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Promoting healthy food preferences from the start: a narrative review of food preference learning from the prenatal period through early childhood

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Summary

The palatable, energy-dense foods that characterize modern environments can promote unhealthy eating habits, along with humans' predispositions to accept sweet tastes and reject those that are sour or bitter. Yet food preferences are malleable, and examining food preference learning during early life can highlight ways to promote acceptance of healthier foods. This narrative review describes research from the past 10 years focused on food preference learning from the prenatal period through early childhood (ages 2–5 years).

Exposure to a variety of healthy foods from the start, including during the prenatal period, early milk-feeding and the introduction to complementary foods and beverages, can support subsequent acceptance of those foods. Yet development is plastic, and healthier food preferences can still be promoted after infancy. In early childhood, research supports starting with the simplest strategies, such as repeated exposure and modelling, reserving other strategies for use when needed to motivate the initial tasting necessary for repeated exposure effects to begin.

This review can help caregivers and practitioners to promote the development of healthy food preferences early in life. Specific implementation recommendations, the role of individual differences and next steps for research in this area are also discussed.

Keywords: Early childhood, food preferences, infancy, learning.

Introduction

Humans are born predisposed to accept sweet tastes and reject those that are sour or bitter (1). These predispositions promoted adaptive eating behaviours in the environments of scarcity that characterized most of human history but can promote unhealthy eating in modern environments characterized by palatable, energy-dense foods. Fortunately, taste preferences are malleable: humans are also predisposed to acquire new likes and dislikes through experience. Examining such learning processes during early life can highlight ways to promote the acceptance of healthier foods in modern environments. This is an important goal given poor diet quality in young children (2) and the high prevalence of nutrition-related diseases in many nations (3).

A review of the current literature on early food preference learning can facilitate the use of up-to-date evidence in informing feeding approaches taken by parents, caregivers and practitioners. To this end, this manuscript is a narrative review of literature on children's food preference learning during the prenatal period, infancy and early childhood (ages 2–5), focusing on recent research, with incorporation of older, seminal studies and animal model research where appropriate, and a discussion of how findings can be applied to promote healthier eating among children. The search strategy focused on articles published in English in peer-reviewed journals during the past 10 years,

representing the time since Cooke (4) reviewed the role of exposure in child eating. Key search terms included: prenatal, foetal, infant, children, toddlers, preschoolers, breastfeeding, formula feeding, introduction to solid foods, complementary feeding, food preferences, flavour preferences, taste preferences, sensory learning, mere exposure, taste exposure, repeated exposure, familiarization, associative conditioning, variety exposure, neophobia, liking, acceptance, consumption, social influences, marketing, branding, visual exposure, modelling and rewards. We reviewed the identified articles, retaining those that included at least some human participants in the age range of interest. Then, in the interest of parsimony, we trimmed the pool of articles by eliminating some with results that were already represented among the retained references, giving preference to recent research and rigorous designs. The selected infant and early childhood studies are summarized in Tables 1 and 2; the prenatal period is not included in the tables due to a dearth of new research on this period within the indicated time frame. In the text, we augment the discussion of these studies with the incorporation of additional relevant human and animal research.

Prenatal influences

In humans *in utero,* gustatory and olfactory systems emerge during the first trimester and are functionally mature well before birth (5), providing opportunities for early sensory learning that likely prepares the foetus with attractions to foods that are safe and available in the postnatal environment. Gustatory and olfactory stimuli are transferred into amniotic fluid and detectable by the foetus, and repeated exposure to these stimuli influences behavioural responses after birth. For example, neonates prefer the odour of their own mother's amniotic fluid relative to distilled water (6) or the amniotic fluid of another parturient mother (7). Human mothers who regularly consumed garlic (8) or anise (9) during pregnancy had neonates who showed greater preference for those flavours, and prenatal exposure to carrot flavour led infants to prefer carrot-flavoured to plain cereal at weaning (10). Animal studies, which can systematically manipulate maternal diet, bolster this evidence, showing that *in utero* exposure increases postnatal acceptance of flavours that would be otherwise non-preferred (11), and that maternal consumption of a high-fat diet during pregnancy can result in the offspring's increased attraction to sweet and high-fat foods (12).

Influences during early milk-feeding

Postnatal exposure to flavours in breast milk or formula also influence infants' feeding behaviours (Table 1A). Breast-fed infants are exposed to a wide variety of flavour compounds that are transferred from the mother's diet into the milk (13). Flavour exposures for formula-fed infants are more monotonous, but exposures may vary across infants because formula types differ in their sensory profiles (14).

In the short-term, young infants are attracted to novel flavours experienced in milk (15). Infants also show preference for the milk (breast milk (16) or formula type (17)) that they are currently feeding but show no preference for foods that contain flavours that they are currently being exposed to within the breast milk or formula (18), which may be a form of sensory-specific satiety, or diminished interest in a flavour or food after repeated, short-term exposure to it (15). In the longer-term, infants and young children prefer solid foods with flavours similar to those experienced during previous breastfeeding (10) or formula feeding (17,19). Some associations between taste exposures during early milk-feeding and later food preferences have been shown through at least 10 years of age (20). Thus, infants' attraction to novel flavours during early milk-feeding and weaning likely facilitates acceptance of and learning about these novel flavours, whereas repeated exposure to flavours within breast milk or formula provides an important 'flavour bridge' for subsequent acceptance of these flavours within novel solid foods (10,15,19,21).

Influences during the introduction of complementary foods and beverages

Consistent with research illustrating infants' attraction to novel flavours during milk-feeding, parents report that 5- to 7-month-old infants react positively (e.g. readily accepting spoon, smiling) to the vast majority (~88–91%) of novel foods introduced (22). However, reactions to novelty vary by the taste of the food, with salted vegetables more accepted than plain (22) and fruits or sweeter vegetables more readily accepted than bitter vegetables (23). Popular belief posits that vegetables should be introduced prior to fruits, given infants' natural inclination towards sweet taste. Although few studies have systematically examined whether the timing of exposure to different foods influences acceptance, available research does not support this notion. For example, repeated exposure to fruits did not negatively impact infants' acceptance or intake of a novel vegetable in short-term (23) or long-term (24) assessments, and in another study, daily experience with fruit enhanced acceptance of carrots (25).

Acceptance of novelty generally declines over time, however, suggesting early infancy may be a sensitive period for flavour learning (19). Further, emerging research has highlighted characteristics linked to individual differences in infants' initial reactions to and willingness to accept novel foods (Table 1B), such as taste preferences (22); age (26); enjoyment of food, satiety responsiveness and food fussiness (26); and temperament (27). Overall, research on how infants' preferences develop during the introduction of

Table 1 Influences on food preferences during infancy: Selected human studies from the past 10 years

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
A. Influences during early milk-feeding: effects of flavours in breast-milk and formula						
Hausner, Bredie, Mølgaard, Petersen, & Møller, 2008 (13)	What is the time dependent transfer of flavour compounds into breastmilk?	Within-subjects and between-subjects; sampled milk 2,4,6,8 h after ingestion	Eighteen lactating women with 7- to 35-week-old infants living in Copenhagen, Denmark	Flavour compounds ingested via capsules by mother (*l*-menthol, *d*-carvone, *trans*-anethole, 3-methylbutyl acetate)	Appearance of compounds in milk; analysed via gas chromatography–mass spectrometry Controlled for milk fat content	Concentrations of *D*-carvone and *trans*-anethole peaked at 2 h, whereas *l*-menthol plateaued by 2 h. Only trace amounts of ester 3-methylbutyl acetate could be detected Overall, compounds were found in low amounts
Mennella & Castor, 2012 (19)	Does early exposure to extensive protein hydrolysate formula (ePHF) influence later preferences for foods with similar flavour profiles?	Randomized controlled trial lasting 8 months; infants were randomized to consume cow's milk formula (CMF) only; ePHF only; or ePHF for 1 or 3 months and CMF for the remaining months	Forty-seven mother–infant dyads, followed from 0.5 to 8.5 months; living in Philadelphia, PA (41.3% Black, 21.7% White, 19.6% Hispanic, 17.4% mixed race/other)	Exposure to ePHF at different times (1.5, 2.5 or 3.5 months of age) and durations (1, 3, or 7 months)	Infant acceptance of savoury broth during lab-based feeding sessions and as indicated by 1. Infant intake (compared with plain broth) 2. Infant rate of feeding 3. Maternal ratings of infant liking	Infants exposed to ePHF for 3 or 8 months, but not 1 month, ate more savoury broth relative to plain broth at 8 months and also ate at a faster rate. Maternal ratings of liking did not differ among groups
Mennella, Kennedy, & Beauchamp, 2006 (18)	Does the flavour of formula fed to infants modify their acceptance of some foods?	Observational; infants consuming CMF (n = 50) or ePHF (n = 24) were observed on 2 separate days	Seventy-four 6- to 11-month-old infants living in Philadelphia, PA (44.6% Black, 45.9% White, 4.1% Hispanic, 2.7% Asian 2.7% mixed race/other)	Infants' typical consumption of CMF versus ePHF	Infant acceptance of carrot and broccoli/cauliflower purees during lab-based feeding sessions and as indicated by 1. Infant intake 2. Mother's rating of infant enjoyment	Formula type was not associated with amount of carrots consumed Infants consuming ePHF consumed significantly less broccoli/cauliflower relative to carrots when compared with infants consuming CMF Mothers of infants consuming ePHF were significantly more likely to rate their infants as not enjoying the broccoli/cauliflower puree compared with mothers of infants consuming CMF
Sausenthaler, Koletzko, Koletzko, Reinhardt, Krämer, von Berg, Berdel, Bauer, Grübl, Wichmann, & Heinrich, 2010 (20)	Does the association between formula type and preferences remain at age 10 years?	Longitudinal: children followed from birth to 10 years	Eight hundred thirty-three 10-year-old children who were fed either ePHF (48.8%), partial protein hydrolysate formula (pPHF) (50.4%) or CMF (23.5%) during infancy; children were part of the German	Exposure to different types of formula during infancy	Taste preference test of formulas; preference assessed by Likert scale rating (ranging from 'extremely bad' to 'extremely good')	No differences between groups for mean liking scores. However, exposure to ePHF or pPHF was associated with a positive liking score for one type of ePHF (casein-based)

