The effects of repeated exposure and variety on vegetable intake in pre-school children.

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Abstract

Children's vegetable consumption in the UK remains lower than national recommendations, presenting potential long-term health risks. It is known that repeated exposure promotes intake of novel vegetables and that offering children variety and choice can also encourage intake. The current study aimed to compare the impact of offering variety over simple repeated exposure as a strategy for increasing pre-school children's vegetable consumption. Children (N=95) aged 24 to 55 months were recruited through participating nurseries and assigned to receive repeated exposure (RE) to a single vegetable snack or a mixed snack consisting of five different vegetables (variety: V). A minimum of 5 (maximium 6) exposures were given for both RE and V conditions. Pre and post-intervention intake measures of both the RE and V snacks were taken for each child. Follow up measures took place 1 month post-intervention (n=40). Vegetable intake increased significantly from pre to post intervention for snacks congruent to the condition to which children were assigned. Magnitude of change was smaller for the variety condition. Follow up data revealed that snack intake remained significantly higher than baseline 1 month post-intervention ($p<0.001$). In agreement with previous work this study confirmed that repeated exposure was effective in promoting children's vegetable intake but there was no additional benefit of variety in this context. It may be that for moderately familiar vegetables, serving them alone encourages intake and for this age group, avoids contamination fears or effects of neophobia.

Introduction

Given that vegetable intake is reported to be below current recommendations [1], effective strategies are required to facilitate vegetable acceptance and increase intake. A recent systematic review and meta-analysis has identified repeated exposure as the most successful means to encourage vegetable intake in children, particularly when the vegetable is unfamiliar [2]. Repeated exposure is not the only strategy used to encourage intake, rather a number of methods are used including varying the ways vegetables are prepared and offered [3-6],the use of modelling or rewards for tasting the vegetables [7-9], pairing novel vegetables with familiar flavours or added energy [10-14] . A common finding across these studies is that repeated exposure is a simple and highly succesful technique for increasing children's vegetable consumption, and no additional benefit is observed with adding sweetness or energy [10-12]. Repeated and frequent experience with new foods and flavours without negative consequence allow children to become familiar with these foods and recognise them as safe as described in the "learned safety hypothesis" [15]. Simply by increasing familiarisation with a food, preference also increases [16, 17] and familiarisation increases acceptance, liking and intake of vegetables in young children [18, 19].

Serving an assortment of foods and flavours within a single meal increases intake in adults [20] and young children [21, 22] and is known as the variety effect. An absence of variety has been found to decrease intake [23]. To date, studies offering a variety of vegetables have produced promising results. In one study adult participants were presented with meals in which half the plate contained either a 600g portion of a single vegetable or 200g of three different vegetables [24]. Their results demonstrated that vegetable intake was greater when participants were offered three different vegetables than when they were offered a single type. A subsequent study by Roe and colleagues [25] found similar results when offering pre-school children a variety of vegetables at snack time. Children ate more vegetables when presented with three different types of familiar vegetable compared to when they were offered a single vegetable snack. It is thought that variety operates by interfering with or delaying satiation [26], thus boredom with the sensory attributes of a single food or flavour is prevented with variety [27]. An alternative explanation, but which has not been tested systematically, may be that for children offering variety and choice provides the welcome opportunity to make autonomous decisions about what to eat as well as the chance to select a preferred vegetable among less preferred vegetables.

Several studies exploring parental feeding practices have confirmed that offering children choice in the foods that they consume can influence subsequent food intake, particularly in the case of vegetables [28-30]. Parents who are excessively prescriptive in the foods that they offer their children may inadvertently promote undesirable dietary habits such as low fruit and vegetable intake while those who are excessively permissive in the types of choices children are able to make may produce the same outcome [28, 31]. The potential importance of offering choice is explained by self-determination theory which suggests that choice increases an individual's perception of control and intrinsic motivation [32]. In general, offering choice is appreciated by children [33] and can have a positive effect on acceptance and intake [34, 35]. The coincidence of choice and variety has been explored [36], and offering choice, both before and within the meal, led to an increase in vegetable intake when compared with a no choice condition. Interestingly, no difference was found between explicit choice offering at the beginning of a meal and offering choice via variety suggesting both methods are equally effective.

