Should healthy eating programmes incorporate interaction with foods in different sensory modalities? A review of the evidence

Article

Published Version

British Journal of Nutrition (2012), **108**, 769–777
doi:10.1017/S0007114511007343

Review Article

Should healthy eating programmes incorporate interaction with foods in different sensory modalities? A review of the evidence

Paul Dazeley, Carmel Houston-Price* and Claire Hill

School of Psychology and Clinical Language Sciences, University of Reading, Reading RG6 6AL, UK

(Submitted 8 June 2011 – Final revision received 23 November 2011 – Accepted 7 December 2011 – First published online 23 January 2012)

Abstract

Commercial interventions seeking to promote fruit and vegetable consumption by encouraging preschool- and school-aged children to engage with foods with 'all their senses' are increasing in number. We review the efficacy of such sensory interaction programmes and consider the components of these that are likely to encourage food acceptance. Repeated exposure to a food's flavour has robust empirical support in terms of its potential to increase food intake. However, children are naturally reluctant to taste new or disliked foods, and parents often struggle to provide sufficient taste opportunities for these foods to be adopted into the child's diet. We therefore explore whether prior exposure to a new food's non-taste sensory properties, such as its smell, sound, appearance or texture, might facilitate the food's introduction into the child's diet, by providing the child with an opportunity to become partially familiar with the food without invoking the distress associated with tasting it. We review the literature pertaining to the benefits associated with exposure to foods through each of the five sensory modalities in turn. We conclude by calling for further research into the potential for familiarisation with the visual, olfactory, somaesthetic and auditory properties of foods to enhance children's willingness to consume a variety of fruits and vegetables.

Key words: **Sensory interaction: Fruit and vegetables: Children: Food familiarity**

In a recent study of the food preferences of 1291 British children, fatty and sugary foods were consistently rated the most popular and vegetables the least popular of a selection of 115 foods[1]. Given that children's consumption of fruit and vegetables is primarily determined by their liking of these foods[2,3], it is not surprising that only 16% of preschool children achieve the recommended five portions of fruit and vegetables a day[4]. This is a cause for concern, as the first few years of life act as a critical period for developing food preferences, such that the eating habits that develop during childhood persist into adulthood[5,6]. The present review examines the factors that determine children's food preferences during the early years and interrogates the claim that engaging children in multi-sensory interactions with foods can increase their consumption of fruit and vegetables.

Children's natural predispositions towards foods

Early in life, taste preferences are primarily determined by innate predispositions. Desor *et al.*[7,8] identified a liking of sugary solutions and a dislike of sour tastes in neonates only a few days old. Such preferences are assumed to have evolutionary benefits, as sweet tastes indicate that a food has the energy content necessary for growth while bitter or sour tastes suggest the presence of potentially harmful toxins or bacteria[9]. The post-ingestive consequences of eating a food also determine how much it is liked. For example, energy density is a significant predictor of liking, even within low-energy-dense foods such as fruits and vegetables[10].

Alongside their natural predispositions towards certain food types, children commonly develop a reluctance to try new foods towards the end of the second year, termed 'food neophobia'[11,12]. Neophobia is thought to protect the increasingly mobile child from the risks associated with exploring environments containing harmful substances. However, while the evolutionary advantages of having innate taste preferences and food neophobia are clear, both factors contribute to the difficulty of inducing a liking for healthy foods, and vegetables in particular, in young children. Fortunately, children's natural food preferences can be overcome by experience.

* **Corresponding author:** C. Houston-Price, email c.houston-price@reading.ac.uk

British Journal of Nutrition

The impact of food familiarity on food liking and consumption

Considerable evidence supports the impact of familiarisation with the flavour of an initially disliked or unfamiliar food on children's acceptance of the food[13]. For example, when 2-year-olds were given zero, two, five, ten, fifteen or twenty exposures to five unfamiliar fruits (fresh cherries, figs and lychees; dried apricots and bananas) over a 25 d period, liking of the fruits was found to be a function of the frequency with which they had been tasted[14]. More recently, Birch *et al.*[15] found that 4- to 7-month-old infants doubled their consumption of a commercially prepared pea or banana meal after only a single exposure, confirming the powerful impact of experience. Such exposure effects have been replicated in more naturalistic settings[16,17]. For example, when 6-year-olds were given the opportunity to taste raw red pepper on eight consecutive days at school, the number of pieces they consumed increased almost 10-fold from the first to the last day[17].

In addition to these specific effects on children's consumption of exposed foods, exposure to a varied diet in early childhood has been linked to children's willingness to try new foods at a later age. For example, correlational work has shown that dietary variety at 2 years of age is a strong predictor of food preferences at 8 years of age[18,19]. Further evidence that early experience forms the basis of long-lasting eating patterns comes from children who have outgrown food allergies that severely restricted their diets during infancy[20]; these children have been shown to be significantly more neophobic and to consume a smaller variety of foods than a control group at age 7 years.

