

The Use of Repeated Exposure and Associative Conditioning to Increase Vegetable Acceptance in Children: Explaining the Variability Across Studies

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ONE OF THE MOST FREQUENTLY ASKED QUESTIONS by parents is, “How can I get my child to eat more vegetables?” Despite all their health benefits, vegetables are the least-liked food category among children,¹ and this is one of the reasons why intake remains well below recommendations.² Yet vegetables come in many shapes, sizes, and flavors, some of which are more readily accepted than others. The Feeding Infants and Toddlers Study identified the most popular vegetables in toddlers’ diets as fried potatoes and starchy vegetables (eg, corn), whereas dark green vegetables are at the bottom.³ This is no surprise, because many dark green vegetables contain compounds that are bitter tasting,⁴ and children have an innate dislike of bitter.^{5,6} Because dark green and cruciferous vegetables are rich sources of antioxidants, carotenoids, fiber, and other essential nutrients, identifying strategies to increase children’s acceptance of these foods is an important goal for chronic disease prevention. Many of the methods we have for increasing vegetable acceptance in children might work when it comes to carrots, squash, and peas, but what about more adventurous varieties, like asparagus, kale, and brussels sprouts?

The article by Capaldi-Phillips and Wadhera⁷ in the current issue of the *Journal* begins to address this question. In this article, the authors test the effectiveness of two commonly used strategies to increase vegetable acceptance: repeated taste exposure and a method of associative conditioning they refer to as flavor–flavor learning. In repeated or mere exposure, an animal or human can learn to like an initially unfamiliar or disliked food through repeated tastings.⁸ The number and timing of exposures is still up for debate, but recent studies suggest as few as five exposures were sufficient to increase toddlers’ acceptance of a novel artichoke purée.⁹ The second strategy tested by Capaldi-Phillips

and Wadhera⁷ is referred to in the article as flavor–flavor learning. In flavor–flavor learning, an unconditioned stimulus that is usually a well-liked flavor (eg, strawberry) is paired with an initially unliked flavor or taste. By repeated exposure to the liked plus unliked flavor/taste combination, it is hypothesized that one can increase acceptance for the initially unliked flavor, even when it is presented without the liked flavor accompaniment after the initial exposure or conditioning period. In studies with humans, flavor–flavor learning has been loosely interpreted because researchers are often more interested in the practical aim of developing procedures to increase acceptance of whole foods (eg, vegetables and bitter fruits) rather than simple flavors. This is the case with the article by Capaldi-Phillips and Wadhera,⁷ because the authors use both sweetened and unsweetened cream cheese, a food that contains both sweet taste and energy from fat, as the liked flavor paired with the lesser-liked vegetables (brussels sprouts and cauliflower). Clearly the term *flavor–flavor learning* is used broadly here, as in many studies. Other studies have used sweetness¹⁰ or yogurt-based dips^{11,12} to increase vegetable acceptance or intake in children. An important limitation to point out is that one cannot make conclusions about the mechanism of preference conditioning in these studies. Foods are complex stimuli, and when liked foods are used to increase acceptance of unliked foods, the results could be due to any number of taste, flavor, and textural attributes of the food. In addition to the associative conditioning strategy applied by Capaldi-Phillips and Wadhera,⁷ it is also important to note that other forms of associative conditioning, such as flavor–nutrient conditioning, have demonstrated effectiveness at conditioning preferences for unliked flavors in animals¹³ and in children.^{14,15} Although of interest, these strategies are beyond the scope of the present review.