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
			Infant Nutritional Intervention Program Plus Study (GINIplus)			
B. Influences during the introduction of complementary foods and beverages: individual differences						
Moding, Birch, & Stifter, 2014 (27)	Do infants' temperament and feeding history predict responses to novel foods?	Cross-sectional study	Eighty-nine mother–infant dyads, infants were ~12 months of age; sample was predominantly White and living in Central Pennsylvania	Mother-reported infant temperament (including approach subscale from the Infant Behaviour Questionnaire-Revised) and infant feeding history (exposure to complementary foods and beverages, breast feeding) Mothers' behaviours during feeding (responsiveness and affect), observed in the lab	Acceptance of a novel food (hummus or cottage cheese) during a lab-based feeding session, indicated by 1. Intake 2. Rejection behaviours (turning away, swatting spoon, refusing to take a bite)	Approach was a significant predictor of acceptance of the first offer of the novel foods; lower approach was associated with fewer acceptance behaviours Low approach infants who were previously exposed to a greater number of solid foods showed fewer rejection behaviours Exclusive breastfeeding did not predict rejection behaviours Greater maternal responsiveness was associated with greater acceptance and less rejection
Schwartz, Chabanet, Lange, Issanchou, & Nicklaus, 2011 (22)	What is the role of taste preferences in the acceptance of new foods during the first month of complementary feeding?	Cross-sectional study of infants' reactions to new foods and preferences for basic tastes	Seventy-four mother–infant dyads; infants were aged 5–7 months and the dyads were part of the Observatory Food Preferences in Infants and Children (OPALINE) study in Dijon France[a]	Exposure to new foods or taste solutions	Infant acceptance as indicated by 1. Parents' reports of infants' reactions 2. Intake of the taste solution relative to plain water 3. Liking of the taste solution relative to plain water, rated by a blinded experimenter	The vast majority of parent-reported reactions to new foods (88%) were positive Vegetables with added salt or salty ingredients were more accepted than plain vegetables Positive correlations were seen between infants' acceptance of taste solutions and acceptance of foods with similar taste qualities
C. Influences during the introduction of complementary foods and beverages: effects of repeated exposure and variety exposure						
Barends, de Vries, Mojet, & de Graaf, 2013 (23)	Do infants who are exclusively weaned to vegetables have higher acceptance of vegetables than infants who are exclusively weaned to fruits?	Randomized trial; infants were randomized to one of four groups, which were repeatedly exposed to (i) green beans; (ii) artichokes; (iii) apples; (iv) plums	One hundred one 4- to 6-month-old infants recruited from the Wageningen and Almere regions of the Netherlands[b]	Exclusive repeated exposure to vegetables versus fruits during weaning	Acceptance of vegetables versus fruits, indicated by intake during a lab-based feeding session	At first exposure, intake of fruits was higher than intake of vegetables Repeated exposure increased intake of target fruit or vegetables pre to post exposure when the

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		for 18 consecutive days				target food was green beans or plums. Effects were not seen for artichokes, and a very small effect was seen for apples Repeated exposure to fruit did not impact vegetable intake – intake of green beans after fruit exposure was not significantly different from intake of green beans prior to repeated exposure to green beans (group comparisons). Similar findings for fruits Thus, repeated exposure to fruits did not negatively impact vegetable intake, but also did not lead to increased acceptance of vegetables
Barends, de Vries, Mojet, & de Graaf, 2014 (24)	Do infants who are exclusively weaned to vegetables have higher acceptance of vegetables in the long-term (at ages 12 and 23 months) versus infants who are exclusively weaned to fruits?	Longitudinal – same randomized trial as mentioned earlier, but infants were re-assessed at 12 and 23 months	Infants assessed at 12 (n = 86) and 23 months (n = 81) of age recruited from the Wageningen and Almere regions of the Netherlands[b]	Exclusive repeated exposure to vegetables versus fruits during weaning	Acceptance of green beans and apple purée as measured by intake during a lab-based feeding session Daily vegetable consumption reported by parents using a 3-d food diary	At 12 months: Daily intake of vegetables was significantly higher in the vegetable group compared with the fruit group At 23 months: No difference between groups for vegetable intakes No difference in lab-based intake of either green beans or apples at 12 and 23 months
Hetherington, Schwartz, Madrelle, Croden, Nekitsing, Vereijken, & Weenen, 2015 (39)	Does a step-by-step exposure approach work better than a traditional repeated exposure approach to promoting vegetable acceptance during weaning?	Infants were randomized to 2 groups: vegetable purees were added to milk for 12 d, then rice cereal for 12 d, then 11 repeated exposures in plain puree form (intervention), compared with controls who received the 11 repeated	Thirty-six mother–infant dyads living in the UK, 18 in intervention group and 18 in control group; infants were 4–5 months at study entry and were followed until 6 and 18 months	Intervention versus control	Infant intake and rate of feeding of carrots and green beans during lab-based feeding sessions Maternal and researcher (not blinded) ratings of infant liking	Vegetable intake and feeding rate were higher for the intervention group compared with the control group at all short-term post assessments; intake and rate of feeding for carrots was greater than green beans. Group differences were no longer apparent at 6 and 18 month follow-ups

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		exposures to plain purees				No effect of group on maternal ratings of infant liking, but ratings made by researcher were significant (note researchers were not blinded) At 6 months, there was a group effect on liking that was significant for carrots and marginal for green beans (intervention > control)
Mennella, Nicklaus, Jagolino, & Yourshaw, 2008 (29)	Study 1: To examine the effect of repeated dietary experience to either one fruit (pears) or a variety of fruits on infants' acceptance of pears and green beans Study 2: To compare the effects of variety exposure between tasting occasions (VB) with variety exposure within and between tasting occasions (VBW) on infant acceptance of vegetables	Study 1: Infants were randomly assigned to 1 of 2 groups: (i) 10 daily exposures to pears; (ii) rotating daily exposure to peaches, prunes and apples for 10 d Study 2: Infants were randomly assigned to 1 of 3 groups: (i) 10 daily exposures to green beans; (ii) rotating daily exposure to squash, spinach, carrots and peas for 10 d (VB); (iii) 10 daily exposures to pairs of vegetables fed within the same occasion (e.g. alternating bites of carrots and spinach; VBW)	Seventy-four mothers with 4- to 9-month-old infants, living in Philadelphia, PA (55.4% Black; 29.7% White; 2.7% Hispanic; 12.2% Other/Mixed Ethnicity)	Study 1: Effects of repeated exposure versus variety exposure Study 2: Effects of repeated exposure versus the 2 types of variety exposure: VB, VBW	Infant acceptance of pears and green beans (Study 1) or green beans and alternating bites of carrots and spinach (Study 2) during laboratory-based test sessions, as indicated by 1. Intake 2. Meal length 3. Rate of feeding 4. Mothers' ratings of infants' enjoyment of foods	Study 1: Both repeated exposure and variety exposure to fruits led to increased intake of pears but no changes in meal length, rate of feeding or mothers' perceptions. No effect of repeated or variety exposure to fruits was seen for intake, meal length, or mothers' perceptions during the green bean meal. However, both groups consumed green beans at a faster rate after the home exposure period relative to before Study 2: Vegetable VBW led to a significant increase in intake of green beans compared with baseline; only a trend was seen for the other two groups. Both the repeated exposure and VBW groups ate at a faster rate. No significant changes were seen for length of feed and mothers' perceptions VBW also led to a significant increase in intake of alternating carrots and spinach compared with baseline; no effect was

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
						seen for VB and repeated exposure. Both the VBW and VB groups ate the carrot-spinach meal at a significantly faster rate. No significant changes were seen for length of feed and mothers' perceptions
D. Influences during the introduction of complementary foods and beverages: comparing repeated exposure and associative conditioning						
Caton, Blundell, Ahern, Nekitsing, Olsen, Moller, Hausner, Remy, Nicklaus, Chabanet, Issanchou, & Hetherington[c], 2014 (26)	(i) Do individual characteristics predict initial acceptance of a novel vegetable, (ii) What individual characteristics predict intake over time, (iii) What individual differences predict the effectiveness of repeated exposure for promoting vegetable intake?	Randomized trial – participated in a pre-exposure test, 5–10 exposures, a post-exposure test; participants were randomized to experience (i) repeated exposure to a single vegetable; (ii) repeated exposure to the vegetable with added sugar (labelled as flavour–flavour learning condition; FFL); (iii) repeated exposure to the vegetable with added fat (labelled as flavour–nutrient learning condition; FNL)	Three hundred thirty-two infants between 4 and 37 months old (mean age ~18 months), recruited from childcares and preschools in the UK, Denmark and France[d]	Individual characteristics of infants (age, BMI, satiety responsiveness, food fussiness, duration of breastfeeding)	Pre-exposure intake of puréed artichoke, measured intake during a lab-based feeding Responsiveness to the repeated exposure conditions: (i) plain artichoke purée versus (ii) sweetened artichoke purée (FFL); (iii) energy-dense artichoke purée (FNL)	Significant predictors of the amount of vegetable consumed during pre-test were age and satiety responsiveness – younger and less satiety responsive children consumed more Significant predictors of change from pre-test to post-test were enjoyment of food and FNL condition When limited to children who did not eat as much during the pre-test, a highly significant model was found: age, enjoyment of food were significant predictors, with lower age and higher enjoyment of food predicting greater intake
Remy, Issanchou, Chabanet, & Nicklaus, 2013 (38)	To compare the ability of 3 different learning mechanisms to increase vegetable acceptance during weaning: (i) repeated exposure (RE); (ii) flavour–flavour learning (FFL); (iii) flavour–nutrient learning (FNL)	Randomized trial – participated in a pre-exposure test, a 2-week exposure period, a post-exposure test, then follow-up tests at 3 and 6 months; infants were randomized to experience (i) repeated exposure to a single vegetable; (ii) repeated exposure to the vegetable with added sugar	Ninety-five infants ~6 months of age, living in Dijon, France[d]	Repeated exposure to (i) plain artichoke purée versus (ii) sweetened artichoke purée (FFL); (iii) energy-dense artichoke purée (FNL)	Acceptance of the plain artichoke purée and carrot purée, as assessed by intake during a lab-based test feeding Liking as rated by parents (9-point scale of parent-perceived liking)	During the exposure period, intake in the FFL group was higher than the RE and FNL groups. Liking was higher in the FFL and RE groups compared with FNL group Pre-to-post increase in intake and liking of artichoke puree was significant for the RE group; only increase in intake was significant for FFL group. No change for FNL group At post-test, no