Experimental work has produced more direct evidence of a causal relationship between early dietary variety and later food choice. In one study[21], formula-fed infants were exposed to commercially prepared puréed carrots, potatoes, or a carrot and vegetable mixture every day for 11 d during weaning. As would be expected, infants who were fed carrots or mixed vegetables had a greater intake of carrots after the exposure regimen. However, infants who were fed mixed vegetables also consumed more of a puréed chicken meal, which was an unfamiliar food for all participants, suggesting that experience with a variety of flavours facilitates acceptance of completely new foods. Dietary variety appears to be equally important for clinical populations. Williams *et al.*[22] employed an incremental exposure regimen with six children (aged 2–8 years) who had been referred to a feeding clinic for extreme food refusal and/or selectivity. A variety of foods was included, including fruits, vegetables, meats, starchy carbohydrates and dairy products. While the first foods children were offered required six to ten presentations before they were accepted, the number of presentations required declined as the number of exposed foods increased. In sum, familiarity with a food increases liking for that food, and familiarity with a variety of foods eases the introduction of yet further foods into the child's diet.

Interventions promoting hands-on, sensory interaction with healthy foods

Parents, preschools, nurseries and primary schools are increasingly signing up to healthy-eating interventions that claim to increase children's fruit and vegetable consumption by increasing children's familiarity with these foods. In recent years, there has been a particular surge of interest in approaches that emphasise the importance of gaining such familiarity through 'hands-on' exploration of foods. What is the evidence that interacting with foods in this way has an impact on children's fruit and vegetable intake and liking?

Garden-based interventions

School-based gardening lessons that actively involve children in the planting, watering, harvesting and preparation of fruits and vegetables for consumption are increasingly popular in the UK. By the end of 2011, more than 26 000 schools and nurseries had signed up to the 'Let's Grow!' vegetable garden campaign, run by a national supermarket chain[23]; this scheme provides schools with gardening supplies, equipment and lesson plans in exchange for vouchers collected in-store. Researchers have investigated the potential for gardening schemes to have an impact on children's willingness to consume the fruit and vegetables they have grown. For example, Morris *et al.*[24] found that 6- to 9-year-olds who had spent 8 months helping to grow spinach, carrots, peas and broccoli in a school garden were more willing than a control group to taste the raw vegetables that they had grown, although there was no impact on how much children liked the vegetables' taste. Other work has investigated whether helping to grow carrots, courgettes, broccoli, spinach and cabbage in a school garden programme provides additional benefits among 7- to 8-year-olds over and above those gained through a 28-week nutritional education programme[25]. This work reported that both the 'nutritional education' group and the 'gardening plus nutritional education' group were more willing to taste the targeted vegetables than a control group, and that both groups showed increases from baseline in how much they liked the vegetables' taste. Importantly, the children who had taken part in the gardening activities showed the greatest willingness to taste vegetables of all three groups, and they were the only group to report increased levels of liking of raw spinach. In addition, the gardening group was observed to eat significantly more vegetables in the school canteen at lunchtime, suggesting that helping in a vegetable garden is more effective than classroom lessons about healthy eating in encouraging children to make healthy food choices.

Related research has followed the progress of ninety-three 9- to 12-year-old children who spent 6–12 weeks at a summer camp at which a gardening project was a key component[26]. Participants planted, weeded and harvested the garden twice a week and engaged in discussions about the smell, texture, colour and origins of a large variety of fruit and vegetables. The children also had lessons on how to prepare fruit and vegetable recipes and took part in

weekly taste sessions, where they were encouraged to 'taste with all of their senses'. By the end of the camp, significant increases were reported in participants' liking of cucumber, spinach, radishes, peppers, courgettes and beetroot. According to their responses to a self-report questionnaire, children also asked their parents to buy fruit and vegetables more often when they returned home from the camp than they had done before they took part in the programme. While the authors acknowledge that this study was limited by the lack of a control group, their results corroborate the potential for interactive garden-based lessons to produce positive changes in children's diets. However, the active component(s) of such garden-based lessons remain unclear. Children's greater willingness to taste the vegetables they have been involved in growing might result from their greater awareness of the origins of the foods, for example, rather than their greater familiarity with the foods' sensory properties. Future interventions should separate the different elements of a typical garden-based programme and systematically compare the effectiveness of these against a non-intervention control group, in order to establish the extent to which familiarity with the sensory properties of foods contributes to the positive effects associated with growing vegetables.

Sensory exploration interventions

Sense-based interventions are explicit in their aims to encourage healthy eating by encouraging children to engage with foods with all their senses. A sensory engagement intervention that has been empirically evaluated is *Le Goût de L'enfant*[27], a popular programme that originated in France and has since been translated into Swedish[28]. This intervention teaches 7- to 11-year-old children how to prepare regional dishes and aims to educate each of the five senses through classroom lessons focusing on taste, vision, olfaction, touch and hearing. In taste lessons, for example, children explore the sensory properties of drinks with and without added sugar or of foods with differing levels of salt content, or they explore the relationship between a food's flavour and its visual appearance. In a study of 244 7- to 11-year-old children who had participated in the programme, Mustonen *et al.*[29] found that the younger children, in particular, were better able to identify and distinguish odours and tastes than a control group after receiving ten *Le Goût de L'enfant* lessons. At the end of the programme, parents also reported a reduction in the participants' food neophobia and an increase in the number of new foods they had tried, relative to controls[30]. Mustonen and colleagues[29,30] suggested that these changes in eating behaviour were achieved by encouraging children to interact with food with all their senses.