The aim of the current study was to test the hypothesis that offering pre-school children repeated exposure to moderately familiar vegetables in the form of variety would produce greater overall vegetable consumption compared to offering a single vegetable. It was predicted that repeated exposure would increase intake of the target vegetables in both the single and variety conditions, but that variety would have an additive effect to repeated exposure by increasing overall vegetable intake.

Method

Participants

Parents of pre-school children aged 24-60 months were recruited through local day care nurseries in the West and South Yorkshire areas, UK. Ten nurseries were initially contacted via telephone to ascertain whether they wished to take part. Those that expressed an interest in participating were visited by a researcher and meetings were held with staff teams to discuss the purpose of the study. Further meetings were arranged with those staff that would be responsible for the day to day running of the study so that they were fully prepared for the intervention. Details of the intervention were then distributed to parents who were asked to inform nurseries if they preferred that their child did not take part.

Of the ten nurseries approached, five agreed to participate. Children attending two of the nurseries were predominantly White British, while children at the remaining three were predominantly South Asian. All five nurseries served areas located within the 50% most deprived (small areas) in England according to the Index of Multiple Deprivation scores [https://www.gov.uk/government/collections/english-indices-of-deprivation]. In total 184 children were recruited, screened for food allergies (as reported by parents) and assigned to one of the two clusters; the single vegetable or repeated exposure (RE) or variety (V) group. The aim of recruitment was to achieve at least 60 participants in each cluster. This number was guided by a previous within-subjects study with pre-school children (25; n = 61), and sensitivity analysis (G*Power) with intended N of 120, assuming alpha = 0.05, and power of 0.80, indicated that an effect size of f =0.25 should be detectable, which is a medium effect size.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the School of Psychology (University of Leeds) ethics committee (12-0240). Written informed consent was obtained from parents and caregivers of all participating children.

Procedure

Three vegetables were selected as targets for the intervention. Vegetables were identified as potential targets from a previous study [37]; namely vegetables that had been introduced to this age group of children (so were familiar), but were not typically eaten as snacks. Given that is was not possible to ascertain whether individual vegetables had been regularly offered as snacks to participating children prior to the start of this study, three target vegetables were selected. These were baby sweet corn, celery and red pepper. The target vegetables were offered as the single snacks (in the RE condition) and included in the mixed vegetable snack (in the V condition). To ensure variety, a further 2 vegetables, radish and green pepper, were also selected to be included in the mixed vegetable snack based on the same criteria (familiar, but were not typically consumed as snacks).

A between subjects design was used. Given that children in each nursery class would be consuming snacks together during snack time, cluster randomisation was used for condition and vegetable assignment. Nursery classes were randomly assigned to a condition (RE or V) and then randomly assigned to a target vegetable (baby corn, red pepper, or celery) using a block approach. This was to ensure all children within the same class were offered the same snack.

Pre -intervention intakes were measured two to five days prior to the intervention. All children were offered a bag containing slices of a single vegetable (their assigned target vegetable) and a bag containing a variety of sliced vegetables on two separate days and this was counterbalanced to avoid order effects. A summary of the procedure is shown in Figure 1.

Figure 1 about here

The exposure phase of the intervention began 2 to 5 days after pre-intervention intakes were measured. Children received between 5 and 6 exposures to either the single vegetable snack (RE condition) or the mixed vegetable snack (variety condition). Intake was measured after each exposure and post-intervention measures of intake of both the single and mixed vegetable snacks took place 2 to 5 days later. A further measure of intake of both snacks was taken 1 month post-intervention.

All snack sessions were carried out by nursery staff although a researcher was present for the first session at each nursery. The single vegetable snack consisted of 100g of one of the three target vegetables (baby sweet corn, celery or red pepper). The variety snack was a mix of 20g of each of the five vegetables (baby sweet corn, celery, red pepper, green pepper and radish).

