisition of novel preferences, particularly if social interactions during these eating occasions are negative.

Preschool-aged children's characteristics that influence vegetable preference and consumption

Individual characteristics. Individual characteristics such as genetically based responses to bitter taste have also been associated with children's food acceptance and vegetable intake (31–33). Early literature reported that children who displayed sensitivity to 6-n-propylthiouracil (PROP) rated vegetables as more bitter; however, the relation to vegetable intake has not been consistent across studies (34). The literature suggests that PROP sensitivity interacts with other individual characteristics, such as being "food adventurous," and that individuals who are more adventurous eaters consume a wider variety of strong-tasting foods, including vegetables, irrespective of PROP taster status (35).

Children's temperament has been related to food responsiveness, or how children react to or engage with food. Infants who were rated higher on approach (novelty seeking) showed fewer distasteful faces, consumed more food, and were perceived by their mothers to enjoy eating more (36). However, in this study, the length of time that children ate mediated the relation between infant temperament and maternal ratings of child enjoyment (36), suggesting that some of the information that mothers rely on to determine child enjoyment is more related to how long children engage in eating instead of the child's facial expression. Higher surgency, or outgoingness, has been correlated with higher fruit and vegetable consumption (37). Vollrath et al. (37) suggested that when children respond and adapt well to new foods, it serves as reinforcement to parents to continue to offer these foods. In contrast, children with externalizing temperaments (hyperactive and aggressive) who react more negatively may entrain parents to avoid repeatedly offering new foods so that negative interactions can be circumvented. In general, emotional reactivity and shyness have been associated with food fussiness (38), neophobia (39), and food avoidance (40).

Food neophobia, or the fear and rejection of novel foods, is thought to be part of typical child development, and first emerges during the toddler period and, for most children, dissipates after the preschool years (39). Children who are perceived by caregivers to display high levels of neophobia are *1*) reported to consume less food variety in general (41–47) and *2*) display lower preferences for and intakes of vegetables (1, 46). Parents, when faced with neophobic behavior, often use pressuring tactics in attempts to improve children's food intake (47–49). Pressuring feeding strategies also have been correlated in studies that used cross-sectional designs to lower intakes of vegetables in preschool-aged children (45–50). The relation between child neophobia and parenting practices is likely bidirectional in nature; however, evidence to support the interaction between feeding practices and child characteristics has not been studied adequately in longitudinal studies (51).

Overcoming neophobia. Sufficient repeated exposure to novel foods is one mechanism through which children learn about new foods and come to accept them (52–59). Laboratory studies using repeated exposure protocols indicate that the optimal number of required exposures is at least 5–6 exposures to a new food (60), and perhaps as many as 8–12 exposures (28, 53, 61), with fewer exposures seeming to be required in infancy, before children come to accept and like a novel food. Studies of parent perseverance in offering new or rejected foods reveal that parents display far less persistence in re-offering initially rejected foods (26, 62). Although children may be exposed occasionally to novel foods, it is unlikely that they encounter these foods often enough, and without pressure to eat them, it is unlikely they will learn to overcome their initial reluctance.

Parenting influences related to children's vegetable consumption

Home environment effects. Young children are heavily influenced by the home environment and caregivers who make decisions regarding foods and eating experiences offered to children. Caregivers purchase and prepare food, serve as models for appropriate and normative eating behavior, determine the structure of meals and snacks, and use feeding styles and practices that influence children's eating and food acceptance patterns (63). Larson and Story (63) referred to caregivers as the "nutritional gateway" for children's eating and pointed out that not only are purchasing decisions important but so too are storage capacity and shelf life of the foods purchased, because more processed, energy-dense foods and snacks (compared with the shelf life of fresh vegetables) can be bought in bulk and safely stored for long periods of time. Consistent associations have been reported across the childhood period, in numerous countries and across socioeconomic strata, for the influence of availability of vegetables in the home and children's vegetable intake (64–67). In addition to availability, accessibility (particularly for older children) is a significant influencer in children's food choices: that which can be accessed and easily eaten has a higher probability of being chosen and consumed (68).