However, a study of 180 8- to 10-year-olds who had passed through the same programme revealed that sensory education activities have only a short-term impact on children's food neophobia[31]. While this study also reported an increase in children's willingness to try new foods and a decrease in food neophobia after twelve *Le Goût de L'enfant* classes, these effects had disappeared within 10 months of completing the course. Further research is therefore needed to establish whether the immediate, positive effects of sensory education programmes persist in the longer term, and whether such lessons might be used to enhance children's fruit and vegetable intake, as these food groups are not typically targeted by the *Le Goût de L'enfant* programme.

In the UK, large numbers of nursery schools have signed up for the *Taste for Life* programme[32], which is based on the book *Mange Tout* by Lucy Thomas[33]. Unlike other sensory interaction programmes, *Taste for Life* does not expect children to taste the new foods, but encourages them to smell them, feel their texture against their skin, make bite marks in them and explore what is inside. The aim is to familiarise children with healthy foods without provoking potential concerns they might have about eating them. The programme includes activities focusing on the sensory properties of foods, such as finding a material with a similar texture or an object with a similar shape or colour, and activities finish with a 'song and rhyme time' about the food of the day. A similar emphasis on engaging with foods with all five senses is seen in *Food Loving Kids: Taste with Your Face*[34]; this book encourages children to explore foods during mealtimes by looking at their colour and shape, smelling them, and eating them slowly to savour their flavours. To date, there has been no formal evaluation of the efficacy of the recommendations made by either of these authors in shaping children's dietary habits; a properly controlled study that explores the impact of participating in such programmes is required.

It is important to note that a key component of the sensory engagement programmes that have been discussed is that children enjoy taking part in the activities. The success of these interventions may, therefore, derive from the fun children have while engaging with the foods and the positive associations they acquire with the foods as a result; the same point applies to garden-based interventions. However, it is equally plausible that it is children's enhanced familiarity with the sensory properties of the foods used in the activities that is responsible for increasing their interest in eating the foods; we now turn to the evidence that speaks to this issue.

Familiarisation with the sensory properties of food

With the possible exception of the *Taste for Life* programme, the interactive interventions described in the previous section all provide children with opportunities to taste the target foods. Given the robust evidence that repeated taste exposures increase food liking[14–17,21], it is possible that it is this component of sensory exploration interventions that supports their positive outcomes. If this is the case, one might question the need for the elaborate interventions that have been developed; repeated opportunities to taste healthy foods are all that is required to elicit changes in children's diets. However, the same body of research suggests that as many as ten to fifteen exposures to the flavour of a food may be needed before a positive impact is seen on preschoolers' eating behaviour[14–17]. We know that repeatedly feeding a child with a disliked or unwanted food can be challenging and distressing for parents. In fact, 80% of

parents stop offering their toddler a food when it has been refused three to five times, on the grounds that the child does not like it and will not eat it[35]. Children's unwillingness to taste new and disliked foods is, therefore, a major obstacle to parents' attempts to introduce a healthy diet, and consideration is needed regarding how parents might be supported in their efforts to do so.

What is often ignored by researchers in this field is that tasting a food typically exposes the consumer to the sight, smell and texture of the food, and to the sound associated with eating it, as well as to its flavour. The potential for familiarity with the non-taste properties of new or disliked foods to increase children's interest in eating them is therefore an avenue worth exploring. Eating a food provides numerous sensory experiences: visual stimulation from the size, shape and colour of the food; olfactory stimulation from the food's odour; somaesthetic stimulation from grasping and holding the food, and from the texture and consistency of the food in the mouth; auditory stimulation from the noise created by biting into and chewing the food. Cardello[36] has described in some detail the role played by the five sensory systems in adult food acceptance, such as how our expectations about the flavour and nutrient content of a food are influenced by its colour and texture. However, little is known about the impact of a food's non-taste properties on children's food intake and liking, or about the potential for prior exposure to foods through the non-taste senses to influence children's willingness to eat them. The following section of the present review explores the literature relating to the impact of exposure to food through each of the five sensory modalities in turn, drawing on research involving children, adult and animal populations.

The impact of exposure to a food's taste on food preferences

As has been discussed, most studies offering 'taste exposure' to foods simultaneously provide experiences in several sensory modalities. One way to isolate the impact of a food's taste is to examine the effect of the maternal diet during breast-feeding on infants' acceptance of the food at weaning. The taste of a mother's breast milk is altered by her diet; the infant is therefore exposed to the taste of the foods she eats without receiving visual, auditory, olfactory or somaesthetic stimulation from the food. The evidence suggests that exposure to a food's taste through breast milk enhances later uptake of the food. For example, breast-fed infants are more willing to consume a never-tasted fruit (peach) at weaning if they have experienced that food through their mother's milk[37]. Gerrish & Mennella[21] have also shown that the variety of flavours to which breast-fed infants are exposed before weaning is related to neophobia levels at weaning. Such studies confirm that food acceptance is enhanced by exposure purely through the taste modality.

An alternative approach to exploring the influence of a food's taste in isolation is through 'flavour–flavour learning'[38], a technique that conditions participants to associate the taste of a target vegetable with an already-liked taste, such as sugar. In this experiment, 5-year-old children were asked to taste two of six vegetable drinks, made by boiling and puréeing carrots, courgettes, peas, pumpkin, broccoli or cauliflower, six times over two consecutive days. For each child, one of the drinks was sweetened with dextrose, one was not; drinks were presented in a lidded cup, so that children could not see or smell the contents. In a subsequent taste test, when neither drink was sweetened, children preferred the vegetable drink that had previously been paired with dextrose, suggesting that positive attitudes transfer from one flavour to another through association. Taken together, these studies demonstrate that food preferences can be manipulated through exposure to the food's taste alone.