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Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		(labelled as FFL condition); (iii) repeated exposure to the vegetable with added fat (labelled as FNL condition)				differences were seen between FFL and RE groups for intake or liking These same increases were not seen at 3 and 6 month follow-ups Carrots were initially more accepted than artichokes during pre-test, but at post-test, the RE group liked artichokes just as much as carrots. In the FFL and FNL groups, carrot intakes were still greater than artichokes
E. Influences during the introduction of complementary foods and beverages: individual and interactive effects of infant feeding mode and exposure						
Forestell & Mennella, 2007 (28)	What are the independent and interactive effects of breastfeeding and repeated exposure on acceptance of fruits and vegetables during weaning?	Breast-fed and formula-fed infants were randomly assigned to 1 of 2 groups: (i) eight daily exposures to green beans; (ii) eight daily exposures to green beans followed by peaches. Infant acceptance of green beans and peaches was tested during the 2 d before and 2 d after exposure period	Forty-five mother–infant dyads; infants were 4–8 months of age and had little experience with fruits and vegetables; living in Philadelphia, PA (36.4% Black, 45.5% White, 6.8% Hispanic, 11.4% mixed race/other)	Feeding mode during first few months postpartum Repeated exposure to green beans versus green beans + peaches	Infant acceptance of green beans and peaches during lab-based feeding sessions and as indicated by 1. Infant intake 2. Infant duration of feeding 3. Infant rate of feeding 4. Infant facial expressions of distaste during feeding 5. Maternal ratings of infant liking	During initial acceptance test, breast-fed infants consumed more peaches, for a longer time, at a faster rate and with fewer expressions of distaste compared with infants who were formula-fed; no differences in initial acceptance of green beans Repeated exposure to green beans, with or without peaches, increased intake and rate of feeding of green beans during post-test. No interaction between feeding mode and acceptance Green beans + peaches group showed fewer expressions of distaste after compared with before; green beans group did not
Hausner, Nicklaus, Issanchou, Mølgaard, & Møller, 2010 (33)	Part 1: Will 10 exposures to caraway via human milk increase infant acceptance of	Part 1: Breast-fed infants randomized into: non-exposed (n = 20) or exposed via breast milk	Forty-eight mothers and their 4-to 6-month-old infants living in Copenhagen, Denmark	Exposure to caraway flavour in breast milk (Part 1) or a potato purée (Part 2)	Infant acceptance assessed during lab-based feeding sessions and indicated by	For breast-fed infants, no effect of exposure to caraway in breastmilk (Part 1) or in solid food (Part 2) on intake, number of

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
	caraway in a potato purée? Part 2: Will 10 subsequent exposures to caraway via solid foods further increase acceptance of caraway in a potato purée?	(n = 20) groups. Mothers in the exposed group consumed a caraway-flavoured hummus. A third group was composed of formula-fed infants whose mothers consumed the caraway-flavoured hummus (n = 8) Part 2: All infants given caraway flavoured potato purée for 10 d For both parts, preferences were assessed in two lab-based feeding sessions			1. Infant intake (relative intake of caraway vs. plain potato purée) 2. Maternal rating of infant liking 3. Duration of feeding 4. Number of spoons accepted or rejected	accepted spoons, meal duration and liking of caraway-flavoured potato purée, but infants exposed did refuse significantly fewer spoons For formula-fed infants, repeated exposure in solid food (Part 2) increased acceptance to the level of breast-fed infants Breast-fed infants had higher initial acceptance of the caraway-flavoured purée than formula-fed infants
Lange, Visalli, Jacob, Chabanet, Schlich, & Nicklaus, 2013 (34)	How do duration of exclusive breastfeeding, age of introduction of complementary foods and beverages (CFB) and variety of foods introduced influence acceptance of new foods during weaning?	Prospective observational study	Two hundred three mother–infant dyads followed from birth to 15 months; dyads were part of the Observatory Food Preferences in Infants and Children (OPALINE) study in Dijon, France[a]	Breastfeeding duration Age of CFB introduction Variety of foods offered during weaning	Acceptance of novel foods, as rated by parents when the food was first introduced to the infant	Most reactions to new foods were rated positively by parents. Exclusive breastfeeding and age of CFB introduction were not significant predictors of novel food acceptance during the first 2 months of complementary feeding. An exception was vegetables – the earlier vegetables were introduced the higher their acceptance was New food acceptance increased with the number of new foods introduced; this was especially the case for fruit and vegetables
Maier, Chabanet, Schaal, Leathwood, & Issanchou, 2008 (31)	What are the independent and interactive effects of feeding mode and the degree of variety exposure on acceptance of fruits and	Breast-fed and formula-fed infants were randomly assigned to 1 of 3 groups: (i) 1 vegetable, given for 9 consecutive days; (ii) 3	One hundred forty-seven mothers with 4- to 6-month-old infants, recruited from Alen, Germany (51%) and Dijon, France (49%)[e]	Formula fed (breast-fed for $<$15 d) versus breast-fed (for $>$30 d) No, low, or high variety exposure	Infant intake of novel foods (vegetables, meat and fish) during laboratory-based feeding sessions	Breastfeeding was associated with higher intake of the four new foods Infants in the high variety group also had the greatest intake of

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
	vegetables during weaning?	vegetables, each given for 3 consecutive days (4 changes); (iii) 3 vegetables given on a rotating schedule for 9 d (9 changes)			Mothers' and observers' ratings of infant liking of the novel foods	new foods compared with infants in the low or no variety groups There was a significant interaction between feeding mode and high variety – infants who were breast-fed and in the high variety group had the greatest intake of new foods compared with other groups There were also main effects of breastfeeding and high variety exposure, but not an interaction between the two, on mothers' and observers' ratings of infant liking of the novel foods
Maier-Nöth, Schaal, Leathwood, & Issanchou, 2016 (32)	What are the long-term influences of feeding mode and repeated exposure on children's preferences at 15 months and 3 and 6 years?	Same randomized trial as mentioned earlier, with follow-up assessments at 15 months and 3 and 6 years	One hundred forty-seven mother–infant dyads at study entry, infant age ~5 months; final sample at 6 years was 75; dyads were recruited from Alen, Germany (51%) and Dijon, France (49%)[e]	Formula-fed (breast-fed for <15 d) versus breast-fed (for >30 d) No, low, or high variety exposure	At 15 months and 3 years, parent reported foods offered and foods accepted (i.e. 'ate and like') At 6 years: lab-based feeding session where children were offered different vegetables (one new, four liked, one initially disliked but then repeatedly exposed vegetable)	Children who had been breast-fed were reported to like more vegetables at 15 months than those formula-fed; no effect of early variety experience on number of vegetables liked For vegetables that were initially disliked, then repeatedly exposed during infancy, 72 (85%) were still being offered the initially disliked vegetable at 15 months. Of these, 57 (79%) were rated by the mother as eating and liking it, 8 (11%) as eating it but not liking it and 7 (10%) as disliking or refusing it. (Similar findings at 3 years.) No effects of feeding mode or variety exposure on number of vegetables eaten or liked at 3 years. At 6 years, children who

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Table 1 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
						had experienced high variety reported that they liked the new vegetables more than those who had low or no variety; no effect of feeding mode. Also showed higher mean reported liking for familiar vegetables When focusing on intake of novel vegetables, children who had been breast-fed consumed more of the new vegetables than did children who had been formula-fed, and children who had been exposed to high variety ate more than low or no variety. For familiar vegetables, there was an effect of variety but not feeding mode. Similar findings for willingness to taste

Note: The intent was to include in Table 1 the relevant human studies conducted since 2007 on the prenatal period and infancy. However, new studies during the prenatal period were not identified; thus, this first table is focused on infancy.
[a]Sample overlaps with another study reported in the table.
[b]Sample overlaps with another study reported in the table.
[c]Included in both Tables 1 and 2 given wide age range.
[d]Sample overlaps with another study reported in the table.
[e]Sample overlaps with another study reported in the table.
CFB, complementary foods and beverages; CMF, cow's milk formula; ePHF, extensive protein hydrolysate formula; FFL, flavour–flavour learning; FNL, flavour–nutrient learning; RE, repeated exposure; VB, variety exposure between tasting occasions; VBW, variety exposure between and within tasting occasions.

complementary foods and beverages has primarily focused on repeated exposure, variety exposure (Table 1C) and associative conditioning (Table 1D) as approaches to promote preferences for healthy foods.