Parental beliefs and feeding self-efficacy. Parents hold strong beliefs regarding children's eating behaviors. These ideas may relate to parental beliefs about all children or to beliefs about their particular child's preferences for taste, color, texture, and need for sameness. In a unique qualitative research study aimed at investigating parental beliefs regarding the mutability of children's eating behaviors and food acceptance patterns, Australian parents conveyed the belief that children are influenced by individual child attributes such as neophobia and temperament, but that children's preferences change with time and development and can be influenced by socialization experiences with parents and peers and in child care (43). One study revealed that parent child-feeding self-efficacy mediated the extent to which children were exposed to new foods and to children's vegetable intake and variety (69). That is, mothers who were confident

that children can be encouraged to accept new foods and vegetables were more likely to offer these foods to their children and their child's intake of vegetables was higher. Therefore, parental beliefs are important in that they influence the kinds of foods that parents purchase and make available to their child and possibly their expectations for their children's consumption (70, 71).

Vegetable availability and parental vegetable intakes. Parental purchasing and dietary intake patterns also have been related to child vegetable intakes. In lower socioeconomic status families enrolled in WIC (Special Supplemental Nutrition Program for Women, Infants, and Children), greater purchasing behavior of vegetables was associated with preschool-aged children's willingness to try vegetables (72). In general, greater home availability of vegetables has been associated with higher maternal and preschool-aged children's intakes (64, 65, 73). Numerous studies have reported a positive relation between maternal vegetable intake and children's vegetable consumption, and this effect has been attributed to both the availability of vegetables in the home and to parental modeling of vegetable consumption (50, 63, 65, 74–79). This view of parental modeling, i.e., routine parental consumption of foods serving as social facilitation of children's food acceptance patterns, aligns well with the mere exposure theory as put forth by Zajonc (80). Zajonc suggested that mere exposure effects are "subliminal in nature," with the requirement that the stimulus (vegetables being ingested) is accessible to the individual's sensory receptors (in this case, the child being able to observe this behavior), but that cognition is not required. Thus, repeated observations of parents consuming vegetables may be a plausible mechanism through which parents influence the development of children's eating norms and their willingness to engage in the behavior. One study by Goldman et al. (64) directly queried parents about the extent to which they modeled fruit and vegetable consumption and reported that, in combination with availability and accessibility, parent modeling of vegetable consumption was associated with higher child vegetable intakes. Direct observations of caregiver modeling influences on children's vegetable consumption are limited but support the theory that young children are more likely to place a food in their mouths when viewing adult role models (81).

Parental feeding styles and practices. The feeding styles and strategies that parents use to convince young children to try and eat vegetables are varied in tactic, emotional tone, and effectiveness and are critical influencers of children's vegetable preferences and consumption. Both the feeding style, the overall approach, and emotional overtone of the feeding environment that is molded by parent experience and behaviors and specific feeding practices have been reported to influence children's vegetable liking and consumption (82, 83). In general, parental feeding styles that are responsive to the child, use negotiation (but not coercion or bribery), make appropriate demands for mastery, and that are influenced by health-related goals for children's eating are associated with reduced child neophobia, greater willingness to try vegetables, and greater intake of vegetables (38). This feeding style aligns with the general authoritative parenting style described by Baumrind (84) and others (58, 67), which is characterized by limit setting and negotiation with an underlying tone of responsivity and warmth.

Positive parental feeding practices that have been associated with greater acceptance and ingestion of vegetables by young children are child-centered in nature and are consistent with what has been termed "responsive feeding" (85, 86). Among these practices are the use of encouragement and praise (75, 76, 87); parent modeling of vegetable consumption (48, 64, 65, 75, 76); monitoring of low-nutrient, highly palatable foods (75); offering home-prepared vegetables (64, 65, 75); and the use of structure and rules for mealtimes and feeding (64, 65, 87–89). The use of appropriate nonfood rewards (e.g., stickers) has been reported to improve children's willingness to try vegetables (53). In contrast, feeding styles that are uninvolved, overly rigid, or permissive are all associated with poor vegetable acceptance and ingestion by young children, with permissive feeding styles (e.g., children are indulged or decide which foods are offered) being associated with the lowest vegetable intake (90). Negative feeding practices that have been associated with lower vegetable intake include the use of contingencies [rewards of desired foods for eating less desired vegetables (83, 88, 91)], pressure to eat (48, 50, 83, 91), and catering to children's demands for foods (83, 91).