There is a wealth of literature on the effectiveness of repeated taste exposure for increasing vegetable acceptance and intake in children.^{9,11,16–22} Based on this evidence, it is not surprising that many resources directed at parents include repeated exposure as an effective feeding strategy to introduce vegetables into a child’s diet.^{23,24} It is important to point out that not all studies have found this strategy to be effective,^{25–27} and among those that have shown an effect, as many as one third of children have been dropped from the analyses due to a failure to taste any vegetables.^{11,17} For children who have heightened sensitivity to bitter taste or high levels of neophobia, repeated exposure, by itself, might not be successful. In addition, there is evidence that some foods, like fruits, require fewer exposures to achieve

acceptance than do vegetables²⁸ and, in some cases, frequent exposure to more common foods can have the opposite of the intended effect on acceptance due to boredom.²⁹ Given the range of factors that can influence the success of repeated exposure, future experiments should be designed to identify individual and environmental characteristics that can influence the outcomes of this method.

One of the factors that could influence the success of strategies used to condition vegetable acceptance is the bitterness level in the target vegetable. Capaldi-Phillips and Wadhwa⁷ argue that strategies like flavor–flavor learning, where unliked vegetables are paired with a preferred dip or sauce, might be more effective at getting children to taste, and eventually accept, highly bitter vegetables like brussels sprouts. The addition of a familiar dip serves not only to mask the bitter taste of the vegetable, but if the dip is well-liked, it can help to condition a preference for the initially unliked vegetable through flavor–flavor conditioning.^{10,11,19} Although repeated exposure and flavor–flavor learning are compared with one another in the study by Capaldi-Phillips and Wadhwa,⁷ it is not possible to completely separate their effects from one another in a free-living environment. Increased preferences for vegetables may occur, in part, because children are repeatedly being exposed to vegetables over time during flavor–flavor pairings. Ultimately, the most effective strategies to change food acceptance might come from using a combination of techniques. Capaldi-Phillips and Wadhwa⁷ use flavor–flavor conditioning, but they also pair vegetables with cool names (eg, “power flowers”)³⁰ to increase children’s willingness to try them. This combination of strategies successfully increased children’s liking and intake of brussels sprouts compared with the use of repeated exposure alone. In addition, they also tested a less-bitter vegetable, cauliflower, and found that repeated exposure (by itself) was successful at increasing children’s liking and consumption. The suggestion made by these findings is that foods that are more bitter (and presumably less well-liked) might require more intense conditioning procedures than foods that are less bitter. These data are intriguing, and they suggest that more personalized approaches to conditioning vegetable acceptance might be warranted.

In a recent review, Blissett and Fogel³¹ make a distinction between intrinsic (eg, taste sensitivity) and extrinsic (eg, parental feeding practices) factors that influence children’s food acceptance. This review serves as an excellent starting place for identifying individual child, family, and food-related characteristics that might influence the success of strategies to increase children’s vegetable acceptance, including repeated exposure and flavor–flavor learning. Using this review as a starting place, one can identify individual-level intrinsic characteristics and environmental-level extrinsic characteristics that should be considered when designing future experiments to test the effectiveness of strategies to increase vegetable acceptance in children. In the remaining sections, several key characteristics have been elaborated upon because they are likely to inform future research in this area.

INTRINSIC CHARACTERISTICS

Individual Variation in Taste Perception

There are numerous genetic variations in perception of taste and the chemosensory compounds found in foods.³² One

well-known example with relevance to vegetable acceptance is the inherited variation in the ability to taste bitter thiourea compounds, most notably 6-*n*-propylthiouracil (PROP).³³ Children who are sensitive to the taste of PROP (“tasters”) report lower liking of raw broccoli³⁴ and raw spinach,³⁵ and lower short-term intake of raw, bitter-tasting vegetables³⁶ compared with children who are nontasters. PROP status is relatively easy to assess in young children, and the measure has high reliability.³⁷ Yet only one study has investigated whether PROP status moderates the success of strategies to increase vegetable intake. Fisher and colleagues³⁸ found that pairing raw broccoli with a dip or sauce increased intake by 80% in Hispanic preschool-aged children who were PROP-sensitive, but the dip did not affect intake in PROP-insensitive children. Testing markers of perceived bitterness, like PROP status, may inform the strategies used to increase vegetable intake in children. Those who have heightened bitterness perception might be more successfully conditioned with paradigms that mask vegetable bitterness (eg, flavor–flavor learning using sweet, fat, or potentially savory tastes like umami). In addition, other genes related to the perception of sweet³⁹ and bitter^{40,41} have also been identified and could influence the process of learning to like new vegetables. Identifying genetic taste markers that interact with strategies to increase vegetable intake will help researchers develop more effective, personalized approaches to child feeding.

