VeggieSense: a non-taste multisensory exposure technique for increasing vegetable acceptance in young children

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Abstract

Vegetable consumption falls well below recommended levels for children in the UK. Previous research has found that repeated non-taste sensory exposure over the course of several days increases young children's willingness to touch and taste vegetables. The current study examined the impact of a one-off multisensory non-taste exposure intervention that took place on a single day on children's willingness to taste and intake of the exposed vegetables. Children (N = 110) aged 3- to 4-years-old were assigned to one of three intervention groups or to a control group. Children in all groups participated individually in a single activity session delivered in their nursery. Children in the intervention conditions took part in fun activities that provided either (a) visual exposure, (b) smell and visual exposure, or (c) smell, touch and visual exposure to six raw and prepared vegetables. Children in the control group engaged in a visual exposure activity with non-food items. After the exposure activities, all children were offered the prepared vegetables to eat; their willingness to taste and intake of the vegetables were measured. Results confirmed previous findings of sensory exposure activities increasing children's willingness to taste and intake of vegetables and revealed linear trends in both measures of acceptance with the number of senses engaged; children who took part in smell, touch and visual activities showed the highest level of acceptance. Findings suggest that multisensory exposures are effective in increasing consumption of vegetables in young children and that the effect of sensory exposure to healthy foods may be cumulative, with the more senses engaged prior to offering a food, the better.

Keywords: *vegetables, young children, multisensory exposure, intake, willingness to taste, VeggieSense*

1. Introduction

Only 18% of school-aged children in the UK eat the recommended five portions of fruit or vegetables per day (NatCen Social Center, 2018) and a growing body of work suggests that preschool children across Europe also fail to meet recommended levels of fruit and vegetable intake (Angelopoulos, Kourlaba, Kondaki, Fragiadakis, & Manios, 2009; Huybrechts et al., 2008; Manios et al., 2009). Preferences for sweet tastes in infants (Desor, Maller, & Andrews, 1975; Desor, Maller, & Turner, 1973) may well be of evolutionary origin (Wardle & Cooke, 2008), with the more bitter taste of vegetables (Chung & Fong, 2018) possibly accounting for young children's greater dislike of vegetables compared to fruit (Cooke & Wardle, 2005; Harnack et al., 2012). Given that the eating behaviours that are established during the early years often last into adulthood (Coulthard, Harris, & Emmett, 2010; Harris, 2008), it is perhaps not surprising that adults also fail to consume recommended levels of vegetables (Pomerleau, Lock, Knai, & McKee, 2005).

Fortunately, however, children's food preferences are not solely determined by their initial taste preferences and continue to develop as a result of the child's experiences with food. Research has drawn on the known influence of the child's early food environment to devise new strategies for increasing vegetable acceptance during the preschool years. Repeated taste exposure – which involves offering the child between 10 and 15 exposures to a food's taste – is a well-evidenced tactic for increasing acceptance of a disliked vegetable (Birch & Marlin, 1982; Gerrish & Mennella, 2001; Wardle, Cooke, et al., 2003; Wardle, Herrera, Cooke, & Gibson, 2003). Yet, whilst this approach is highly effective when implemented, in practice most parents will only offer their child a disliked food three to five times before giving up (Carruth, Ziegler, Gordon, & Barr, 2004), which limits the likelihood of successful dietary change through taste exposure alone.