As previously noted, parental feeding practices are related to the child's eating characteristics: parents who perceive their child to be more neophobic report that they use more pressure to try to get their child to eat (46, 50). Parents who report higher neophobia scores for their child offer new foods less persistently and have children who like fewer foods and fewer vegetables (46). It should also be noted that parental feeding practices, especially modeling and social facilitation of eating behavior, are also associated with parent neophobia: parents who self-report as being more neophobic consume fewer vegetables and have less vegetable variety and have children who are more neophobic and consume fewer vegetables (47). Thus, it seems that there is an intergenerational component to vegetable acceptance and intake that is related to individual characteristics (e.g., neophobia) and parental eating and feeding practices. Very few longitudinal studies, to our knowledge, have been conducted that have simultaneously collected information on parental feeding practices, child characteristics, parents' and children's food preferences, and dietary intakes. Therefore, the relations among young children's food acceptance, parental feeding practices, and children's food intake should be interpreted as associations and developmental trajectories of preschool-aged children's food preferences, and intake cannot be inferred from these data.

The conditions that seem to promote child vegetable acceptance are consistency (in availability of vegetables with fewer unhealthful competing foods, structured mealtimes

during which parents model vegetable consumption, and high expectations for consumption), flexibility (willingness to negotiate and provide choice), and responsiveness (warmth and encouragement, engagement, positive affect in the eating environment, and avoidance of pressuring or coercive strategies). These parenting attributes require high cognitive and attentional input as well as confidence and trust that children will accept foods with time and positive experience. This combination of parental feeding style and practices is difficult to achieve under everyday circumstances and when resources are sufficient; but for the parent with lower educational attainment, stressors related to poverty and violence and the demands of work, multiple children, and other social pressures, the pathway to achieving healthy dietary intake patterns for their children is quite challenging for parents and children alike.

Sociodemographic Influences Related to Children's Vegetable Consumption

Children's consumption of vegetables is also influenced by maternal and familial socioeconomic factors. Maternal education and nutrition knowledge are consistent predictors of maternal vegetable intake as well as her preschool-aged child's intake (2, 92, 93). In lower socioeconomic status families, availability and accessibility of vegetables in the home are consistently associated with cost, both in terms of monetary expense and preparation time and with maternal self-efficacy to offer fruit and vegetables to her preschool-aged child (68). Financial support to low-income women and children, via WIC, appears to improve infant vegetable intake and variety, underscoring the effectiveness of simultaneously providing education and financial support to families to provide vegetables to their young children (94).

Class disparities in vegetable consumption have increased in the United Kingdom and the United States, with children from lower socioeconomic status families reporting lower intakes and less variety in vegetable consumption (95). Food insecurity has been associated with lower preschool-aged children's intakes of fruit and vegetables (92) and, in particular, of dark-green vegetables of high nutrient density (96). The drivers of social class differences in vegetable intakes are reported to be the higher cost (per calorie) of vegetables (97, 98), poorer access to healthful foods [in neighborhoods and because lower income families are less likely to own a vehicle to go elsewhere to purchase foods (97, 98)], lack of cooking skills and time for preparation (98), and apathy of low-income families toward nutrition messages (98). Class differences result in disparities in total vegetable consumption and in negative impacts on overall nutrient intakes [β-carotene, folate, vitamin C and fiber (95)].

These impediments exist in stark contrast to marketing incentives for low-nutrient/high-energy foods (95). The effects of television viewing and branding on children's vegetable consumption have not been extensively studied. However, investigations of marketing content reported that the preponderance of food cues during programming (on public television shows aimed at preschool-aged children) more often gave positive endorsement to unhealthy (over healthy) foods (99). Targeted advertising for high-energy, low-nutrient-dense foods has been observed to be higher in areas with greater proportions of black children and lower-income households (100). Findings from large cohort studies reported that television viewing is negatively associated with diet quality of preschool-aged children and, specifically, with lower intakes of fruit and vegetables (101–103).

Kraak et al. (104) underscored that companies spend far less in marketing for nutrient-dense foods (e.g., vegetables) than for less healthful and highly palatable foods that compete with vegetable consumption in young children. They further noted that interventions that aim to increase the availability and consumption of healthy foods target motivation and behavior change without addressing cost for low-income, high-risk families and children. The effectiveness of such interventions, without incentives to support purchases, has been questioned (95, 104).