Study Foods

The selected vegetables were purchased and prepared by the experimenter in the laboratory kitchen. The vegetables were bought whole, sterilised in Milton fluid and sliced in identical 3cm long pieces before being sealed in clear plastic bags that were labelled with the child's name. Each bag contained 100g of vegetables in total.

Anthropometrics

Where consent had been given, the heights and weights of participating children were measured at the end of the intervention. Children were weighed using SECA digital scales and had height measured using a Leicester SMSSE portable stadiometer. BMI z-scores were calculated using the WHO anthropometric calculator (http://www.who.int/childgrowth/software/en/).

Questionnaires

Questionnaires were distributed to parents of participating children through their nurseries. These included a number of demographic questions, questions regarding milk feeding and complementary feeding, a parental Food Frequency Questionnaire (FFQ; [38]) and a parental measure of food neophobia (Food Neophobia Scale: FNS, [39]). A child FFQ, the Child Food Neophobia Scale (CFNS; [40]) and the Child Eating Behaviour Questionnaire [41] were also included.

Statistical Analysis

Data were analyzed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). Since the aim of the study was to compare repeated exposure to a single versus a variety of vegetables on the change in intake of the vegetables offered data from children who consumed a large amount of the target vegetable (≥40g; assuming a child's portion is half of an adult portion) at pre-test were excluded from the analysis ($n = 20$). This was done on the basis that consumption above 40g demonstrated an existing preference for this vegetable but they were not excluded from taking part in the study. All remaining children who completed the intervention were included in the analyses ($n=95$).

In order to identify differences in the age, BMI and gender of the two groups a one way analysis of variance and also chi-square tests were conducted. Repeated measures ANCOVA were performed on intake data (both absolute and change in intake) with time (3 levels: pre-intervention, post-intervention and 1 month post-intervention) as the within-subject factor and with condition (2 levels – RE vs V) and type of target vegetable (3 levels: baby sweet corn, celery and red pepper) included as between-subjects factors. The covariates were age and BMI-z scores since these differed by group (Table 1). The same analyses were then repeated with time (2 levels - first and last exposures) as the within subjects factor. Paired t-tests produced within group contrasts of intake and a further ANCOVA explored patterns of intake across the exposure period, including consumption of each of the component vegetables of the mixed vegetable snack. Pearson's correlation analysis was performed to identify any relationships between pre and post-intervention intake for the two conditions (clusters) and snack types. In order to investigate whether the nursery conditions produced any clustering, the intra cluster correlation for the pre intervention intake was assessed by calculating a mixed model using lmer in R with only nursery as a random factor. This produced an ICC of 0.04, VIF = 1.72. In order to ensure this did not impact the result, all the main analyses were recalculated using multilevel models with nursery and child as random factors. This produced no change in the pattern of results reported, and for simplicity the simpler ANCOVA results are reported here.

Results

In total, 115 children received at least 5 of the 6 exposures and were present for all pre-intervention and post-intervention measures. Of these, twenty children consumed ≥40g of the target vegetable pre-intervention. A summary of the remaining 95 participants can be found in Table 1. To control for significant differences in age and BMI z-scores, analyses included these factors as covariates. Age was first recalculated to be mean centred.

Table 1 about here

Intake pre and post intervention

<u>Pre-intervention intake (baseline)</u>

Pre-intervention intake did not differ by snack type (mixed 8 ±1.3 g; single 6.1 ±0.9g, p=0.16). Considering the two group separately at baseline, children in the V condition consumed similar amounts of both the variety and the single snack. However children in the RE condition ate significantly more of the mixed vegetable snack at baseline (p<0.01).

While intake did not differ significantly by target vegetable assignment (p=0.09), children consumed more red pepper than either of the other two single vegetable snacks at pre-test (red pepper: 8.48±1.81g; baby sweet corn: 4.78±1.23g; celery: 4.22±1.25g). This may suggest that of the three target vegetables, red pepper was preferred at baseline. However, further examination of the mixed vegetable snack intake did not support this preference relative to the other vegetables offered (Figure 2a).