Investigations of practical alternatives to repeated taste exposures have found that both short-term and longer-term acceptance of vegetables and other healthy foods (as indexed by measures of willingness to taste (WTT) and intake) can be increased by non-taste sensory exploration of a food's visual (De Droog, Buijzen, & Valkenburg, 2014; Heath, Houston-Price, & Kennedy, 2014; Houston-Price et al., 2009; Owen, Kennedy, Hill, & Houston-Price, 2018; Rioux, Lafraire, & Picard, 2018) or olfactory (Luisier, Petitpierre, Clerc Bérod, Garcia-Burgos, & Bensafi, 2019) properties. The effectiveness of visual familiarity as a means of increasing vegetable acceptance has been investigated using children's books, which show the child what vegetables look like and where they come from. Repeated readings of such books have been found to increase children's WTT, intake and liking of vegetables and to support parents in the process of introducing vegetables at mealtimes (Heath et al., 2014; Houston-Price, Owen, Kennedy, & Hill, 2019; Owen et al., 2018). In other work, Luisier et al. (2019) examined the effect of familiarity with a food's odour on the food choices of children with autism. When presented with two identical foods, one with a control odour and one with an odour with which the child was familiar, 68% of children chose the food with the familiarised odour, suggesting that familiarity with a food's smell plays a role in food preferences. Less is known about the effects of familiarisation with the tactile properties of foods, although Coulthard and Thakker (2015) and Coulthard and Sahota (2016) have reported strong associations between children's tactile sensitivity and enjoyment of tactile play with non-food items and their levels of food neophobia (unwillingness to try new foods), suggesting that tactile familiarity may play a role.

In addition to these studies exploring the effects of familiarisation with individual sensory attributes of foods, several studies have explored the effects of engaging in multisensory food-related activities on food acceptance. There are theoretical grounds for expecting multisensory familiarity to be beneficial; in other domains, multisensory environments are more supportive of learning than unisensory environments (Shams & Seitz, 2008). Moreover, taste exposures to foods are necessarily multisensory experiences (Coulthard, Harris, & Emmett, 2009; Forestell & Mennella, 2007; Kringelbach, 2015; Spence & Piqueras-Fiszman, 2014), as the visual, tactile and smell properties of foods are all available when they are eaten. This raises the question of whether food familiarisation techniques that involve multiple non-taste senses might be more effective in inducing food acceptance than exposure in a single sensory modality has been shown to be.

Several interventions have incorporated multisensory exposure within more holistic approaches to supporting children's engagement with foods, with some success. For example, the French (Puisais, Pierre, & Pierre, 1987) and Swedish (Hagman & Algotson, 2000) '*SAPERE*' programs for 6- to 11-year-olds encouraged children to focus on their sensory perceptions of food. Results following SAPERE method interventions have been mixed. While one study found an immediate reduction in child neophobia and increased willingness to try a wider range of foods compared to a control group (Mustonen & Tuorila, 2010), another found that children's neophobia and WTT novel foods had returned to pre-intervention levels by 10 months later (Reverdy, Chesnel, Schlich, Köster, & Lange, 2008).

Another approach to engaging children in multisensory activities has been to involve them in 'hands on' activities such as gardening and cooking (DeCosta, Møller, Frøst, & Olsen, 2017). A systematic review of gardening interventions with children and adolescents (Savoie-

Roskos, Wengreen, & Durward, 2017) concluded that access to a fruit and vegetable garden, and the knowledge and sensory exposure to foods that results from this access, leads to a small but positive difference in children's fruit and vegetable intake. Involving children in cooking and meal preparation has also been shown to increase their vegetable intake (Jarpe-Ratner, Folkens, Sharma, Daro, & Edens, 2016; van der Horst, Ferrage, & Rytz, 2014). However, while nursery staff report that sensory exposure methods are an effective educational tool for 2- to 3-year-old children, they also report finding cooking sessions to be time consuming and difficult to implement in practice (Johannessen, Helland, Bere, Øverby, & Fegran, 2018). Moreover, some nurseries do not have the physical space or resources to set up gardening and/or cooking activities with children. If an intervention is to be feasible within a nursery setting, its methods must be fun for young children while making minimal demands on nursery staff.