Findings from Experimental Studies Aiming to Improve Children's Vegetable Acceptance and Consumption

The classic conundrum of young children's food acceptance patterns is that children "like what they know and eat what they like" (105). That is, young children, particularly those whom have entered the period when neophobia is highly expressed, appear to need adequate knowledge or familiarity to agree to engage in sensory learning and to taste a novel food (**Figure 1**). It is with increased familiarity that children's taste preferences change: the food becomes known, tasted, potentially liked, and eventually ingested (106). However, neophobia and novelty conspire to increase the barrier to children choosing to taste the food. In addition, for some children, sensory characteristics such as genetically determined responsiveness to bitter taste and sensory sensitivities may result in negative affective experiences related to trying new foods and thus increase the difficulty of increasing children's consumption of novel foods (21, 107). These conditions seem to be especially potent in the case of children's vegetable acceptance and ingestion. The challenge for researchers and caregivers alike is in identifying the circumstances in which children can be persuaded to try foods and that result in positive learning experiences such that children acquire food preferences and, ultimately, eat sufficient quantities to affect diet quality positively.

Laboratory studies undertaken with the aim of improving children's liking and consumption of vegetables have focused on several areas of inquiry: the effects of repeated exposure (taste and visual) (80, 108), flavor-flavor and flavor-nutrient learning (108), manipulation of portion size offered (109), and the use of rewards to increase willingness to try, preference, and consumption (108, 109). The most consistent positive effects are found for repeated exposure on children's vegetable acceptance (54–56, 60) and, to some extent, on children's consumption (56, 59, 110–113). Irrespective of child age and neophobia, persistent offering of

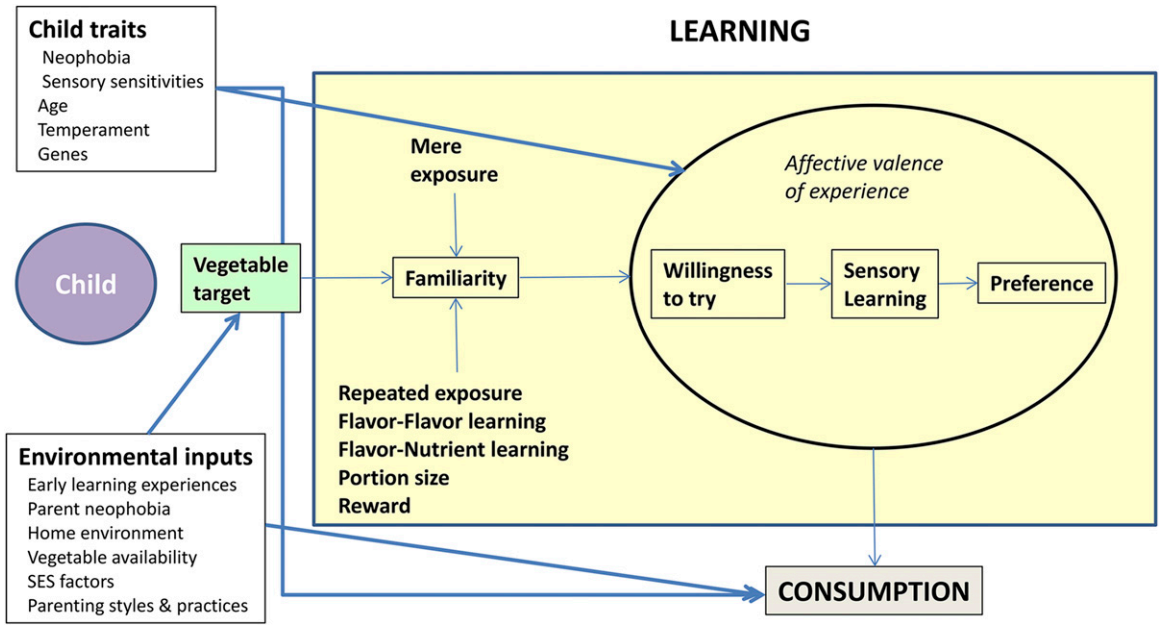

FIGURE 1 A 2-stage model of influences on the development of children's vegetable preferences and consumption. Stage 1 reflects influences on children's willingness to try vegetables. Stage 2 considers inputs on children's vegetable consumption. SES, socioeconomic status.

a vegetable results in improvements in children's preference and (in the few studies that have measured it) ingestion of a vegetable—even those vegetables that are initially ranked as disliked (114). However, individual characteristics such as child age, parental reports of neophobia, and sensory sensitivity do have an impact on the trajectory of acceptance and number of required exposures.