Age and Neophobia

Although previous investigations have used child age as a covariate, the age range of children tested within most studies has been narrow. This reduces the variability in response to the conditioning method used. However, little is known about how child age and development influence the success of repeated exposure and other types of associative conditioning. There is some evidence that willingness to try new foods can be overcome with a single exposure to a novel food with high palatability in children older than age 9 years, but this strategy was not successful with younger children.⁴² In addition, before age 2 years, most children are willing to accept a variety of foods,⁴³ although the extent to which these early food preferences carry across childhood and adolescence is not clear. It is possible that there are sensitive periods during development where children might be more responsive to one strategy over another. Infants and toddlers (aged 2 years) have a predisposition to avoid novel foods that is thought to protect them against the ingestion of potentially toxic substances.⁴⁴ But as children leave the toddler stage, neophobia begins to decline, and therefore one might expect conditioning vegetable acceptance to become easier with age. Future investigations that compare the effectiveness of repeated exposure and associative conditioning across a wider age range are needed to identify potential sensitive periods during which children are more willing to integrate vegetables into their diets.

The influence of age on the effectiveness of strategies to increase vegetable acceptance may in part be mediated by level of food-related neophobia, or fear of novel foods.⁴⁴ Children with more extreme levels of food neophobia or food refusal might require a more aggressive approach than children without these issues. Williams and colleagues⁴⁵

found that children with extreme levels of food refusal required as many as 27 exposures before accepting the food; however, as the number of new foods introduced into the diet increased, the exposures required for acceptance decreased. Alternatively, for children with lower levels of neophobia, 27 taste exposures is likely to be excessive and might not produce the desired outcome. Baseline levels of neophobia, therefore, should be tested to identify possible interactions with strategies to increase vegetable acceptance in children.

Additional research is needed to recommend the best strategies to use with children who have extremely high levels of neophobia or food refusal. For these children, using rewards or incentives might increase effectiveness. Some researchers have demonstrated success by pairing repeated taste exposure with small rewards (eg, stickers) for trying vegetables to encourage tasting among children.⁴⁶⁻⁴⁸ In our lab, we increased vegetable intake in preschool-aged children who were low-vegetable consumers by packaging them in colorful, child-friendly containers that included sticker incentives for repeat consumption.⁴⁹ Yet another approach for children who are highly neophobic might be stealth incorporation of vegetables into familiar entrées. Rolls and colleagues⁵⁰ successfully used these strategies; however, it is not known whether exposure to vegetables in this context translates to acceptance of the vegetables more broadly. Children who are particularly reluctant to try new foods might benefit from some of these strategies. Future research should be done to determine whether the above-mentioned strategies can encourage children with a high degree of neophobia to try new foods.

EXTRINSIC CHARACTERISTICS

Early Flavor Experiences

Early exposure to vegetable flavors in utero or during breastfeeding has been hypothesized to influence vegetable acceptance later in life.^{51,52} Children who are exposed to a variety of vegetable flavors early in their development might require less-intensive exposure later in life to condition acceptance than children with little to no early vegetable exposure. Early feeding method has been hypothesized to influence the success of attempts to introduce foods into a child's diet later in life. For example, infants who were breastfed showed greater increases in acceptance of green beans with repeated exposures than did formula-fed infants.⁵³ In another study, exclusively breastfed infants whose mothers reported greater fruit consumption more readily accepted peaches in the laboratory, but the same relationship was not found in formula-fed infants.⁵⁴ Previous research has shown that flavors consumed in the maternal diet are transmitted in amniotic fluid⁵⁵ and influence the chemosensory properties of the milk produced during lactation.⁵⁶ These early flavor experiences could serve to prime children for acceptance of these foods later in life by decreasing initial neophobic responses to these flavors. Previous studies have not reported whether vegetable exposure prenatally or during breastfeeding shortens the time to acceptance of those vegetables later in life, or affects other attempts to condition acceptance. Future studies that assess not only early feeding methods, but also the timing and duration of flavor delivery during gestation and weaning, will help refine feeding strategies to increase vegetable intake in children.