Several recent interventions have sought to provide multisensory exposure in preschool settings via 'sensory play' activities, in which children engage with foods via multiple senses prior to tasting them as snacks or during mealtimes (Coulthard, Palfreyman, & Morizet, 2016; Coulthard & Sealy, 2017; Dazeley & Houston-Price, 2015; Dazeley, Houston-Price, & Hill, 2012; Hoppu, Prinz, Ojansivu, Laaksonen, & Sandell, 2015; Kähkönen, Rönkä, Hujo, Lyytikäinen, & Nuutinen, 2018). For example, Dazeley and Houston-Price (2015) trained nursery staff to deliver a range of engaging activities that provided toddlers aged 12 to 36 months with non-taste sensory exposures to fruit and vegetables. Each day's activities focused on one sensory domain (sound, smell, sight or touch) and over the course of 4 weeks, children gained repeated exposures to the raw and cooked foods in each sensory modality. Results suggested that the sensory activities increased the children's willingness to touch and taste the vegetables with which they had been familiarised. Coulthard and Sealy (2017) also investigated the effects of non-taste sensory exposures to a variety of fruit and vegetables. Children were allocated to one of three conditions: 1) a tactile-visual condition, in which children created a picture on a plate using fruit and vegetables; 2) a visual-only condition, where children watched a researcher create a picture using the same foods; 3) a control group, who created a picture using non-food items. Children in the tactile-visual condition tried significantly more fruit and vegetables in a subsequent taste test than children in the visual-only and control conditions. While this finding suggests that multisensory exposure is more effective at increasing WTT than exposure in a single modality, it is also compatible with the possibility that tactile familiarity plays the primary role in food acceptance.

Thus, although previous studies suggest that there is likely to be value in developing practical non-taste multisensory exposure methods for increasing children's acceptance of vegetables, it has not yet been established whether exposure via multiple senses is cumulative in its effects. Moreover, while visual exposure has been shown to have a lasting impact on food acceptance if exposure is repeated over several days or weeks (e.g. Owen et al., 2018), it remains unknown whether more immediate effects following a single exposure session might be demonstrated if the exposure activities engages multiple senses. If multisensory exposure has a more immediate impact on children's food acceptance of a food, parents' (or nursery staff's) tendency to cease offering children a new food following its initial rejection (e.g. Carruth et al., 2004) is less likely to pose a barrier to the food's successful introduction.

In this study, therefore, we compare the effects of unisensory versus multisensory exposure conditions on children's immediate acceptance of foods, as indexed by their WTT and intake of familiarised vegetables. The aims of this study were two-fold. First, we investigated whether a brief, one-day intervention involving non-taste sensory exposure had any impact on preschool children's immediate acceptance of vegetables, as defined by their WTT & intake of the vegetable shortly after the exposure activities. Children individually took part in a single familiarisation session, during which they were exposed to a selection of raw, whole vegetables and to the prepared (chopped and cooked, as appropriate) forms of those vegetables. Second, we investigated how the number of sensory modalities in which exposure occurred (visual vs. smell & visual vs. smell, touch & visual) impacted on children's acceptance of the foods. Exposure activities were presented as a fun vegetable matching game, in which the child was asked to match a mystery vegetable (or a non-food object for those in a control condition) to its picture on a poster. The number of senses engaged during the matching game varied according to the child's condition. After the matching game, children were invited to taste the exposed vegetables, and measures of WTT and intake were collected.

We hypothesised that: 1) all three vegetable exposure conditions would result in higher levels of WTT and intake compared to the control condition; and 2) levels of immediate acceptance would be related to the number of senses engaged in the exposure activities, with children in the smell, touch and visual condition demonstrating the highest levels of WTT and intake.

2. Method

2.1. Participants & Design

Ethical approval was granted by the University of Reading Ethics Committee. A G*power a priori analysis indicated that, in a study with four condition sub-samples, an overall sample of 108 participants would be required to detect a moderate ($\eta^2 > .06$) effect size.

Purposive sampling was used to recruit participants from day nurseries in the south-east of England. Seven nurseries agreeing to participate, although one failed to collect consent forms from parents and was excluded. Parents of all participating children provided written consent for their child to take part prior to data collection. Additionally, researchers gained verbal assent from each child prior to conducting each test session. An allergy to any of the vegetables used in the study was a designated exclusion criterion, but no participant was excluded on this basis. The final sample included 110 children (64 male) aged between 3 years 0 months and 4 years 11 months (*M* = 46.42 months; *SD* = 5.78).

The study adopted a between-subjects randomised control design. Participants were randomly allocated to one of four exposure conditions: Control, Visual-only, Smell-Visual or Smell-Touch-Visual (see Table 1 for the age and gender of participants in each condition).