The dogma has been that young children require 8–10 exposures of a novel food to learn to accept and acquire positive food preferences for foods, although it should be noted that this was established based on studies that enrolled preschool-aged children (61). Newer research suggests that toddlers younger than 24 mo may require as few as 5 exposures (60) and that these learned preferences result in increases in children's vegetable consumption (24, 60). Furthermore, it appears that individual differences in trajectories of food acceptance come into play, with some children displaying easier adoption of novel foods ("plate clearers") than children for whom repeated exposure does not seem to be sufficient to overcome food rejection ["noneaters" (57)]. Whether noneaters are more neophobic or have greater sensory sensitivity (i.e., greater sensitivity to smell, taste, or texture of foods) has only just begun to be explored.

Aldridge et al. (106) suggested that increasing familiarity, through exposure, is a key component of reducing neophobia and improving the likelihood that children will become willing to try foods (102). Familiarity is thought to be attained through a number of paths: visual cues (recognition and awareness), taste (sensory knowledge, experience, predictability, physiologic feedback from ingestion), context (food preparation and presentation), and category (the category in which the food belongs). Each of the modes of familiarity could result in decreases in the neophobic child's fear and anxiety. These conditions are not unique to the construct of food acceptance. Zajonc (80, 115), the acknowledged thought leader in the realm of mere exposure theory, posited that the development of any preference (be it music, food, or ideological values) occurs when an individual is exposed repeatedly to a particular stimulus. Furthermore, any unconditioned stimulus paired with exposure (e.g., emotion or experience) is likely to have an impact on the individual's preference development and this unconditioned stimulus can be positive or negative. For example, in the food acceptance domain, exposures paired with negative experiences (e.g., being pressured to eat a food or an aversive taste) reinforce the development of negative taste preferences. Therefore, not only do foods such as vegetables need to be persistently offered, the manner in which they are offered is important and can have long-lasting effects.

Studies investigating the impact of exposure via visual cues (e.g., books or pictures) have not reported increases in children's vegetable acceptance and consumption, although some effects have been noted for fruit acceptance (58). Heath et al. (108) argued that visual exposures may serve to increase knowledge, recognition, and sensory learning (as shown by increases in toddlers' looking times) about foods and thereby potentially affect willingness to approach and try a new food. Studies that focused on food preparation to alter visual cues (making foods attractive or "cute") reported no impact on children's consumption and preference (116, 117).

Some evidence of effectiveness of flavor-flavor pairing (e.g., providing a familiar dip to eat with vegetables or

sweetening vegetables) on children's willingness to try novel foods has been reported; however, findings are mixed with respect to the effectiveness of these strategies on children's vegetable intake (55, 56, 112, 118, 119). As with repeated exposure, toddlers appear to be more positively influenced by flavor-flavor learning. However, the results of flavor-flavor learning, as distinct from repeated exposure, are difficult to deduce because flavor-flavor learning protocols must also include repeated exposure. The additive effects of flavor-flavor learning, over and above repetition, may be ascribed to *1*) reducing children's reluctance to try new foods by increasing familiarity, particularly in the case of pairing familiar palatable dips with vegetables, or 2) reducing negative sensory input (i.e., masking bitter taste). As depicted in the model of children's acquisition of vegetable preferences and ingestion (Figure 1), willingness to try is a necessary and antecedent step to improving food preference and ultimately consumption.

Flavor-nutrient learning (e.g., the addition of energy to increase the energy density of a food) has been shown in animal (120) and human (120, 121) studies to increase food preference. Studies have manipulated energy density by varying both carbohydrate and fat content and subjects' preferences have aligned with the version of the food that is higher in energy density. In general, these methods have not been shown to have positive effects on children's liking or consumption of vegetables (green or root vegetables) when fat is added to vegetable formulations (56, 60). This is particularly interesting because it is inconsistent with data supporting children's high consumption of fried vegetables (4, 122, 123). Of note, the literature that focuses on flavor-nutrient learning most often uses target foods that are sweet [e.g., yogurt (121)] and it may be that sweet-fat combinations are more easily (or differently) conditioned than vegetables that are paired with fat [e.g., artichoke purée with added fat (60)].

The portion size and the timing of vegetable portions offered are among experimental manipulations that have shown positive impacts on the amounts of vegetables that young children eat. One study that offered large portions of vegetables as a first or appetizer course (such that vegetables were consumed while children were still hungry) resulted in increased consumption of vegetables at the meal (124). Another study that offered vegetables as a snack with a dip (such that vegetables did not compete with other, more palatable foods) resulted in increased consumption of vegetables (118). Similarly, increasing the portion offered by concealing vegetables in other dishes also increased consumption, albeit not vegetable preference or overt acceptance (125). Increasing the portion of vegetables offered when fruit is simultaneously available led to increases in consumption of fruit but not of vegetables (126).