Repeated exposure and variety exposure

During this period of complementary feeding, mere repeated exposure to a novel food leads to increased intake and positive behavioural responses (e.g. positive facial expressions) in the short-term (28–30), with some evidence that repeated exposure effects generalize to similar foods (e.g. repeated exposure to green beans led to increased intake of artichokes but not apples or plums (23)). A number of studies have illustrated that repeated exposure to a variety of foods may be even more effective in promoting acceptance of novel foods, which may be an adaptive response based on the way new foods and flavours are experienced during infancy (e.g. exposure to a variety of flavours from the maternal diet during breastfeeding). Formula-fed infants who were repeatedly exposed for 9 d to carrots or a rotating variety of starchy vegetables (peas, potatoes and squash) later consumed more carrots than infants who were repeatedly exposed to potatoes only (25). Variety exposure, but not repeated exposure to only carrot, also facilitated acceptance of an entirely novel food, puréed chicken (25), suggesting an added benefit of variety. Variety exposure trials with fruits (29) and other types of vegetables (31) produce similar effects. Additionally, more extensive variety exposure (i.e. daily change) increases infant intake and acceptance of a target vegetable better than lower variety exposure (i.e. changes every third day) (31), and effects of variety exposure appear to be robust, lasting at least 3 to 6 years (32). There is some evidence that breast-fed infants are more responsive to exposure effects than formula-fed

Table 2 Influences on food preferences during early childhood (ages 2–5): selected human studies from the past 10 years

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
A. Repeated exposure and variety						
O'Connell, Henderson, Luedicke, & Schwartz, 2012 (52)	Does repeated exposure (RE) to vegetables in the context of lunch at a community preschool increase vegetable intake?	Randomized trial in community preschools, with pre-test, 6-week exposure period, first post-test and then delayed intervention administered to the control group, followed by another post-test During intervention, 1 of 3 (cauliflower, snow peas, green pepper) vegetables was served over 30 d until each was served 10 times Target vegetables were selected based on parents' survey responses; these were the most unfamiliar and least liked vegetables	Ninety-six children ages 3–6 years old, with most (85%) 4–5 years old; children attended 1 of 2 private preschools in Northeast USA	Condition: One preschool was assigned to administer 6 weeks of RE to three vegetables, and the other served as a control. Afterward, a delayed intervention was administered in the control group	Vegetable intake was measured by researchers at pre-test and both post-tests. The main analysis used pre-test and first post-test, which positioned the preschool receiving RE first as the intervention school and the other as the control	Effects of RE on intake were in the opposite direction of what was expected: vegetable intake decreased in the intervention group, driven by decreases in cauliflower intake in the intervention group and increases in pepper intake in the control condition The vegetables were served at lunch, and tasting the vegetables was not required. Half of children were willing to try vegetables at least 3 times during exposures 2–9 Children's vegetable intake was associated with average intake of their tablemates
Rigal, Rubio, & Monnery-Patris, 2016 (62)	Do caregiving and temperament modify effects of RE to an initially rejected target food?	Between-subjects, with a pre-test, 5 exposure trials and a post-test Jarred baby corn was selected as the target vegetable based on a pre-test with 5 toddlers who showed negative reactions to the food but were willing to taste it	Ninety-eight children aged 21–41 months attending 1 of 2 childcare centres in a middle-income suburb in France	Condition: Gentle or harsh instruction given during tastings Temperament: Child's inhibitory control level	Intake of the target food at pre-test and post-test	Intake of the target food increased in all groups, with the greatest increases in the gentle instruction and high inhibitory control group and the lowest in the harsh instruction and low inhibitory control group Findings provide evidence that caregiving and temperament may exacerbate or attenuate RE effects
Roe, Meengs, Birch, & Rolls, 2013 (63)	How does offering a variety of vegetables or fruits versus a single vegetable or fruit	Within-subjects design; experienced all conditions across eight snack times	Sixty-one 3-to 5-year-old children attending a university childcare centre in	Condition: served each of three vegetables or a variety (all three types), served each	Selection of and intake of the vegetables and fruits	Children selected and ate more vegetables and more fruits when a variety was

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
	affect children's intake?	Vegetables and fruits were selected from foods already served at the childcare: cucumber, sweet pepper, tomato; apple, peach, pineapple	Pennsylvania, 56% White, 29% Asian, 11% Black or African-American and 4% Pacific Islander	of three fruits or a variety (all three types)		provided versus provision of a single vegetable or fruit Selection and intake were assessed during exposure to the study conditions (no separate post-test)
B. Comparing repeated exposure and associative conditioning						
Ahern, Caton, Blundell, & Hetherington, 2014 (47)	What are the effects of RE and associative conditioning (AC) on intake of root vegetable puree?	Within-subjects design, with a pre-test, an exposure period with 6–8 exposures each to unmodified and modified vegetable purees, post-test and 1 and 6 month follow-ups Three target vegetables (celeriac, swede and turnip) were selected after a prior study indicated that they were relatively novel and neutrally liked by preschool children	Twenty-nine children aged 1.25 to 4.67 years recruited from childcare centres in West Yorkshire area, UK	Condition: Children were assigned to be exposed to one of the vegetable purees plain and one with added apple puree during the exposure period (and to not taste the third flavour during the exposure period)	Intake of the plain purees at pre-test and post-test and follow-ups, as well as intake of purees in their assigned condition during the exposure period	Intake of vegetable purees increased from pre-test to post-test for all conditions. Findings did not support effects of AC over and above RE. The addition of the apple puree did not lead to further increases When examining intake within the exposure period, results suggest that as few as three exposures increased intake Within children, post-intervention intakes across conditions were correlated Younger children consistently ate more puree across the intervention
Anzman-Frasca, Savage, Marini, Fisher, & Birch, 2012 (49)	Does AC increase liking and intake of a raw vegetable that was previously not liked over and above effects of RE?	Two experiments: 1 between-subjects, 1 within-subjects, both with a pre-test, eight tasting trials and post-test Vegetables and dips that the children did not like and liked, respectively, were selected, with selection at the classroom level	Eighty-four children aged 3–6 years (n = 41 in Experiment 1, 84% White; n = 43 in Experiment 2, 80% White) in childcare centres in Pennsylvania	Condition: RE to the vegetable (yellow squash, red pepper) or AC in which it was repeatedly paired with a liked dip In Experiment 1, children were randomly assigned to one of the conditions mentioned earlier, and in Experiment 2, each child tasted	Liking measured using a 3-point ordinal (happy-face) scale at pre-test, post-test and each tasting trial (both experiments) Intake of the vegetable at pre-test and post-test (Experiment 1 only)	Children's liking and intake increased from pre-test to post-test. Effects of AC did not differ from RE effects In both experiments and conditions, increases in liking were detected by the 6th exposure to the previously not liked vegetables

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
				two vegetables, one with dip and one without		
Bouhlal, Issanchou, Chabanet, & Nicklaus, 2014 (54)	How do RE and two forms of AC affect children's liking and intake of a non-familiar vegetable?	Between-subjects design, with a pre-test, eight exposure trials, post-test and 1-month, 3-month and 6-month follow ups The target vegetable was selected to be unfamiliar and neutral to toddlers. The unconditioned stimuli (salt, spice) were selected to be familiar and liked. Selections of the foods/flavours were made using a survey administered to 229 parents of children not in the current study sample	One hundred fifty-one toddlers (mean age = ~2.3 years) attending 1 of 6 nurseries in Dijon, France	Condition: assignment to RE group or 1 of 2 AC groups Here both AC groups are flavour–flavour learning (FFL) groups as unconditioned stimuli did not contain energy Groups were exposed to basic salsify puree (RE) or salsify puree with additional salt (FFL-salt) or spice (FFL-nutmeg)	Children's liking and intake of the target vegetable was measured at all time points. Intake of carrot puree was measured at pre-test, post-test and the 3-month and 6-month follow-up assessments (for comparison).	Intake of the target vegetable increased from pre-test to post-test in all groups, with greatest increases in the RE group vs. FFL-salt (significant) and vs. FFL-nutmeg (trend). Intake of comparison vegetable did not increase Liking increased linearly from pre-test to post-test in all groups, with liking at post-test highest in the RE group Acceptance was maintained at the 6-month follow-up by all groups. Liking did decrease in the RE group by the 6-month follow-up, but intake remained highest in this group at 6 months In the RE group, the increase in intake from pre-test to first tasting trial was significant, with continued increases thereafter; in the other groups, these initial increases were trends Overall findings show no effects of FFL over and above RE in increasing liking and intake of the target vegetable, which in this study was pureed and not bitter