Table 1. *Participant age and gender by condition.*

Condition	***N***	**Gender**	**Age in months** *M* (SD)
Control	28	F = 10 M = 18	*46.86* (5.854)
Visual	28	F = 13 M = 15	*45.57* (6.445)
Smell-Visual	26	F = 10 M = 16	*46.77* (5.264)
Smell-Tactile-Visual	28	F = 13 M = 15	*46.50* (5.693)

2.2. Materials and measures

2.2.1. Vegetables and containers

Six different vegetables were used, selected to vary in colour, shape and smell (broccoli, fennel, leek, parsnip, radish & swede). Vegetables were prepared in a university nutrition laboratory in adherence to Food Standards Agency regulations (2018b). For exposures to whole, raw vegetables, the six vegetables were washed and placed into separate containers. For exposures to prepared foods, the six vegetables were peeled (if necessary), chopped into bitesize pieces of varying shapes (e.g. circles of leek, florets of broccoli) and either steamed (broccoli, fennel, leek, parsnip & swede) or chilled (radish). Six pieces of each of the prepared vegetables were placed in separate containers. Containers were transparent plastic pots that were covered with black material to allow control over when the contents could be seen. For the smelling activities, a mesh cloth covered the opening to the container to allow the vegetable to be smelled without being seen when the lid was removed. For children in the control condition, two examples of each of six non-food items (e.g. toy cars, Lego blocks) were placed in the same type of container used in exposure conditions.

A plastic tasting tray with six compartments was used for each child's taste test. Immediately before the taste test, two new pieces of each prepared vegetable were placed in separate sections of the tray.

2.2.2. Matching game posters

An A4 colour laminated vegetable poster was created for the Visual-Only, Smell-Visual and Smell-Touch-Visual exposure sessions. The poster included images of all six vegetables used in the study, each showing the whole vegetable alongside two pieces of the cut up prepared vegetable. A similar poster was prepared for the control condition; this showed two examples of each of the six non-food items used in this condition.

2.2.3. Measures of immediate acceptance

WTT and intake were used as measures of children's immediate acceptance of the exposed vegetables (Heath et al., 2014). WTT was scored from 0-6, with one point awarded for each of the vegetables that the child touched to their tongue or lips, in line with previous uses of this measure. Intake was scored from 0-12, according to the number of pieces of prepared food the child consumed from the tasting tray. Half a point was awarded if less than a full piece was eaten. If the child chewed a piece of food but spat it out, that item counted towards WTT but not intake.

2.3. Procedure

The exposure activities and the taste test were completed on the same day at the child's preschool. Activities were conducted on a one-to-one basis with the same researcher. The researcher began by asking children individually if they would like to play a matching game. If they were happy to take part, the child was invited to sit at a table with the researcher in an area of the nursery away from other children. For children in the vegetable exposure conditions, two rounds of exposure were provided' the first involved exposure to the six whole, raw foods, and the second involved exposure to the six sets of prepared vegetables.

2.3.1. Exposure Sessions

For children in the three vegetable exposure conditions, the researcher introduced the activities as follows, "*Hello, we are going to play a matching game with vegetables. Here is our vegetable matching poster and inside these boxes are some vegetables. Let's see if you can match them to the poster*". The researcher then placed one of the containers containing a vegetable on the table and the matching game would begin. When the game had finished with that vegetable the next container was placed on the table, and this process continued until all six vegetables had been exposed. Vegetables were presented in random order.

Visual-only. As each container was presented, the researcher removed the cloth surrounding the container and asked the child to point to the picture on the poster that matched the vegetable inside. The researcher then asked follow-up questions to encourage visual exploration: "What does it look like?" "What colour is it?" If the child correctly matched the vegetable to its image on the poster, the researcher congratulated the child and labelled the vegetable, before moving onto the next container. If the child answered incorrectly, the researcher asked them to try again, before correctly identifying which vegetable it was.