In-home observations of children's consumption at dinner meals revealed that the amounts children ingested were predicted by the amounts that they were served, both with respect to total energy intake and the portion of vegetables offered and consumed (127). In this study, parents selected the vegetables served to their children and it is possible that they offered those that their preschool-aged children already knew and liked. A qualitative study focusing on mothers' decisions regarding what and how much food to serve their child at meals at home reported that mothers typically serve those vegetables that they know their children are likely to consume to avoid waste of time, money, and effort (128). Continued offering of rejected vegetables was not considered to be an effective strategy, particularly for mothers of children who reported that their children were "picky eaters."

An additional rationale for trying to increase vegetable portion size beyond the aim of improving vegetable intake is to decrease energy density, and therefore energy intake, at the meal. Although the use of "hidden" vegetables at a meal to decrease energy density (the "stealth" effect) may be effective in passively reducing energy consumption at a meal, altering portions served as vegetables at a meal, to either increase liking or intake or to reduce overall energy consumption at the main meal, has proven to be ineffective (126).

Perhaps the most debated approach to influencing children's food acceptance patterns has been the use of reward. The effectiveness of reward to modulate children's responses to foods appears to be determined by 3 different aspects of the type of reward used: *1*) affect associated with the use of reward, *2*) the extent to which the reward affects child agency, and *3*) the size or level of the reward being offered. Birch et al. (129, 130) showed that the use of contingencies or bribery to influence children's food preferences, although effective in the short run to achieve ingestion, was not sufficient to improve liking of target foods. This may have been due to the nature of the foods that were used in the studies: highly palatable foods for rewards and vegetables as target foods that were selected to mimic parental feeding practices. Subsequently, Wardle and colleagues (53, 131, 132) undertook a series of studies to determine whether rewards such as stickers could be offered to a child to improve children's willingness to try foods and their consumption of foods. These studies have consistently shown that use of an immediate reward is effective in improving child compliance to try foods and, with repeated exposure, in improving liking and consumption (immediately and up to 6 mo postintervention). Important characteristics of the rewards used in these studies were that the stickers were offered with neutral or positive affective valence (e.g., "good job") and that the size of the reward was in proportion to the task that the child was being asked to perform. The use of this category of rewards is time-honored in the behavior change/motivation literature for children (133). As noted by Cooke et al. (132), this type of reward is less likely to have negative impacts on children's intrinsic motivation to try and like foods and may therefore be a practical method to improve children's willingness and motivation to try foods. Appropriate rewards may serve to bridge the barrier between neophobia and food acceptance, which is a significant hurdle for caregivers. A limitation to this area of inquiry is the inability to separate exposure from reward effects (i.e., repeated

exposure is part of reward-based paradigms). Furthermore, to our knowledge, no studies have been conducted that include extinction intervals as part of the experimental design, which would allow for the determination of lasting effects of appropriate rewards on children's food acceptance behaviors.

Conclusions

Summary of the evidence

Children's caregivers are the gatekeepers of exposure to a variety of foods. What, when, and how caregivers offer foods to children arguably has as much influence as biology on children's food preferences and acceptance. Caregivers' decisions about the foods they choose to consume (and model); which foods they offer to their children; the frequency, consistency, and amounts that they offer; and their expectations for children's consumption are critically important in understanding children's dietary intakes. The available evidence supports that early exposure to vegetable flavors in utero and through breastfeeding, as well as the timing, variety, and consistency of introduction of vegetables during the weaning period and beyond, sets the stage for optimal vegetable acceptance and consumption. However, the latter part of this interval, from toddlerhood through the preschool years, is also the time of the greatest surge in children's autonomy seeking (134) and neophobia (45). The result is that children's vegetable intakes are significantly limited and parents often avoid addressing the issue, or do so ineffectively and become frustrated and anxious (128). Given the links between early dietary behaviors and later dietary and chronic disease risks, it is worrisome that vegetable intakes are so low at the time when children should be learning how to consume them so that future health is positively affected (135).