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
Capaldi & Privitera, 2008 (57)	Does AC increase liking of a sour fruit flavour?	Between-subjects design, with pre-test, a 20-d exposure period, 5-d post-test period and follow-up 2 weeks later It appears that study foods/flavours were selected by researchers a priori	Forty-nine 2- to 5-year-old children recruited from two university childcare centres in Florida (The article also reports a 2nd experiment with undergraduates, which is not included here given the focus on early life.)	Condition: assignment to grapefruit juice with 20% sucrose or 30% sucrose	Liking of plain grapefruit juice before, during and after a testing period in which it was paired with sucrose Liking of a comparison beverage (Kool-Aid) at pre-test and post-test	Among those who did not already like unsweetened grapefruit juice at baseline, liking for the plain juice increased after the exposure period in which it was paired with sucrose (both concentrations). Among those who liked the plain juice at baseline, these increases were not significant (but liking did not decrease either) There was no RE control in this study to which AC could be compared This study differs from many others in this area given its focus on fruit/sour flavours versus vegetable/bitter flavours
Capaldi Phillips & Wadhera, 2016 (58)	Does AC increase liking and intake of bitter and non-bitter vegetables?	Within-between design, with a pre-exposure preference assessment, 14-d exposure period and post-test day 15 Study foods/ flavours were selected based on survey responses from these children's parents, selecting target vegetables never tried by the majority	Twenty-nine 3- to 5-year-old children from Arizona, recruited via email	Condition: assigned to receive (i) cooked Brussels sprouts (bitter) with sweetened cream cheese and cooked cauliflower (non-bitter) with unsweetened cream cheese, (ii) the opposite pairing or (iii) both vegetables without any cream cheese	Liking and intake of both vegetables plain at post-test	Liking of the bitter vegetable at post-test was higher among children who had tasted the vegetable paired with cream cheese (sweetened or unsweetened), demonstrating effects of AC over RE. Post-test liking of the non-bitter vegetable did not differ by condition Intake of vegetables did not differ by condition but was correlated with liking in the case of both the bitter and non-bitter vegetable Authors concluded AC may be more effective than RE in increasing liking of

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
						bitter vegetables; RE may be enough to increase liking otherwise
Caton, Ahern, Remy, Nicklaus, Blundell, & Hetherington, 2013 (55)	How do RE and two forms of AC affect intake of a novel vegetable puree?	Between-subjects design, with a pre-test, 10 exposures, post-test and follow-up assessments at 3, 4 and 5 weeks after the study period Target vegetable (artichoke puree) was selected based on responses to a questionnaire completed by 71 caregivers of preschoolers, showing it was unfamiliar	Seventy-two children ages ~1–3 years recruited from six private childcare centres in West Yorkshire, UK[a]	Condition: Children were randomly assigned to 10 exposures of basic artichoke puree (RE) or the puree with increased sugar or oil (AC)	Intake of basic artichoke puree and carrot puree (for comparison) at pre-test and post-test and of the assigned puree throughout the exposure period	Exposure to the target vegetable increased intake over time, regardless of study condition, and over and above increases in intake of the comparison vegetable Five exposures significantly increased intake, versus 1st exposure
Caton, Blundell, Ahern, Nekitsing, Olsen, Moller, Hausner, Remy, Nicklaus, Chabanet, Issanchou, & Hetherington[b], 2014 (26)	Which characteristics predict individual differences in RE effects?	Between-subjects design, with pre-test, post-test and 5–10 exposures in between Selection of target vegetable (artichoke puree) was informed by survey results suggesting it was unfamiliar	Three hundred thirty-two children aged 0.33 to 3.17 years (3 groups of children from studies in the UK, Denmark and France)[a,c]	Condition: assigned to 1 of 3 versions of a novel vegetable (artichoke puree): basic, sweet or added energy	Intake of basic artichoke puree before and after the exposure period	40% of children were 'learners', increasing intake over time, while the other children exhibited other patterns (plate cleaners, non-eaters, other/variable) Older children were more likely to be non-eaters. Non-eaters had the highest 'food fussiness' scores Plate cleaners were lower on satiety responsiveness than non-eaters Authors concluded that, while RE is effective, alternative strategies focused on initial willingness to taste may be needed for fussier and older children
Fisher, Mennella, Hughes, Liu, Mendoza, &	Can AC increase intake of a moderately liked raw vegetable	Within-subjects and between-subjects design, with a pre-test, 7-week (13	One hundred fifty-two 3- to 5-year-old predominantly	Condition: children were assigned at the classroom level to 1 of 4 groups: raw	Familiarity with and liking of six vegetables at pre-test and intake of	The main effect of condition on intake of the raw bitter target vegetable

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
Patrick, 2012 (59)	among children sensitive to bitterness?	exposure) exposure period and post-test Children's familiarity with and liking of six raw vegetables were used to select a moderately liked raw target vegetable (half of children thought it was 'yummy' at baseline), which would be paired with a familiar, liked dip	Hispanic (88%) children	broccoli with regular or reduced-fat ranch salad dressing, broccoli with no dressing or broccoli with the regular dressing as a sauce (no dipping)	the selected target vegetable (broccoli) and five other vegetables at post-test Sensitivity to bitterness (PROP) also assessed and examined as a moderator of AC effects	was not significant, but effect of condition did interact with genetic sensitivity to bitterness: AC in the form of providing salad dressing (both dips and as a sauce) increased target vegetable intake among bitter-sensitive children Liking of target vegetable increased after exposure period, and increases in liking from pre-test to post-test were greater for the target vegetable vs. the other five. Post-test liking did not vary by condition or bitter sensitivity
Hausner, Olsen, & Moller, 2012 (48)	How do RE and AC affect children's intake of a novel vegetable?	Between-subjects design, with a pre-test, 10 exposures, post-test and 3-month and 6-month follow-ups Target vegetable (artichoke puree) selected because survey about vegetables introduced to children this age in this country suggested it was unfamiliar and neutral	One hundred four 2- to 3-year-old children recruited from five nurseries in Copenhagen, Denmark, area[c]	Condition: children were assigned to unmodified artichoke puree, sweetened puree (labelled as FFL condition) or puree with added fat (labelled as FNL condition)	Intake of unmodified artichoke puree and carrot puree (for comparison) at pre-test, post-test and follow-ups and artichoke intake at each exposure	Intake of artichoke puree increased in the RE condition by the 5th exposure, in the FFL condition by the 10th and did not increase in the FNL condition. RE led to the largest increases in intake at post-test and follow-up
Havermans & Jansen, 2007 (53)	Does flavour–flavour learning increase children's liking of a specific vegetable?	Within-subjects design, with a pre-test, six pairs of conditioning trials across 2 d and a post-test Children tasted and ranked six cooked and mashed vegetables (zucchini, pumpkin, peas, cauliflower, broccoli, carrots);	Twenty-one children, mean age of 5.2 years, recruited from primary schools in the Netherlands, 13 of whom completed the experiment	Condition: one of the child's target vegetables was sweetened throughout the exposure period (labelled as FFL condition), and one was not	Vegetable preference	Results showed increased preference for the vegetable that had been sweetened during the conditioning trials, supporting FFL effects

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		those they ranked 3rd and 4th were used as their target vegetables				
C. Social influences: pairing food options with characters, toys and/or branding						
de Droog, Valkenburg, & Buijzen, 2010 (65)	Do characters increase children's liking of and intent to request fruit and candy?	3 × 2 mixed factorial design, 1 time point Target foods were selected by the researchers, with similar flavours selected across the healthy/unhealthy foods (banana, banana candy) to decrease the influence of flavour preferences on results	Two hundred sixteen 4-to 6-year-old children from three Kindergartens in the Netherlands	Condition: Children were assigned to receive the healthy (banana) snack and unhealthy (banana candy) snack, each with either no character, a familiar character or an unfamiliar character	Children's liking of each snack and their intent to request it the next time they were in the market (4-point smiley face scales)	Overall, children liked the unhealthy snack more compared with the healthy snack. Further analyses showed that this difference was only significant for the condition in which there was no character paired with the food. When the healthy snack featured a character, fruit and candy liking were equal, for both familiar and unfamiliar characters. Results were consistent for purchase request intent
Kotler, Schiffman, & Hanson, 2012 (66)	Do media characters influence children's food choices?	Between-subjects design, 1 time point Foods were chosen by the researchers (see outcome measures)	Three hundred forty-three children ages 2 to 6, recruited from 14 childcare centres around New York City; 42% White, 35% African-American, 11% Latino, 5% Asian American, 7% multiracial. Families were lower-income to middle-income	Condition: Children were assigned to receive either (i) no characters paired with food pictures, (ii) familiar characters with 1 food item from each pair and unfamiliar characters with the other or (iii) familiar/unfamiliar character pairings that were the opposite of Group ii	Food preference: Nine pairs of foods were shown, and children picked one from each pair that s/he would like to eat: zucchini vs. celery, mushrooms vs. peas, grapes vs. banana, donut vs. Cheerios, potato chips vs. apple, chocolate vs. broccoli, star fruit vs. melon, tomatoes vs. cauliflower, Saltines vs. pumpernickel crackers	When comparing similar foods (two vegetables, two fruits, two grains), children were more likely to prefer the target food associated with familiar characters vs. unfamiliar or no character When comparing dissimilar foods (a non-nutritious snack vs. healthier option), familiar characters promoted selection of the unhealthy snack but not the healthy snack
McAlister & Cornwell, 2012 (67)	How do collectible toys affect children's attitudes about and preferences for healthy and unhealthy meals?	Two within-subjects experiments, 1 time point each	Experiment 1: 85 children ages 3–5 years from 1 middle-income US preschool Experiment 2: 56 children ages 3–	Experiment 1: Each child viewed an unhealthy 'meal deal' (pizza, fries, soda) and a healthy 'meal deal' (soup, salad, milk) paired with each of the	Experiment 1: attitude score, which was an average of children's ratings of their liking for each meal and anticipated taste	Experiment 1: The unhealthy meal received higher ratings than the healthy meal when there were no premiums provided. For each meal,