The impact of exposure to a food's smell on food preferences

Olfactory stimulation from a food is also difficult to isolate due to its close link to a food's taste. However, research with young rats has shown that prior exposure to the smell of a disliked food increases subsequent consumption of the food. After rat pups had been immersed in a room with a pungent garlic odour (a food to which rats are intolerant from birth), their intake of a garlic-flavoured food increased[39]. However, the effect did not persist beyond weaning. In another study, Hennessy *et al.*[40] explored whether exposing rat pups to a variety of odours would encourage them to try new foods. Pups were exposed to thirty-six odours (including scented soap and rosemary) over 14 d, after which their water bottles were replaced with a bottle containing a novel sucrose–milk solution for 1 h. The rats that had been exposed to a variety of smells drank more of the milk solution than controls. Thus, for rats at least, exposure to a food's smell appears to operate similarly to taste exposure in children: smelling a food increases their willingness to eat the food, and exposure to a variety of smells facilitates acceptance of further new foods.

Olfactory experience also encourages eating behaviour in some human populations. Fedoroff *et al.*[41] exposed young women to the smell of a pizza before offering them pizza slices and asked them to rate their desire to eat the pizza and their liking of its taste, smell and spiciness. Restrained eaters expressed a greater desire to eat the pizza and consumed more of it if they had been pre-exposed to its smell. However, while this work demonstrates that the smell of an already enjoyed food can induce consumption, it remains unknown whether similar effects would be found for healthy (or less desirable) foods, such as fruit and vegetables. Given that many vegetables are either disliked by or unfamiliar to young children, research is needed to establish that olfactory experience with these food types encourages (rather than discourages) children's intake of them.

The impact of exposure to a food's texture on food preferences

Early exposure to a variety of food textures is associated with later dietary quality. For example, children who are not

British Journal of Nutrition

introduced to lumpy foods before 9 months are more difficult to feed, have more rigid food preferences and are significantly less likely to eat family meals at 15 months[42]. Others have reported that the introduction of textured foods after 9 months of age is linked with long-term feeding difficulties up to 7 years later[43]. Experimental research supports the view that early experience of a variety of textures plays an important role in later food acceptance. For example, Blossfeld *et al.*[44] found that texture preferences at 12 months were related to children's previous experience of different food consistencies. In this study, infants were offered chopped or puréed boiled carrots until they refused the spoon three times or became upset; liking was determined by the mother's impression and the quantity of food consumed. In general, puréed carrots were preferred to chopped carrots but there were considerable individual differences and the strongest predictor of liking of chopped carrots was the child's prior familiarity with foods of different textures. Thus, early dietary variety, including variety of textures, facilitates acceptance and uptake of foods with new textures.

In addition to the somatosensory experiences associated with biting, chewing and swallowing a food, a food's texture can be experienced through touching and holding it. Tactile experience is integral to eating raw fruits and vegetables (e.g. when holding a carrot stick or orange segment, or when peeling a banana); toddlers also learn about the texture of cooked foods when handling these at mealtimes. Further opportunities to touch fruits and vegetables and feel the texture of their skins may be presented during shopping and food preparation activities. It is therefore surprising that no research to date has considered the impact of holding or feeling a food on the young child's interest in eating it.

The impact of exposure to a food's sound on food preferences

There is growing evidence that arbitrary environmental sounds, such as background music, loud engine noise or simple auditory tones, affect the quality of the eating experience (see Spence & Shankar[45] for a review). For example, Masuda *et al.*[46] found that pretzels were perceived as less moist if they were tasted while participants heard loud white noise over headphones. However, the literature is limited in its exploration of how food liking is affected by sounds that are intrinsically associated with foods, such as the sound made when eating. However, it is worth noting the very strong association between a food's texture and the sound made when it is eaten. Vickers[47,48] has discussed the poorly defined boundary between the somaesthetic and auditory stimulation received while experiencing the quality of 'crunchiness', for example. According to Vickers, the judgements of a food's crispness that participants make while listening to the sound of another person biting a food are indistinguishable from the judgements they make when biting into a food and experiencing both the sound and the texture themselves. Vickers therefore suggests that our perception of food quality may be influenced by the auditory cues associated with biting into and chewing it.

To explore this possibility, Zampini & Spence[49] controlled the real-time auditory feedback participants experienced while eating crisps. In this study, twenty adult participants rated the crispness and freshness of each of 180 crisps that were uniform in shape and appearance while biting into them. The loudness and the frequency of the sound made by biting into each crisp were artificially manipulated when played to participants through headphones. Results showed that amplification of either the overall sound level or the higher-frequency components of the sound led participants to perceive the crisps as fresher and crisper. In a similar study[50], participants rated carbonated water as fizzier when the auditory feedback about the water's sound was manipulated in similar ways, or when the bubbles were heard to pop at a faster rate. Given that crisp and crunchy textures are interpreted as markers of a food's freshness and pleasantness[51], and that the fizziness of a carbonated drink is similarly indicative of its freshness, it is plausible that hearing favourable auditory cues while eating (or while hearing someone else eating) would increase the listener's interest or pleasure in consuming the food. If so, research should examine whether food-related sounds similarly modulate the pleasure associated with eating in infancy, or whether the influence of auditory cues develops as children experience a variety of food textures and properties over time and learn to associate differences in food quality with specific components of the auditory feedback.