Smell-Visual. As each container was presented, the researcher removed its lid and asked the child to smell the vegetable through the cloth, asking, "What does it smell like?" and encouraging the child to try to match the smell to one of the vegetables on the poster. If they guessed correctly, they were congratulated. If they guessed incorrectly, they were asked to have another guess. The cloth mesh was then removed so that the child could see the vegetable, and the child was asked again to match the vegetable to the poster, as in the Visual-only condition.

Smell-Tactile-Visual. The researcher first conducted the 'smelling' matching game as described for the Smell-Visual condition above. She then released the cloth mesh covering the container just enough to allow the child to slip their hand in to feel the vegetable. The child was asked to guess which vegetable they were feeling by pointing to the matching picture on the poster. Finally, they were invited to see if they had guessed correctly, at which point the mesh and cloth cover were fully removed to allow the child to see the vegetable in the container. The child was then asked to match the vegetable to the poster, as described in the Visual-only condition.

Control. The procedure for children in the Control condition was identical to that in the Visual-only condition, except that children were asked to match six non-food items in containers to the pictures of these on a poster. For each item, the researcher said: "Look what is in the container. Can you point to the matching picture on the poster?" The second exposure session was identical except that it involved new exemplars of the same items.

2.3.2. Taste Test

The taste test was the same for children in all four conditions. Each child was presented with a tray that included two prepared pieces of each of the six vegetables. Those in the vegetable exposure conditions were told that these were the same vegetables they had seen in the matching game. The researcher labelled each vegetable in turn while matching it to its picture on the poster. The child was asked if they would like to taste the vegetables, and which one would they like to try first. Children were given time to taste the foods at their own pace and were encouraged to taste as many as they liked. Once they had clearly stopped engaging with the vegetables, the researcher asked if they had finished and cleared the tray away.

3. Results

3.1. Data analysis

We used non-parametic analyses to test our hypotheses that immediate vegetable acceptance (as indexed by WTT & intake) would be greater in the exposure conditions than in the control condition and would increase in line with the number of senses engaged in the exposure activities, as both measures of acceptance were non-normally distributed (see details below). Jonckheere-Terpstra (J-T) trend analyses were used to look for linear trends on each measure, with exposure conditions treated as ordinal and ranking from 0 senses engaged (control group) to 3 senses engaged (Smell-Touch-Visual condition), while Kruskal-Wallis tests with Mann-Whitney U tests between conditions were used to investigate differences between conditions. Table 2 shows the means and standard deviations for the two measures of acceptance, by condition.

Table 2. *Descriptive statistics for WTT and intake by exposure condition. Superscripts denote significant differences between medians (e.g. the median WTT in the Control group differs to the median WTT in the Smell-Visual and Smell-Touch-Visual conditions).*

	Median	Mean	SD	Min score	Max score
WTT					
Control [a]	3^{cd}	2.89	2.13	0	6
Visual [b]	5^{d}	3.50	2.57	0	6
Smell-Visual [c]	6^{a}	4.81	1.79	1	6
Smell-Touch-Visual [d]	6^{ab}	4.93	1.88	1	6
Intake					

Control [a]	1.25[cd]	3.07	3.31	0	11
Visual [b]	1.5[cd]	3.55	3.98	0	12
Smell-Visual [c]	4.5[ab]	5.63	4.07	0	12
Smell-Touch-Visual [d]	7[ab]	6.71	4.32	0.5	12

3.2. WTT

The J-T trend analysis revealed a significant positive linear trend; WTT scores increased with the number of senses exposed, T_{JT} = 3024.0, z = 4.248, p <.001, τb = 0.27. Similarly, the K-W test revealed a significant difference between the group medians, $H(3)$ = 18.77, p < .001, η^2 = 0.18 (Table 2 & Fig. 1). Between-condition Mann-Whitney U comparisons revealed that children in the Smell-Visual and Smell-Touch-Visual conditions showed significantly greater WTT than those in the Control condition (U = 174.0, p < .001, η^2 = 0.21 & U = 171.0, p < .001, η^2 = 0.26, respectively). Children in the Smell-Touch-Visual condition also showed significantly greater WTT than those in the Visual-only condition (U = 252.5, p = .012, η^2 = 0.12), while the difference between those in the Smell-Visual and Visual-only conditions did not quite reach significance (U = 265.0, p =.069, η^2 = 0.06). There were no differences in WTT between the Visual-only and Control conditions (U = 328, p =.286, η^2 = 0.02) or between the Smell-Visual and Smell-Touch-Visual conditions (U = 321.5, p =.394, η^2 = 0.01).