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Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
			5 years, from 2 campuses of a middle-to-upper-income US preschool	following: no premium, a collectible toy monster (shown to complete a set of 3) and a non-collectible toy truck Experiment 2: children were shown pairs of images (meals from Experiment 1 paired with toys or not)	(each on a 5-point smiley-face scale) Experiment 2: When being shown pairs of meals, children chose which meal they would like to have (preference). They also completed a similar rating task as in Experiment 1 with a broader set of meal possibilities: unhealthy/healthy, paired with no premium, non-collectible toy, collectible toy or superfluous toy premium	ratings were highest when the collectible toy was included. The toy premiums had greater effects on the healthy meal vs. the unhealthy meal, with possible ceiling effects. The healthy and unhealthy meals were rated as equally appealing when paired with the collectible toy, but not the non-collectible toy Experiment 2: When choosing among pairs, children were more likely to choose unhealthy meal if no premiums were shown, while number choosing the unhealthy meal did not differ from those choosing the healthy meal when collectible toy premiums were shown. The only instance in which healthy meal was chosen over unhealthy is when former had a toy premium available, and latter did not. Attitude ratings for the meals were higher when paired with both collectible and non-collectible toys vs. none, with a stronger influence of collectibles
Nicklas, Goh, Goodell, Acuff, Rieher, Buday, & Ottenbacher, 2011 (68)	Do fruit and vegetable commercials affect preschoolers' fruit/vegetable liking?	Between-subjects, with a pre-test, four exposures to separate fruit and vegetable commercials within a 15-min TV program (for the intervention group) and a post-test	One hundred eighty-three preschool children (age 3–6) from four Head Start Centres in Houston, TX	Condition: Children were randomly assigned to the intervention group, which viewed the 30-s fruit and vegetable commercials, or the control group	Fruit and vegetable liking (3-point yummy, yucky, just OK scale). Scores across 11 fruits and 15 vegetables were averaged to obtain total fruit and vegetable liking scores; average	Children in the intervention group had higher liking for the target vegetables vs. controls after exposure to the vegetable commercial. Fruit preferences were

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Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		In the commercials, 'Judy Fruity' promoted apples and bananas, and 'Reggie Veggie' promoted broccoli and carrots. Target foods were chosen by the researchers			scores for the target fruit and vegetables were also calculated	not affected, possibly due to ceiling effects
Robinson, Borzekowski, Matheson, & Kraemer, 2007 (69)	How does fast-food branding affect children's taste preferences?	Within-subjects design, 1 time point	Sixty-three children ages 3–5 years, 55.6% Latino/ Hispanic, 1.6% African-American, 6.3% Asian/Pacific Islander, 1.6% Native American/ Alaskan Native, 12.7% White and 22.2% multiracial or other	Children tasted five pairs of the same foods/beverages, 1 in fast-food packaging and 1 in unbranded packaging	After tasting each food pair, children were asked to indicate if they tasted the same or if one tasted better. A total preference score was calculated	Children preferred the branded foods over unbranded, with greater effects among children with more exposure to television and the target fast-food restaurant
D. Social influences: modelling						
Frazier, Gelman, Kaciroti, Russell, & Lumeng, 2012 (70)	How do models' characteristics affect children's food preferences?	Within-subjects design, 1 time point	Study 1: 35 children ages 3–5, 37% Black, 40% White, 20% biracial, 3% Other Study 2: 40 children ages 3–6, ~33% Black, 53% White, 10% biracial, 5% Hispanic	Children were asked to pick between photographs of different models eating foods, with models varying along dimensions of: gender, race (Black, White), age (child, adult), expression (acceptance or rejection of the food)	Children looked at photographs (see independent variables) and picked which food they would like for snack	Children preferred foods being eaten by models with positive (vs. negative) expressions and who are of the same gender and of a similar age (child vs. adult)
Greenhalgh, Dowey, Horne, Lowe, Griffiths & Whitaker, 2009 (71)	How do positive and negative peer modelling affect children's consumption of novel foods?	Between-subjects design, with four snack occasions and two samples Target foods were created by colouring and renaming potato bread and quorn. Target foods were presented with other foods (grapes, cheese, pita bread, carrot)	Study 1: 35 5- to 7-year-olds Study 2: 44 3- to 4-year-olds Children were recruited from primary schools in the UK	Condition: Group A was exposed to a positive peer model in sessions 1 and 3; Group B was exposed to negative peer modelling in session 1 and positive peer modelling in session 3; Group C was a control condition (always ate alone)	Amount of each target food consumed	Both positive and negative modelling affected consumption, with evidence that negative modelling may be particularly robust as its effects were not reversed by positive modelling in the younger children
Staiano, Marker, Frelier, Hsia & Martin, 2016 (72)	Does screen-based peer modelling influence children's vegetable consumption or preference?	Between-subjects design, with DVD exposure and post-test sessions on days 1, 2 and 7	Forty-two 3- to 5-year-olds (73.8% White) who were attending 1 of 2 full-day US preschools	Condition: Children were assigned to view a DVD featuring children promoting bell peppers, a non-	Children's preference for, selection of, consumption of and requests for bell peppers	Participants in the vegetable DVD group consumed more bell peppers on day 7 than participants in the

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
				food-related DVD from the same series or no DVD		control group (but not significantly more than the other DVD group). Children in the vegetable DVD condition who ate the modelled vegetable reported a higher preference for eating that vegetable again
E. Social influences: rewards						
Anez, Remington, Wardle, & Cooke, 2013 (61)	Does previous experience with food rewards moderate effects of a non-food reward on liking and intake of a target vegetable?	Randomized trial (school-based intervention), with a pre-test, 12 daily taste exposures, post-test and 1-month and 3-month follow-ups Each child's target vegetable was his or her 4th liked vegetable, based on rank ordering of: carrot, red pepper, snap pea, cabbage, cucumber, celery	Subsample of one hundred thirty-seven 4- to 6-year-old children from a large school-based study in the UK. 64% were White; their school had greater diversity in race/ethnicity and socioeconomic status than the national average[d]	Condition: RE to the vegetable, RE with a tangible reward (sticker), RE with a social reward (praise) or no-treatment control group Past experience of instrumental feeding (IF, or being rewarded for eating) assessed via parent survey	Liking and intake of the target vegetable were measured at pre-test, post-test and follow-ups using a free-choice consumption task	Liking increased in all intervention groups (tangible reward-sticker, social reward-praise, RE only) regardless of experience of IF Both reward groups increased intake versus controls, but in the RE only group, only those with limited IF experience increased consumption, suggesting RE may be enough to increase intake among children who do not expect to be rewarded but not among those who do
Cooke, Chambers, Anez, Croker, Boniface, Yeomans, & Wardle, 2011 (76)	What are the effects of pairing RE to a disliked vegetable with a tangible reward (sticker), social reward (praise) or no reward, with one another and a no-treatment control?	Cluster-randomized trial, with a pre-test, 12 daily taste exposures, post-test and 1-month and 3-month follow-ups Each child's target vegetable was his or her 4th liked vegetable, based on rank ordering of: carrot, red pepper, snap pea, cabbage, cucumber, celery	Four hundred twenty-two 4–6-year-old children[c] The school chosen for this study had greater diversity in race/ethnicity and socioeconomic status than the national average	Condition: RE to the vegetable, RE with a tangible reward (sticker), RE with a social reward (praise) or no-treatment control group	Liking and intake of the target vegetable were measured at pre-test, post-test and follow-ups using a free-choice consumption task	Liking increased more in all three intervention conditions versus the control group, with sustained effects at follow-up and no difference between the sticker, praise and RE conditions Intake increased in all groups as well, although effects of RE alone became non-significant by the 3-month follow-up assessment

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Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
Horne, Greenhalgh, Erjavec, Lowe, Viktor, & Whitaker, 2011 (74)	Does an intervention that combines modelling and rewards increase preschoolers fruit and vegetable consumption?	Within-subjects design, with Baseline 1, a fruit intervention, Baseline 2, a break, Baseline 3, a vegetable intervention, Baseline 4 and a 6-month follow-up Sixteen fruits/ vegetables consumed at >50% by no more than half the sample were selected for presentation during the study (four target fruits, four non-target fruit, four target vegetables, four non-target vegetables)	Twenty 24- to 52-month-old children (14 at follow-up) attending a university childcare centre in the UK	All children were exposed to the interventions, which included modelling (via videos) and reward (for consuming target fruits/vegetables) components, with the target foods changing over time	Intake of target foods over time and relative to non-target foods	Increases in intake of target fruits and vegetables increased after the respective intervention periods and were maintained at 6-month follow-up Results did not support the presence of mere repeated exposure effects, as acceptance of target vegetables did not increase over repeated exposures prior to the implementation of the vegetable-focused intervention
F. Social influences versus other strategies: comparisons of multiple learning paradigms						
Holley, Haycraft, & Farrow, 2014 (75)	Can parent led home-based interventions using repeated exposure, modelling and/or rewards increase children's acceptance of a disliked vegetable?	Randomized trial, with children assigned to 1 of 4 intervention groups or a no-treatment control. Intervention group children were exposed to a disliked vegetable by a parent for 14 d, with a pre-test and post-test before exposure Parents ranked their child's liking of six raw vegetables (corn, celery, red pepper, tomato, cucumber, snap peas); the 4th ranked vegetable was selected as the target	One hundred fifteen 2- to 4-year-old children recruited from parent–toddler groups and childcare centres around the East Midlands, UK. 85% of parents were White	Condition: RE only; modelling and RE; rewards and RE; or modelling, rewards and RE	Outcomes: Liking and consumption of the target vegetable	The modelling, rewards and RE group and the rewards and RE group had the highest liking ratings, followed by the modelling and RE and RE groups, with the lowest ratings in the control group Consumption increased in the modelling, rewards and RE group and the rewards and RE group, versus controls
Vandeweghe, Verbeken, Moens, Vervoort & Braet, 2016 (60)	What strategies work best to improve a child's willingness to taste disliked vegetables, and to what extent does reward sensitivity moderate these effects?	Between-subjects design with 1 session The vegetable used in the experiment was one that the child disliked based on parent	Two hundred four 3- to 5-year-old children recruited from Kindergartens in Ghent, Belgium	Condition: children were assigned to 1 of 4 strategies: reward, modelling, verbal encouragement, neutral instructions	Willingness to taste (coded from videos)	Compared with neutral instructions, willingness to taste was higher when using modelling and rewards, with the latter effect moderated by reward sensitivity:

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Table 2 (Continued)

Authors & year	Research question	Design	Sample characteristics	Independent variables	Outcomes	Conclusions
		responses to a list of 10 vegetables (Brussels sprouts, broccoli, cauliflower, chicory, fennel, leek, mushrooms, peas, spinach, zucchini)		Moderator of interest was children's reward sensitivity		children with high reward sensitivity were more likely to taste immediately when rewarded. Also, children with lower reward sensitivity were more likely to taste when verbally encouraged (with hesitation) Note: This study differs from most others in examining willingness to taste instead of liking, preference, consumption. Willingness to taste is an important first step in initializing exposure or other learning effects (and oftentimes those who are not willing to taste are removed from learning studies like those reviewed earlier)

[a]Sample overlaps with another study reported in the table.
[b]Included in both Tables 1 and 2 given wide age range.
[c]Sample overlaps with another study reported in the table.
[d]Sample overlaps with another study reported in the table.
AC, associative conditioning; FFL, flavour–flavour learning; FNL, flavour–nutrient learning; IF, instrumental feeding; RE, repeated exposure.

infants (31,33), which may be a product of prior exposure during breastfeeding but warrants further examination due to conflicting results (Table 1E) (22,23,28,34).

Associative conditioning

Infants can also learn to prefer complementary foods and beverages through associative conditioning, or pairing familiar, preferred flavours with the complementary foods. Two specific forms of associative conditioning are flavour–flavour learning, in which a target flavour is paired with an already-liked flavour and acquires the valence (i.e. perceived positive or negative value) of the latter, and flavour–nutrient learning, in which the target flavour becomes liked through the association with the positive post-ingestive consequences of consumption. Animal models have shown associative conditioning can be powerful, with flavour–nutrient learning in particular capable of inducing avid consumption of stimuli that would ordinarily be rejected. For example, rats trained to associate a bitter or sour solution with intragastric glucose infusion reversed their reaction to treat that taste as attractive as a sugar solution (35). Infant rats demonstrate both flavour–flavour learning and flavour–nutrient learning prior to weaning (36), suggesting associative conditioning may underlie the aforementioned flavour preferences human infants acquire during breastfeeding, via pairings of breast milk with novel flavours. Some evidence suggests juvenile rats are more sensitive to flavour–nutrient learning immediately following weaning, compared with adolescent rats approaching puberty (37), supporting the idea that associative conditioning may play an important role at the time of transition from exclusive reliance on mother's milk to a wider range of complementary foods and beverages.

Compared with animal model research as well as human research later in the lifespan, there is less research on

associative conditioning in humans during infancy. Human infants prefer cereal prepared with their mothers' milk to cereal prepared with water (16). They also show more positive facial expressions in response to green beans that are repeatedly paired with a sweet taste (peaches) compared with green beans repeatedly presented alone, but no intake differences between these conditions (28). Similarly, in a study involving exposure to artichoke puree served alone (repeated exposure) or paired with sweetness (flavour–flavour learning) or fat (flavour–nutrient learning), the associative conditioning paradigms did not show a superior effect on infant intake over repeated exposure (38). A different study suggested that the combination of associative conditioning and variety exposure increased infants' acceptance and liking of carrot and green bean purées, although the relative contribution of each of these strategies could not be disentangled (39). Given the methodological differences between these studies and the small body of literature on associative conditioning in human infants, more research in this area is needed, with the extant literature most strongly supporting effects of repeated and variety exposure in the meantime.

Other early influences

While much of the human research in this area focuses on specific foods, animal models have addressed broader diet characteristics, such as overall sweetness and energy density. Humans' liking for sweetness is highest early in life and declines with slowing of physical growth (40). Animal studies suggest that the post-weaning diet determines that trajectory. Feeding a high-fat diet from weaning into young adulthood maintains rats' immature preference for high sweetness (41), and high-fat diet exposure during the juvenile stage (prior to puberty) increases young rats' subsequent motivation to obtain sweets (42). Lasting effects on motivation into adulthood do not necessarily require early chronic excess energy intake. Even occasional brief access to very sweet snacks (sugary breakfast cereal) in the days following weaning increased rats' consumption of sweets in adulthood (43). The effects of chronic sugar consumption through adolescence are more pervasive and appear to reduce the reward value of sweetness, which may reflect onset of a 'reward deficit' syndrome driving selection of progressively sweeter foods to maintain the initial subjective pleasure (44).

Relatedly, one study compared the effects of chronic consumption (from pre-puberty into young adulthood) of a highly processed, 'junk food' diet versus an equally diverse but 'natural' diet of minimally processed whole foods (fruits and vegetables, whole grains, lean meats, etc. without added fats, sugars or flavours) (45). The 'junk food' diet was selected to mimic modern diets high in processed foods and included a wide variety of packaged foods with added sugars, fats and flavours, such as pastries, sugary breakfast cereals and ready-to-eat microwavable pasta. Unsurprisingly, 'junk foods' induced hyperphagia and overweight, while the natural diet did not. Yet, a paradoxical effect was revealed in adulthood when sweet solution was offered *ad libitum*: natural-diet-fed rats showed exaggerated hedonic responses but persistently low intake. While specific causal mechanisms remain to be explored, this outcome may reflect that these rats are attracted to sweetness but 'satisfied' by small amounts.

Taken together, research supports exposure to a variety of healthy foods, as well as limited exposure to sweetened foods and those high in saturated fat, during the prenatal, early milk-feeding and introduction to complementary foods and beverages periods as a promising approach to establish healthy food preferences. More human research is needed to better understand impacts of associative conditioning and order of solid food introduction on infants' food acceptance and preferences, as well as the extent to which animal research mentioned earlier applies to humans and possible interactive effects of repeated exposure, variety exposure and associative conditioning.

Influences during early childhood (age 2–5)

The transition from infancy to early childhood brings heightened neophobia, or rejection of new foods, along with increased autonomy and self-regulation abilities. Toddlers have typically transitioned to the family diet and continue to 'learn how to eat', internalizing messages about the foods and customs of the culture. While some of the influences that shaped preferences during infancy remain relevant during this period, the characteristics of early childhood mean that these strategies look different in practice.

Repeated exposure

Repeated exposure continues to be relevant; a robust way to increase acceptance of new foods among 2- to -5-year-olds is by repeatedly exposing them to small tastes of the food (Table 2A). Repeated exposure also appears to teach young children the appropriate context for novel foods: after exposures to either sweetened, salty or plain tofu (46), children learned to prefer the now-familiar type over the others. An often-cited conclusion is that it takes ~15 exposures to increase children's acceptance of new foods. However, in many studies, the number of exposures between pre-tests and post-tests are predetermined, and measures are not taken at intermediate points to identify when repeated exposure effects emerge. Recent research that has performed the latter has shown effects after three (47), five (48) or six (49) exposures, which may vary by specific food, child characteristics or past experience.

In addition to repeated exposure experiments conducted with children, animal research can be instructive for applying this strategy. To the extent that exposure effects involve habituation of neophobic responses, it is helpful to

understand factors influencing neophobia. Rats consuming several flavours in sequence show primacy and recency effects, with greatest neophobia reductions seen for the first and last flavours (50). Taste exposure also exhibits an 'incubation' effect, such that reduction in neophobia is stronger when some time has elapsed since exposure (51). These findings suggest that exposures to small tastes of new foods at well-spaced time intervals before or after meals of familiar foods may be most effective to promote acceptance. More research on these principles is warranted in children. In one of the few published human studies that did not show expected repeated exposure effects, target vegetables were served within the meal (at lunch at preschool), with a low rate of tasting target foods (52).

Associative conditioning

Compared with infancy, there are more studies that examine repeated exposure versus associative conditioning in early childhood (Table 2B). These strategies can mean the difference between repeatedly presenting new foods plain (repeated exposure), with salt or sweetener (flavour–flavour learning) or with a caloric accompaniment (flavour–nutrient learning). When comparing effects of associative conditioning and repeated exposure on food acceptance and intake, some studies found that associative conditioning was more effective (53), some found it less effective (48,54) and others have shown no difference (47,49,55). For example, when vegetables (red pepper, squash) were presented alone (repeated exposure) or with a liked dip (associative conditioning), liking and intake of vegetables increased similarly across conditions (49). In another study, after 10 exposures to sweetened (associative conditioning) or unsweetened (repeated exposure) artichoke puree, repeated exposure led to the greatest increases in intake of unmodified puree and increased intake by the 5th exposure, whereas associative conditioning did not do so until the 10th (48).

Nuanced discrepancies in repeated exposure versus associative conditioning effects could be due to variability in the foods used and/or individual characteristics of children studied. Human studies in which flavour–nutrient learning effects are not superior to repeated exposure often use fat as the main energy source in the flavour–nutrient learning condition. Animal work shows fat to be less effective than energy from carbohydrates at increasing preference for a target flavour (56); this may explain some discrepancies. Properties of the target food also matter, with evidence that associative conditioning is less likely to be effective at further increasing the valence of foods that are already liked (57) but may be particularly likely to offer advantages over repeated exposure for bitter vegetables. When preschoolers were repeatedly exposed to bitter (Brussels sprouts) and less-bitter (cauliflower) vegetables with cream cheese or alone, pairing vegetables with cream cheese increased liking and consumption of Brussels sprouts more than repeated exposure, while effects on cauliflower liking and consumption did not differ by condition (58). Similarly, individual children's bitter sensitivity moderated effects of learning on broccoli intake, such that bitter-sensitive children's intake of broccoli increased after exposures to broccoli with dip but not plain broccoli; for non-bitter-sensitive children, the presence of dip did not affect learning (59).