Further interesting questions remain about the impact of food-related auditory cues that originate outside the eating experience. Spence & Shankar[45] pointed out that the sound of food being crushed in the mouth involves auditory stimulation through bone conduction, and speculated about whether feedback effects similar to those described above would be seen if participants crushed the crisps in their hand, rather than in their mouth. This leads to questions about the role played by the auditory information available through handling foods. Second, research has yet to explore whether familiarity with sounds that are directly or indirectly associated with a food plays a role in its acceptance. It is worth noting the potentially very important role played by foods' names; the auditory label associated with a food may be considered an additional (auditory) property of the food with which children must become familiar. Research is required to explore the possibility that efforts to encourage young children to eat new fruits and vegetables would be facilitated by first familiarising the child with the food's name.

The impact of exposure to a food's appearance on food preferences

The appearance of a food is highly likely to make an impact on children's acceptance of it. One approach to exploring this question has been to investigate recent trends towards presenting food in a way that appeals to children, such as in the shape of an animal, face or flower. *Little Food Junction*[52], a graphic designer's blog about how to make food more entertaining for children, attracted over 112 000 visitors in its first year, demonstrating the popularity of this approach with

parents. In one research study, it was found that presenting food in a visually appealing layout did not affect how much of the food preschoolers consumed but merely served to increase the time they took to eat it[53]. However, this study involved snack foods that may have been familiar to and liked by participants; it therefore remains possible that presenting disliked or unfamiliar foods in appealing, familiar shapes might enhance children's willingness to taste them.

Other work has explored the role played by a food's appearance by manipulating its visual familiarity to children. Birch *et al.*[54] compared the effects of visual exposure and taste exposure in 2- to 5-year-old children, who were asked to either repeatedly look at or taste each of six unfamiliar fruits. Children were exposed to bite-sized chunks of the fresh, dried or tinned fruits for 5, 10 or 15 d; three fruits were tasted at each exposure while three were merely looked at. It is important to note that, in this study, visual exposure involved visual and olfactory stimulation, as the prepared food was placed in front of the child, while taste exposure included taste, olfactory, somaesthetic, auditory and visual experience of the food. At the end of the exposure phase, children were asked which foods they preferred while they looked at them or while they tasted them. Results showed that visual exposure had a positive impact on children's ratings of how much they liked the food while they were looking at it, but no impact on their liking of the food's flavour, leading Birch *et al.* to conclude that visual exposure is insufficient to enhance food preferences.

Recent work by Houston-Price *et al.*[55,56] has explored the impact of isolated visual exposure on children's looking and tasting behaviour. In one series of studies[55], parents were asked to read a picture book about a variety of fruits and vegetables with their 17- to 27-month-old toddler every day for 1 to 3 weeks. Books contained photographs showing what the foods look like inside and outside and how they are grown, prepared and cooked. The impact of the books was assessed using visual preference, a looking-time measure of preference for exposed foods over non-exposed foods. Results showed that picture-book exposure enhanced children's visual preferences for fruits and vegetables; this effect generalised to new pictures of the exposed foods, which had not previously been shown in children's books.

In another study[56], parents read similar books with their 21- to 24-month-old toddler every day for 2 weeks. Each book contained pictures of two foods that were familiar to children (e.g. carrots, strawberries) and two foods that were unfamiliar (e.g. radishes, lychees). Children subsequently took part in a taste test, in which they were offered the foods they had seen in their picture book and a set of non-exposed foods. Foods were raw and chopped into bite-sized pieces. Whether the child tasted each food and the order in which they tasted them were recorded. Picture-book exposure was found to reduce children's overall neophobia towards the unfamiliar foods and to increase children's willingness to taste exposed unfamiliar fruits (e.g. lychees) relative to non-exposed unfamiliar fruits (e.g. blueberries). While this study involved only a small sample of twenty toddlers, the results suggest that visual exposure is worth exploring as a means of increasing children's willingness to taste unfamiliar foods (see Heath *et al.*[57] for a review of this literature).

It remains unknown how picture books work to increase children's interest in tasting the foods they display. Enhanced visual familiarity with the foods depicted is one explanation. Alternatively, as was discussed above in relation to garden-based interventions, children's greater awareness of how the target foods are grown and prepared might enhance their willingness to try the foods shown in their picture books. Thus, the mechanism(s) that underpin the effects of visual exposure deserve further exploration.

Conclusions

There has been a recent surge in the popularity of interventions seeking to increase children's liking and consumption of fruits and vegetables through exposure to their sensory properties. Most of these community-based programmes have not been subjected to rigorous scientific evaluation. Several preliminary investigations into the effectiveness of garden-based projects and sensory exploration programmes have produced encouraging results, in terms of producing short-term positive effects on children's willingness to consume new foods. However, many of these studies have failed to adopt an appropriate control group against which to compare the intervention group's changes in food attitudes. Given the influence of demographic factors such as socio-economic status on children's fruit and vegetable consumption[58], it is important that control groups in such studies are closely matched to experimental groups, ideally by drawing both experimental and control participants from the same pool (e.g. from the same school).