Integration of the research into an overarching model (Figure 1) proposes that the path to vegetable acceptance and consumption has at least 2 major stages: *1*) willingness to try vegetables and *2*) vegetable consumption. These stages have different potential inputs, with the majority of research that has yielded positive outcomes having been focused on children's willingness to try vegetables. Influencers that are positively associated with improving children's willingness to try vegetables include the following: *1*) experiential learning (early flavor and food experiences, repeated exposure, sensory-based learning, timing, and variety of introduction); *2*) environmental effects (vegetable availability and accessibility); *3*) parental knowledge, attitudes, beliefs, and behaviors (intake and modeling); and *4*) parental feeding styles and practices (responsive feeding styles, use of negotiation, reasoning and knowledge transfer, appropriate incentives). Factors positively associated with children's vegetable consumption relate to the following: *1*) environmental effects (availability, accessibility), *2*) norms and routines (family meals, structure, limit setting, and expectations for consumption), *3*) parental vegetable intakes, *4*) food preparation and presentation (home-prepared vegetables, portion, and timing of offering in the day), and *5*) socioeconomic factors (cost, income, and education). Conceptualizing the path to vegetable consumption as a 2-stage process of repeated trying that can lead to significant consumption, instead of a singular goal of getting children to consume their vegetables, may not be a conscious part of parental beliefs and practices. Lowering expectations for consumption and focusing on exposure may also relieve some cost concerns of families with limited resources.

Experimental studies confirm a strong role for exposure and persistence—a difficult task for many parents who have more immediate concerns of getting their child to eat the meal and foods at hand (128). Wardle et al. (53) provided evidence for positive effects of appropriate reward. Experimental designs that investigate the lasting effects of proper types of reinforcement (as opposed to bribes and food rewards) should be developed.

With respect to parenting styles and practices, the evidence suggests that negative, controlling, parent-centered styles and practices impede the development of children's vegetable preferences and consumption. The preponderance of evidence has focused on negative parental behaviors and styles. Building the evidence base for positive parent child-feeding interactions is difficult because capturing these processes (e.g., modeling, use of encouragement and praise, positive emotional tone and warmth) is methodologically challenging to operationalize and comes with significant time and funding costs.

Research gaps and opportunities

A number of gaps exist in the current literature regarding the acquisition of children's vegetable preferences and the influences that affect their consumption. Longitudinal studies that shed light on the development of vegetable preferences and the interactions between child, parent, socioeconomic status, and organizational influences would require cohort studies of significant magnitude that are designed to capture mediating and moderating effects. Furthermore, the inclusion of extended families (grandparents homes with multiple caregivers, and children who spend time in more than one family home) and of larger environmental strategies ("nudges" and behavioral economic strategies implemented at the community level) are also important to investigate because these caregivers and environments play an important role in children's dietary intake (136). Studies are called for that more fully examine social class impacts, as well as the role of economic policies on food availability, purchasing practices, and cultural values. Such investigations should consider positive-deviance designs that identify families who are succeeding in feeding their children well. In particular, understanding what motivates some mothers to continue to offer their children initially rejected foods such that children exhibit greater food acceptance will be critical for developing interventions that improve children's vegetable and overall dietary intakes.

Further study of the role of texture, timing, and variety of vegetables introduced during the ages of 6–24 mo will be important for informing the development of guidelines for vegetable feeding practices. In addition, the exploration of

the influence of additional forms of sensory learning (e.g., visual cues and olfactory experiences) and how these interact with sensory sensitivity on children's willingness to try novel foods and vegetables could provide valuable information to help address the barrier of children's neophobia.

The extent to which specific parenting practices influence children's vegetable acceptance, compared with the style of feeding and emotional tone during eating occasions, is an important area of discovery. From a pragmatic standpoint, it may be easier and more achievable to focus on specific feeding practices rather than endeavoring to alter parental warmth and responsivity. Determining the contribution of practices and styles would provide valuable information for intervention development—particularly for those families who have increased stressors, limited resources, and who are most at risk of chronic diseases related to diet. Investigating the impact of providing economic assistance, in addition to tailored education about effective feeding practices, is important because education alone does not change fears about wasting foods nor the capacity to purchase more and healthier foods. Last, given the consistent association between parent and child intakes, the focus of research and intervention strategies should be on the entire family rather than simply on child-feeding practices. The Healthy People 2020 goals call for increasing vegetable intakes for all individuals aged ≥2 y and for increasing vegetable variety (137). Improving the entire family's intake of vegetables may be more effective than focusing only on children's vegetable acceptance and intake.

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