In the aforementioned artichoke study, a third of children were resistant to acceptance changes (48), reinforcing the idea that research on individual differences can inform the precision of implementation efforts. Among existing studies that do consider moderators of food preference learning in early childhood, bitterness sensitivity, temperament and behavioural styles (e.g. satiety responsiveness, sensitivity to rewards and inhibitory control, or the ability to resist automatic behavioural responses) and past experience have been highlighted as relevant (26,59–62). For example, Caton *et al.* (26) found evidence that children with a high enjoyment of food and low satiety responsiveness, as well as those high on food fussiness, may learn less readily.

Overall, repeated exposure is often enough to increase food acceptance during this period, with evidence also supporting variety effects: children served a variety of fruits or vegetables consumed more of each compared with children served a single fruit or vegetable type (63). Thus, repeated exposure to a variety of healthy options is again a logical first attempt in introducing foods. In instances where acceptance has not increased after many exposures, perhaps due to bitter tastes and/or individual attributes of the child, augmented strategies such as pairing vegetables with an already-liked carbohydrate-based food may be useful for encouraging initial tasting. While many studies have focused on vegetables, given their low acceptance among children, these learning strategies have demonstrated effectiveness with other tastes, such as sour fruits (57). In considering the varying taste properties of foods, it is important to underscore that preference is relative to the overarching context. Beets *et al.* (64) showed that children were willing to eat fruit and vegetable snacks when they were the only choice, but less so when presented in competition with sweet and salty snacks. During early childhood, children are learning about the environment, including which foods are available when, and how these foods are positioned in the culture. Thus, it is important to examine the development of children's food preferences in context, including sociocultural influences.

Social influences

Social influences on children's food preference learning are ubiquitous and occur at the macro-levels and micro-levels. One possible reason that human studies are less likely than animal research to show systematic, differing effects of repeated exposure versus other learning paradigms may be

because it is difficult to achieve pure repeated exposure in humans, given that exposures to new foods are typically paired with social contexts that may influence learning. Specific social influences on young children's food preferences include marketing (Table 2C), modelling (Table 2D) and rewards (Table 2E).

Pairing foods with branding, characters and/or toy incentives has been shown to increase preferences in preschool children (65–69). This phenomenon, particularly as it relates to pairing these marketing elements with unhealthy foods, has been robust, with room for future research to (i) clarify whether familiar vs. unfamiliar characters have equal effects, given mixed results (65,66), and (ii) elaborate further on conditions under which these influences could promote healthy foods. Leveraging these processes to promote preferences for healthy foods may work best if character pairings are restricted to healthy options, with minimal direct competition from less-healthy options (66).

It is unclear whether evidence for stronger effects of branding on selection of unhealthy vs. healthy options reflects attributes of the foods themselves or current norms. Children's greater likelihood of having experienced pairings of characters and toys with unhealthy foods may lead them to respond favourably to such pairings based on familiarity. Findings that branding from one fast-food chain was more effective among children who had greater exposure to television sets and that restaurant chain demonstrate the role of experience (69). Together, results highlight areas for future research and underscore the promise of intervention efforts aimed at decreasing children's exposure to unhealthy food marketing.

In terms of micro-level social influences, effects of modelling on young children's eating behaviour have been established, with evidence that preschoolers prefer foods eaten by models who enjoy the target foods and are similar to them in age and gender (70). Modelling can affect both acceptance and rejection of new foods; it may be more difficult to reverse the latter (71). A recent study highlighted the potential for modelling to extend beyond in-person experiences, with children who watched a video of other children eating bell peppers consuming more peppers than controls (72).

Finally, past research had suggested that rewarding children's intake could decrease the valence of the target food (73). However, emerging literature suggests there may be a place for some rewards, such as small tangible non-food rewards or verbal praise, in increasing young children's food acceptance. Horne *et al.* (74) demonstrated increases in consumption of a variety of target fruits and vegetables after an intervention that combined rewards and modelling. When comparing effects of rewards against other learning strategies like modelling and repeated exposure (Table 2F), some studies show that rewards are superior (75), while others show that rewards and other strategies are equal to one another and superior to a control group (60,76). Again, individual differences in temperament and/or past experiences could be responsible for differing effects.

Vandeweghe *et al.* (60) found that the effectiveness of reward strategies was moderated by children's reward sensitivity, such that children high on reward sensitivity were more willing to taste disliked vegetables when rewarded, while modelling strategies promoted willingness to taste regardless of this characteristic. In another study, repeated exposure only worked with children who had low past experience with food rewards (61); those who had high past experience with, and possibly expectations of, this type of 'instrumental feeding' only benefitted from reward strategies and not repeated exposure. Continued research on the role of rewards, particularly in cases of low willingness to taste, is warranted, but caregivers may want to proceed with caution, leveraging simpler approaches like repeated exposure and modelling if foods are already being accepted without rewards.

Conclusions

While recent studies continue to support the role of learning in the development of food preferences through early childhood, some aspects of this research, such as the role of individual differences in modifying learning, is emerging and can offer a more nuanced understanding of these effects in the future. Currently, there is robust evidence to support exposure to a variety of healthy foods from the start – during the prenatal period, early milk-feeding and the introduction to complementary foods – to promote subsequent acceptance of those foods, taking advantage of periods in which neophobia is lower and more foods are new.

While early exposure is important, with some evidence supporting enhanced learning in the youngest age groups (19,26,37), development is plastic, and it is not too late to promote healthier food preferences after infancy. In early childhood, caregivers can test which strategies work best with their child's characteristics, with the extant research providing reasons to start with the simplest strategies (e.g. repeated exposure and modelling) (74). Young children's ongoing learning about the appropriate contexts for new foods (46,61) is a reason to reserve other strategies (e.g. associative conditioning and rewards) for use when needed to motivate the initial tasting necessary for repeated exposure to begin. Researchers should continue to compare effects of these strategies from the earliest years of life, incorporating individual differences as moderators and longitudinal assessments to shed more light on sustainability of different approaches. Across both the infant and early childhood literature reviewed herein, the majority of studies were short-term experimental studies.

An additional next step is to identify ways to increase feasibility of promising strategies like repeated exposure in real-world settings. Nutrition interventions that increase

Table 3 Applying early food preference learning research: Implementation implications and opportunities for future studies

Period of lifespan	Recommendations based on the reviewed research
Prenatal period	There is little new research in this area during the prenatal period, but past findings suggest that the following strategies can promote healthier food preferences among offspring: • Expectant mothers' consumption of healthy foods containing varied flavours from the culture's diet • Limited consumption of less healthy foods (e.g. high in sugar, saturated fat)
Early milk feeding (birth-introduction of solid foods)	• Continued exposure to varied flavours of healthy foods via breast milk can further promote acceptance of these foods among breast-fed infants • While this does not apply to formula-fed infants, repeated and variety exposure during other periods works for them. Thus, it is important for formula-feeding caregivers to be persistent with repeated exposures to a variety of healthy foods during the prenatal period and weaning
Complementary foods and beverages period (introduction of solid foods-end of infancy)	• Introducing a variety of healthy solid foods and limiting exposure to less-healthy foods when the child shows signs of developmental readiness can leverage longitudinal effects of repeated exposure and variety exposure on children's food preferences • Additional research could explore whether findings from animal research generalize to humans and inform intervention implications: for example, examining the implications of different patterns of solid food introduction and expanding research on associative conditioning effects during this period
Early childhood (ages 2–5)	• Continuing to introduce new, healthy foods across repeated exposures can promote acceptance during this period. Research supports effectiveness of repeated exposure to small amounts of new foods across multiple occasions in naturalistic contexts • Caregivers and siblings should model consumption (and enjoyment) of healthy foods and not unhealthy foods • More research on the role of individual differences (e.g. how the aforementioned learning processes vary by individual foods or characteristics like temperament) is warranted to elucidate cases where strategies beyond the above (e.g. associative conditioning, rewards) can overcome barriers to the willingness to take initial taste(s) necessary for repeated exposure effects to take hold • Marketing of unhealthy foods to young children is not recommended, with opportunities for additional research on effects of marketing of healthy foods. As children's ecologies widen, with a greater number of environments influencing them as they grow, efforts to modify environments so they work with, not against, the aforementioned learning processes is warranted (e.g. implementing 'healthy defaults', where the healthy choice is the easy choice)

access to healthy foods in settings such as elementary schools have demonstrated success in increasing children's intake (77,78), with stronger evidence supporting effects on fruit intake compared with vegetables in this setting and age group (79). A qualitative study of low-income African–American and Hispanic parents of preschool children considered constraints present in the home context, and a key theme was that most parents do not serve previously rejected foods to reduce waste and save time (80). Developing intervention approaches that build on food preference learning research while addressing barriers experienced in real-world environments by lower-income families represents a new and important application of this evidence base to promote health equity.

While early food preference learning research provides practical applications that can be shared with caregivers (Table 3), this process will be easier without broader environments counteracting these efforts via ubiquitous, energy-dense, nutrient-poor foods that are consistent with genetic taste predispositions. Changes such as 'nudges' informed by behavioural economics to make healthy choices easy choices in children's everyday environments (81) can provide a supportive environment that facilitates caregivers' use of learning strategies to increase acceptance of healthier foods and sustain those effects over time.

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