A second concern is that it has not been clearly established that the increased willingness to consume fruit and vegetables that has been observed in the school or summer camp environment is mirrored in the child's eating behaviour at home, where most meals are taken. Studies that have reported a positive impact of such interventions in the home environment have tended to rely on self-reports by children or parents and have not always included the requisite control groups[26,30]. Third, there is a dearth of research evidence supporting longer-term changes in children's diets after taking part in garden-based projects or sensory interaction programmes; the only follow-up study of sense-based lessons in the literature to date found no continuing impact 10 months after the intervention[31]. The research evidence is therefore insufficient to justify the prevalence of sense-based activities in schools and nurseries across the UK.

School-age populations are perhaps better served, at present, by classroom interventions that are not primarily based on sensory interaction with foods, such as the *Food Dudes* programme, developed for children aged 4–11 years by psychologists at the University of Bangor. This intervention draws on the psychological principles of modelling and rewarding healthy eating behaviour, as well as repeated taste exposure to the target foods. Every day for 16 d, children are presented with a portion of fruit or vegetable, which they are required to taste in exchange for a *Food Dudes* sticker,

British Journal of Nutrition

with the added incentive of a small prize (such as a pencil case) if they eat a whole portion. The exposure regimen is supported by a daily *Food Dudes* video, in which four cartoon super heroes gain special powers by eating fruit and vegetables in order to do battle with General Junk and his Junk Punks. Evaluations by Lowe *et al.*[59–61], which assessed the impact of the programme in five schools across the country, revealed significant increases in fruit and vegetable consumption at snack time and lunchtime. Importantly, a follow-up study after a 4-month non-intervention period found that children continued to eat significantly more fruit and vegetables than they had done before the intervention.

However, the lack of similar programmes suitable for younger, preschool children presents an opportunity for sense-based interventions to fill a crucial gap. Research has shown that the first few years of life are vital for developing lasting food preferences[5,6], suggesting that healthy eating programmes may be most beneficial when applied to the infant, toddler and preschool-age groups. The increasing popularity of sense-based interventions such as *Taste for Life*[32] in nursery schools suggests that the activities involved in such programmes are appropriate and enjoyable for the age groups targeted, and there is evidence that younger participants benefit to a greater extent from sense-based interventions than older children, albeit among a school-age sample[29]. In our view, the preliminary evidence showing that sense-based programmes can have short-term positive outcomes, in combination with the growing literature supporting the involvement of multiple senses in the eating experience, is sufficient to warrant investment in further research into the efficacy of sense-based interventions in the preschool-age group.

Such investigations face a host of practical challenges in terms of how best to measure changes in children's liking or acceptance of the target foods. In infancy and toddlerhood, foods are typically provided by parents or teachers and children rarely choose what they eat; this precludes the measurement of spontaneous food choices as adopted in investigations of older children's dietary changes[59,61]. However, instruments have been developed for investigating infants' and toddlers' willingness to taste and liking of new foods[14,16,56,57]. A carefully designed, properly controlled, study should be able to ascertain whether changes arise in young children's attitudes towards fruit and vegetables as a result of participation in sense-based activity programmes.

Further research is also required to elucidate the mechanisms that underpin the effects of sense-based interventions, for these may not rest on sensory experiences at all. For example, children's enhanced awareness of the origins of the fruit and vegetables that they have helped to grow in gardening interventions might be sufficient to account for their greater acceptance of these in their diets. However, there are good grounds for anticipating that the familiarity these interventions provide with the taste, sight, smell, texture and sound of the foods also plays a role in driving food acceptance[14–17]. Research is therefore needed to isolate the specific components of sensory activity programmes that are most effective in promoting fruit and vegetable uptake.

While the literature suggests that multiple sensory modalities are implicated in the eating experience[21,37,39,41,43,44,49,51], little work has investigated the impact of prior familiarity with new foods through the individual non-taste senses on later food acceptance. However, encouraging evidence linking prior visual and olfactory exposure to subsequent eating behaviour[39–41,56] suggests that strategies based on looking at and smelling foods are especially ripe for exploration, in terms of their potential to boost fruit and vegetable intake. Given that olfactory exposure has been shown to make an impact on subsequent eating behaviour in adult and non-human populations[39–41], work is needed to ascertain whether repeated exposure to a cooked vegetable's smell might serve to increase young children's willingness to consume the vegetable and/or their liking of its taste when they do eat it. Similarly, while preliminary evidence suggests that toddlers' willingness to taste unfamiliar foods in a laboratory taste test is affected by prior picture-book exposure to these foods[56], research is needed to establish whether visual familiarity can be used to increase uptake of healthy foods in the home environment.

It may also prove fruitful to pursue familiarity with a food's texture and sound as strategies for enhancing children's interest in the food. Familiarity in these modalities is not easily manipulated without requiring the child to taste the food; however, a food's texture could be experienced by handling its external surface or poking one's fingers inside it, while a food's auditory properties could be explored by cutting into or breaking it, or simply by talking about it. By employing such imaginative approaches to sensory familiarisation, and rigorously testing their consequences, researchers will be able to identify the most effective components of sense-based activity programmes and develop effective interventions to increase fruit and vegetable intake.

Acknowledgements

This study was partly funded by a Knowledge Transfer Partnership (KTP) between the University of Reading and Ella's Kitchen (Brands) Limited The authors are aware of no conflicts of interest and had full control over the contents of the manuscript. P. D. is the Research Associate on the KTP. P. D. carried out the literature search and wrote the first draft of the review. C. H.-P. advised on the article's structure and scope and edited the final draft. C. H. advised on the content and scope of the review article.