Method of Vegetable Preparation

A variety of preparation methods have been used across studies, yet the influence of these on the success of the conditioning paradigm is not known. As few as five exposures increased acceptance of a novel artichoke purée by infants and toddlers.^{9,16,19} In addition, a robust increase in intake of spinach and endive soups was observed in toddlers due to repeated exposure.¹⁷ However, no studies have directly compared methods of preparation to determine whether repeated exposure is more effective with some forms of vegetables (eg, raw vs cooked), but not others. Several studies have suggested that children prefer raw vegetables with a crunchy texture compared to cooked varieties,^{57,58} but vegetables that are particularly hard to chew are often disliked by children because they are difficult to manage.⁵⁹ Preparation method can affect texture, taste, and ease of consumption, and future studies to determine how this influences attempts to condition acceptance are warranted. It is also important to test whether acceptance for a vegetable in one context (eg, a soup) carries over to acceptance of that vegetable in another context (eg, a casserole or served plain). In addition, because method of preparation can influence perceived bitterness, future studies should also include assessment of genetic markers of bitter taste to determine whether they interact with preparation method to affect vegetable acceptance conditioning.

Packaging and Presentation

A new, but intriguing, area of research is the influence of vegetable branding or presentation on children's acceptance. For example, children consumed more edamame, chickpeas, and lentils when they were given fun, child-friendly names, compared with when they were presented with names evoking health status.³⁰ Wansink and colleagues⁶⁰ also found that "branding" apples with stickers of popular cartoon characters increased children's selection of these foods in a school cafeteria. In our own studies, we have successfully doubled vegetable intake in children who were low vegetable consumers by packaging them in appealing, child-friendly containers that included sticker incentives, and having parents present the vegetables as the optimal default at snacks and meals. Children selected their favorite cartoon characters on an initial study visit, and we created packaging for each child based on his or her selections. We allowed children to opt for a more highly palatable, alternative snack that we provided (chocolate chip granola bar), but only after a 5-minute wait time, to simulate the inconvenience of non-default options in the environment (K. L. Keller, unpublished data, December 2013). Parents were successful at implementing these feeding strategies in the home. Although these approaches may not be sustainable over the long term, they might be useful for parents to employ under some circumstances, particularly with children who are unwilling to try vegetables in other contexts. Creative packaging and presentation of vegetables is a relatively new area of research that integrates components of associative conditioning and repeated exposure to increase children's vegetable acceptance. Additional research on this strategy is warranted. In particular, future studies should be carried out to determine whether packaging or pairing vegetables with pictures of well-liked cartoon characters, without inclusion of sticker

incentives, is equally as effective at increasing children's intake. In addition, rigorous studies are needed to test whether this strategy might be more effective with some children than others.

Personalizing the Approach to Food Acceptance Learning

Previous research has identified several conditioning strategies that can be used to increase children's acceptance of vegetables. To effectively translate this information to families, it is important for researchers to identify the role of individual child characteristics in influencing the outcomes of attempts to condition vegetable acceptance. These child-level characteristics may interact with properties of the food (eg, bitterness and texture), as well as preparation and packaging techniques, to determine the most effective strategy for introducing new foods into a child's diet. A better understanding of the factors that influence the process of learning to accept vegetables will allow researchers and health care professionals to develop more personalized approaches to child feeding.

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