3.3. Intake

The J-T trend analysis also revealed a significant positive linear trend; intake scores increased with the number of senses exposed, T_{JT} = 2956.5, z = 3.692, p <.001, τb = 0.34. Similarly, the K-W test found a significant difference between group medians, $H(3)$ = 15.42, p = .001, η^2 = 0.09 (Table 2 & Fig. 2). Between-condition Mann-Whitney U comparisons revealed that children in the Smell-Visual and Smell-Touch-Visual conditions showed greater intake of the exposed vegetables than children in both the Control condition (Smell-Visual: U = 222.0, p = .014, η^2 = 0.11; Smell-Touch-Visual: U = 193.0, p = .001, η^2 = 0.19) and Visual-only condition (Smell-Visual: U = 247.5, p = .043, η^2 = 0.08; Smell-Touch-Visual: U = 212.0, p = .003, η^2 = 0.16). There were no differences in intake between children in the Visual-only and Control conditions, U = 388.5, p = .954, η^2 < 0.001, or between those in the Smell-Visual and Smell-Touch-Visual conditions, U = 309.0, p = .339, η^2 = 0.02.

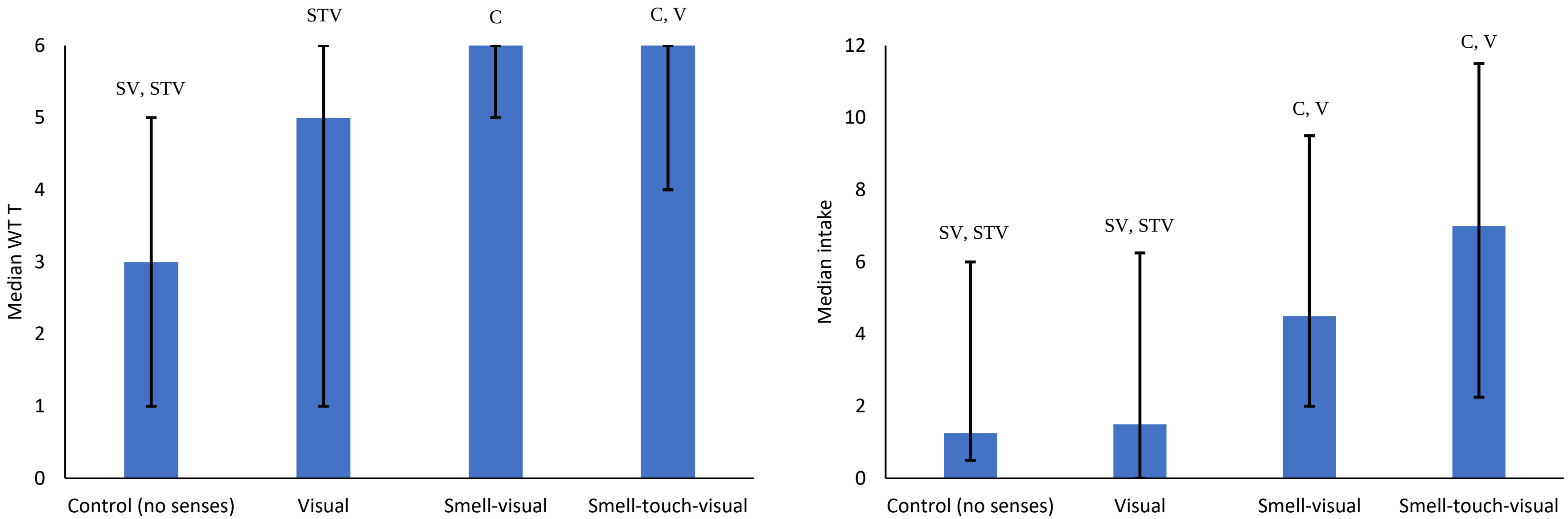

Figure 1. *Median WTT (left panel; max = 6) and Median Intake (right panel; max = 12) across conditions (error bars show 25th and 75th percentile). Letters above bars indicate a significant difference between that condition and the labelled conditions (C = Control, V = Visual-only, SV = Smell-Visual, STV = Smell-Touch-Visual).*