References

1. Cooke L & Wardle J (2005) Age and gender differences in children's food preferences. *Br J Nutr* **93**, 741–746.
2. Domel S, Thompson W, Davis H, *et al.* (1996) Psychosocial predictors of fruit and vegetable consumption among elementary school children. *Health Educ Res* **11**, 299–308.
3. Hervey-Berino J, Hood V, Rourke R, *et al.* (1997) Food preferences predict eating behaviour of very young Mohawk children. *J Am Diet Assoc* **97**, 750–753.

4. Health Survey for England (2008) *Health Survey for England – 2008*. London: The NHS Information Centre for Health and Social Care.
5. Cashdan E (1994) A sensitive period for learning about food. *Hum Nat* **5**, 279–291.
6. Harris G (2008) Development of taste and food preferences in children. *Curr Opin Clin Nutr* **11**, 315–319.
7. Desor J, Maller O & Turner R (1973) Taste in acceptance of sugars by human infants. *J Comp Physiol Psychol* **3**, 496–501.
8. Desor J, Maller O & Andrews K (1975) Ingestive responses of human newborns to salty, sour, and bitter stimuli. *J Comp Physiol Psychol* **89**, 966–970.
9. Wardle J & Cooke L (2008) Genetic and environmental determinants of children's food preferences. *Br J Nutr* **99**, S15–S21.
10. Gibson E & Wardle J (2003) Energy density predicts preferences for fruit and vegetables in 4-year-old children. *Appetite* **41**, 97–98.
11. Rozin P (1976) The selection of food by rats, humans and other animals. In *Advances in the Study of Behaviour*, vol. 6, pp. 21–76 [JS Rosenblatt, RA Hinde, C Beer and E Shaw, editors]. New York: Academic Books.
12. Cooke L (2007) The importance of exposure for healthy eating in childhood: a review. *J Hum Nutr Diet* **20**, 294–301.
13. Birch L (1999) Development of food preferences. *Annu Rev Nutr* **19**, 41–62.
14. Birch L & Marlin D (1982) I don't like it; I never tried it: effects of exposure on two-year-old children's food preferences. *Appetite* **3**, 353–360.
15. Birch L, Gunder L, Grimm-Thomas K, *et al.* (1998) Infants' consumption of a new food enhances acceptance of similar foods. *Appetite* **30**, 283–295.
16. Wardle J, Cooke L, Gibson E, *et al.* (2003) Increasing children's acceptance of vegetables: a randomized trial of parent-led exposure. *Appetite* **40**, 155–162.
17. Wardle J, Herrera M, Cooke L, *et al.* (2003) Modifying children's food preferences: the effects of exposure and reward on acceptance of an unfamiliar vegetable. *Eur J Clin Nutr* **57**, 341–348.
18. Skinner J, Carruth B, Bounds W, *et al.* (2002) Children's food preferences: a longitudinal analysis. *J Am Diet Assoc* **102**, 1638–1647.
19. Skinner J, Carruth B, Bounds W, *et al.* (2002) Do food-related experiences in the first 2 years of life predict dietary variety in school-aged children? *J Nutr Educ Behav* **34**, 310–315.
20. Rigal N, Reiter F, Morice C, *et al.* (2005) Impact du régime d'éviction sur la néophobie dans le cadre d'une allergie alimentaire chez l'enfant: Étude exploratoire (Impact of the elimination diet on neophobia in the context of food allergy in children: an exploratory study). *Arch Pédiatrie* **12**, 1714–1720.
21. Gerrish C & Mennella J (2001) Flavor variety enhances food acceptance in formula-fed infants. *Am J Clin Nutr* **73**, 1080–1085.
22. Williams K, Paul C, Pizzo B, *et al.* (2008) Practice does make perfect: a longitudinal look at repeated taste exposure. *Appetite* **51**, 739–742.
23. Morrisons (2010) Let's grow! http://www.morrisons.co.uk/letsgrow (accessed November 2010).
24. Morris J, Neustadter A & Zidenberg-Cherr S (2001) First-grade gardeners more likely to taste vegetables. *Cal Agr* **55**, 43–46.
25. Parmer S, Salisbury-Glennon J, Shannon D, *et al.* (2009) School gardens: an experiential learning approach for a nutrition education program to increase fruit and vegetable knowledge, preference, and consumption among second-grade students. *J Nutr Educ Behav* **41**, 212–217.
26. Heim S, Stang J & Ireland M (2009) A garden pilot project enhances fruit and vegetable consumption among children. *J Am Diet Assoc* **109**, 1220–1226.
27. Puisais J & Pierre C (1987) *Le Goût de L'enfant* (*The Child's Sense of Taste*). Paris: Flammarion.
28. Hagman U & Algotson S (2000) *Mat För Alla Sinnen-Sensorisk Träning Enligt Sapere Metoden* (*Food for the Senses – Sensory Training According to the Sapere Method*). Stockholm: Blomberg & Jansson.
29. Mustonen S, Rantanen R & Tuorila H (2009) Effect of sensory education on school children's food perception: a 2-year follow-up study. *Food Qual Prefer* **20**, 230–240.
30. Mustonen S & Tuorila H (2010) Sensory education decreases food neophobia score and encourages trying unfamiliar foods in 8–12-year-old children. *Food Qual Prefer* **21**, 353–360.
31. Reverdy C, Chesnel F, Schlich P, *et al.* (2008) Effect of sensory education on willingness to taste novel food in children. *Appetite* **51**, 156–165.
32. Organix (2010) Taste for Life. http://www.tasteforlifenursery.com/about.html (accessed October 2010)
33. Thomas L (2007) *Mange Tout: Teaching Your Children to Love Fruit and Vegetables without Tears*. London: Penguin.
34. Blair-West G & Blair-West P (2010) *Food Loving Kids: Taste with Your Face*. Indooroopilly, QLD: Alclare.
35. Carruth B, Ziegler P, Gordon A, *et al.* (2004) Prevalence of picky eaters among infants and toddlers and their caregivers' decisions about offering a new food. *J Am Diet Assoc* **104**, S57–S64.
36. Cardello A (1996) The role of the human senses in food acceptance. In *Food Choice, Acceptance and Consumption*, pp. 1–82 [H Meiselman and H Macfie, editors]. London: Blackie.
37. Forestell C & Mennella J (2007) Early determinants of fruit and vegetable acceptance. *Pediatrics* **120**, 1247–1254.
38. Havermans R & Jansen A (2007) Increasing children's liking of vegetables through flavour–flavour learning. *Appetite* **48**, 259–262.
39. Bronstein P & Crockett D (1976) Exposure to odor of food determines eating preferences of rat pups. *Behav Biol* **18**, 387–392.
40. Hennessy MM, Smotherman W & Levine S (1977) Early olfactory enrichment enhances later consumption of novel substances. *Physiol Behav* **19**, 481–483.
41. Fedoroff I, Polivy J & Herman P (1997) The effect of pre-exposure to food cues on the eating behavior of restrained and unrestrained eaters. *Appetite* **28**, 33–47.
42. Northstone K, Emmett P & Nethersole F (2001) The effect of age of introduction to lumpy solids on foods eaten and reported feeding difficulties at 6 and 15 months. *J Hum Nutr Diet* **14**, 43–54.
43. Coulthard H, Harris G & Emmett P (2009) Delayed introduction of lumpy foods to children during the complementary feeding period affects child's food acceptance and feeding at 7 years of age. *Matern Child Nutr* **5**, 75–85.
44. Blossfeld I, Collins A, Kiely M, *et al.* (2007) Texture preferences of 12-month-old infants and the role of early experiences. *Food Qual Prefer* **18**, 396–404.
45. Spence C & Shankar M (2010) The influence of auditory cues on the perception of, and responses to, food and drink. *J Sens Stud* **25**, 406–430.
46. Masuda M, Yamaguchi Y, Arai K, *et al.* (2008) Effect of auditory information on food recognition. *IEICE Tech Rep* **108**, 123–126.