4. Discussion

This study was the first to investigate the impact of non-taste sensory exposure on immediate vegetable acceptance in relation to the number of component senses engaged. Results revealed linear increases in WTT and intake of vegetables with the number of senses engaged by exposure activities. The two multisensory exposure conditions were particularly effective; children in the Smell-Visual and Smell-Touch-Visual conditions were more willing to taste and eat the exposed vegetables than children in the Control and Visual-Only conditions.

These findings confirm recent reports that non-taste sensory exposure activities can support children's short-term acceptance of vegetables (Coulthard et al., 2016; Coulthard & Sealy, 2017; Dazeley & Houston-Price, 2015; Houston-Price et al., 2019; Johannessen et al., 2018; Mustonen & Tuorila, 2010; Owen et al., 2018). However, it is worth noting that unlike previous studies that have reported positive outcomes from exposure in a single sensory domain, most frequently visual familiarisation alone (Coulthard & Sealy, 2017; De Droog et al., 2014; Dulay, Masento, Harvey, Messer, & Houston-Price, 2020; Heath et al., 2014; Houston-Price et al., 2009; Owen et al., 2018; Rioux et al., 2018), the current study found no significant differences in acceptance between the Visual-only and Control conditions. The most likely explanation for this discrepancy in findings lies in the brevity of the *VeggieSense* intervention used in the current study; children were exposed to foods during a short session on a single day. In contrast, previous reports of positive effects of visual familiarisation to foods have followed extended exposure periods. For example, Owen et al. (2018) asked parents to look at picture books about foods with their toddler every day for a two-week period. To our knowledge, no study to date has shown a change in food acceptance following a single visual familiarisation episode. It is therefore feasible that visual exposure effects depend on multiple exposures over an extended period, and that visual-only activities of the type used in *VeggieSense* would be effective if repeated several times.

However, while one day of visual exposure to a vegetable appears to be insufficient to bring about acceptance, the current study shows that one day of multisensory exposure can be effective, at least in the short-term. Children who were exposed to foods via two or three sensory modalities were more likely to taste the exposed vegetables than children in the Control group, and those exposed in all three modalities were also more likely to taste the exposed foods than those in the Visual-only group. Children in both multisensory exposure conditions went on to consume more of the exposed vegetables than those in both the Control and Visual-only conditions. No significant differences were seen between the two- and three-sense conditions, likely due in part to ceiling effects, particularly in the WTT data, where most children in these groups tasted all the foods offered. However, the analyses overall suggest that children who engaged in activities involving all three senses showed the greatest benefit of taking part. Only this group consumed significantly more of the foods than children in the unisensory (Visual-only) exposure condition and, importantly, a positive linear trend was found across conditions.

Results therefore suggest a ‘sensory accumulation effect’ in the impact of multisensory exposure activities, whereby acceptance increases with the number of senses engaged. Such an account is congruent with ‘perceptual fluency’ accounts of exposure effects (Bornstein & D’Agostino, 1992), whereby the more perceptual information that is accrued about a stimulus, the easier it is to process that item when it is subsequently encountered, and the more positively disposed we are towards the stimulus as a result (Coulthard & Sealy, 2017; Shams & Seitz, 2008; cf. Spence & Piqueras-Fiszman, 2014). However, there are several alternative accounts of how the multisensory conditions in our design might have enabled additional perceptual information to be accrued, and these require further investigation. One possibility is that the ‘sensory accumulation effect’ is simply driven by the additive impact of information provided in sevearl sensory domains. That is, accruing information about a food’s smell and feel as well as its visual appearance strengthens the representation of the food in such a way as to induce a more positive evaluation of it. A second possibility is that multisensory conditions also afford the opportunity to construct perceptual representations of the food that integrate information across modalities, enabling learning about how the sensory domains are related to one another (e.g. foods that look knobbly feel rough to the touch). Such an account would be congruent with previous demonstrations of learning being facilitated by situations that provide ‘intersensory redundancy’, where information overlaps across sensory domains (Bahrick & Lickliter, 2000). Yet another explanation is that it is not the number of senses that induces the positive effects, but the total sensory exposure time; in this study, exposure in more senses also meant longer overall exposure time. These accounts are not mutually exclusive, of course; it is plausible that benefits accrue from greater exposure time, opportunities to experience foods in multiple sensory domains, and from opportunities to integrate these experiences; further research is needed to tease apart these possibilities empirically.