British Journal of Nutrition

47. Vickers Z (1979) Crispness and crunchiness of foods. In *Food Texture and Rheology*, pp. 145–166 [P Sherman, editor]. London: Academic Press.
48. Vickers Z (1981) Relationships of chewing sounds to judgements of crispness, crunchiness and hardness. *J Food Sci* **47**, 783–786.
49. Zampini M & Spence C (2004) The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *J Sens Stud* **19**, 347–363.
50. Zampini M & Spence C (2005) Modifying the multisensory perception of a carbonated beverage using auditory cues. *Food Qual Prefer* **16**, 632–641.
51. Szczesniak A & Kahn E (1971) Consumer awareness of and attitudes to food texture: I. Adults. *J Texture Stud* **2**, 280–295.
52. Srivastava S (2009) *Little Food Junction*. http://littlefoodjunction.blogspot.com (accessed October 2010).
53. Branen L, Fletcher J & Hilbert L (2002) Snack consumption and waste by preschool children served "cute" versus regular snacks. *J Nutr Educ Behav* **34**, 279–282.
54. Birch L, Mcphee L, Shoba B, *et al.* (1987) What kind of exposure reduces children's food neophobia? Looking vs. tasting. *Appetite* **9**, 171–178.
55. Houston-Price C, Burton E, Hickinson R, *et al.* (2009) Picture book exposure elicits positive visual preferences in toddlers. *J Exp Child Psychol* **104**, 89–104.
56. Houston-Price C, Butler L & Shiba P (2009) Visual exposure impacts on toddlers' willingness to taste fruits and vegetables. *Appetite* **53**, 450–453.
57. Heath P, Houston-Price C & Kennedy O (2011) Increasing food familiarity without the tears: a role for visual exposure? *Appetite* **57**, 832–838.
58. Whichelow M & Prevost A (1996) Dietary patterns and their associations with demographic, lifestyle and health variables in a random sample of British adults. *Br J Nutr* **76**, 17–30.
59. Lowe C, Horne P, Bowdery M, *et al.* (2001) Increasing children's consumption of fruit and vegetables. *Pub Health Nutr* **4**, 387.
60. Lowe C, Horne P & Tapper K, *et al.* (2002) Changing the nation's diet: a programme to increase children's consumption of fruit and vegetables (Technical report), University of Wales, Bangor, Bangor Food Research Unit.
61. Tapper K, Lowe C, Horne P, *et al.* (2002) An intervention to increase children's consumption of fruit and vegetables. *Proc Brit Psychol Soc* **10**, 102.

British Journal of Nutrition