It is also worth noting that results are also supportive of familiarity with a food’s smell playing a key role in its acceptance. The two and three sense conditions in this study were distinguished from the unisensory and control conditions by the inclusion of olfactory exposure. To test this hypothesis, future studies require a design that compares the effects of exposure in one, two or three modalities while varying the specific senses involved in each condition – a design that is practically challenging but perhaps not impossible to achieve. Future work might also consider varying the set of vegetables investigated. While the vegetables used in the current study varied in shape and feel when raw, and in their texture and smell after they had been cooked, they were relatively mild in odour when they were presented as raw foods, and their discriminability may have been challenging to children. Previous research has also shown that food preparation method and individual differences in texture preferences can influence children's vegetable acceptance (e.g. Laureati et al., 2020; Zeinstra, Koelen, Kok, & de Graaf, 2010). Using vegetables with different textures and odours – along with alternative preparation methods – would confirm whether results generalise beyond the foods used in the current study. It should also be acknowledged that the findings reported here were collected in a UK-based sample. Given that background exposure to, consumption of, and culture surrounding the preparation of vegetables varies considerably across countries, one should be cautious in assuming these findings would apply to non-UK-based populations.

It would also be valuable to consider both age-related differences and individual differences in children's visual, tactile and olfactory sensitivity in relation to the effectiveness of different exposure activities, to establish whether sensory sensitivity is relevant to the success of an intervention involving sensory exploration. Previous research has established developmental change in attention to sensory information. For example, in a sample of 7- to 11-year olds, Coulthard et al. (2016) found that younger children were more likely to rate a novel vegetable as looking strange, while older children were more likely to rate the same vegetable as smelling strange. Familiarisation techniques may be optimised for different groups of children by providing exposures in domains that carry more weight for them.

Finally, it is worth noting that adults also need support with increasing their dietary variety and their intake of vegetables, in particular (Spence, 2020). It is interesting to note that recent evidence from real-life dining situations suggests that multisensory experience may not play the straightforward role in adult food acceptance that it does in children. For example, Spence and Piqueras-Fiszman (2014) highlight the heightened enjoyment that can result when a diner's senses are challenged by forced attention to a food's taste in isolation (e.g. when eating in the dark) or by incongruity between a food's visual cues (e.g. colour) and its flavour. Further research might fruitfully explore the factors that determine when unisensory versus multisensory stimulation is most likely to induce intake, including the role played by eating experience.

4.1. Conclusions

This study examined the effects of a one-day non-taste sensory exposure intervention on preschool children's WTT and intake of vegetables. Multisensory, but not unisensory (visual-only), exposure was found to increase WTT and intake of vegetables relative to a control group. A positive linear trend in immediate acceptance of the food with the number of senses engaged by exposure activities was interpreted as indicating a 'sensory accumulation effect': the more sensory information provided during exposure activities, the greater children's acceptance of the exposed foods. The longevity of these effects remains to be established, as does the specific role played by the individual sensory activities included in the intervention. Nevertheless, results indicate that *VeggieSense* activities provide a promising avenue for supporting immediate increases in vegetable acceptance in pre-schoolers.

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Author Contributions

Alan Parry Roberts – oversaw data collection, conducted data analysis, wrote first draft of manuscript.

Lara Cross – contributed to literature review and design of study, collected data

Amy Hale – contributed to literature review and design of study, collected data

Carmel Houston-Price – designed study, advised on data collection & analysis, contributed to writing of manuscript

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