Figure 2a (upper panel) and b (lower panel) about here

<u>Post-intervention intake</u>

The single vegetable snack intake was greater post-intervention than the mixed vegetable snack (single = 15.23±2.32g; mixed = 8.56±1.56g); t (94) = 2.43, p<0.05. Within group contrasts revealed that this difference was present for the RE group (single 18.9 ± 3.5g, mixed 6.6 ±1.4g; p=0.001) but not the V group (p=0.58). No effect of vegetable assignment was found on post-intervention intake. Post-intervention consumption of the three vegetables offered as single snacks was similar and no significant differences were found between vegetables in the mixed snack (Figure 2b).

The ANCOVA revealed a main effect of time with overall snack intake increasing significantly pre to post-intervention (F(1, 71) = 9.84, p<0.01[1]). Although no main effects of snack type or condition were found, a significant snack type x time x condition interaction was observed (F(1, 71) = 9.26, p<0.01). Intake of the mixed vegetable snack increased significantly among the children assigned to the V group (t (36) = 2.60, p<0.05) pre to post-test but intake of this mixed snack decreased in the RE group (p=0.08). Single vegetable snack intake increased significantly

[1] The F values for ANCOVA are presented with data from n = 75 children since BMI z scores were missing for 20 children.

in the RE group ($t(57) = 4.18$, $p < 0.001$) but did not change for the V group ($p=0.17$) (Figure 4). No main effects or interactions involving age or BMI z-scores were found.

Figure 3 around here

Changes in intake

Change in intake was calculated to give difference (delta) values. Analysis revealed that overall change in intake was significantly greater for the single snack when compared with the mixed vegetable snack ($t(94) = 2.80$, $p<0.01$). Change in intake for both snack types from pre to post intervention was also found to differ significantly by condition (RE vs V; delta mixed $F(1, 93) = 9.81$, $p<0.01$; delta single ($F(1, 93) = 8.01$, $p<0.01$). Further analysis revealed a significant difference in change in intake between the mixed and single snacks for children in the RE condition ($t(57) = 4.05$, $p < 0.01$) but not the V condition ($p=0.1$). No significant effect of target vegetable assignment was found on change in intake, however, magnitude of change was significantly greater for the single snack in the red pepper group ($t(37) = 2.88$, $p<0.01$).

Intake across exposures

Since number of exposures differed between children, intake was also compared from first to last exposure. A significant main effect of time demonstrated that intake increased significantly from the start to the end of the exposure period, $F(1, 93) = 9.16$, $p<0.01$, but this was not found to differ as a result of condition or target vegetable assignment. A main effect of exposures was found ($F(4.64, 308.04) = 3.90$, $p<0.01$) and intake had increased significantly by exposure 3 ($p<0.05$). There was no further significant increase after the third exposure (Figure 4). Intake of snack across the exposure period did not differ in terms of condition or target vegetable assignment. Further examination of children's intake of the mixed vegetable snack within the V condition then took place.

Intake at Follow Up

In all, 40 children from the original sample went on to complete measures of intake 1 month post-intervention. Analysis revealed that overall snack consumption increased significantly over time [F(2, 76) = 13.02, p < 0.001]. Bonferroni corrected post hoc comparisons revealed an increase in intake from pre-intervention to immediately post-intervention (p=0.001) and this was maintained at 1 month follow up (p=0.001). This was not affected by condition and no condition by time interaction was found. Overall snack intake at 1 month follow up was significantly greater than immediately post-intervention (p = 0.044). For children assigned to the V group intake of the two snacks did not differ significantly at any point during the intervention. However, post-intervention and follow up intake of the single vegetable snack was significantly greater than mixed vegetable intake in the RE condition (Figure 5). Again no effects of age or BMI z-score were found.

Questionnaires

Overall, only 22 parents of participating children completed and returned questionnaires, all of whom were mothers. This was less than 20% of the sample and therefore was considered too small for further analyses.

Discussion

The results of this study confirm previous findings that repeated exposure to a single vegetable can promote pre-school children's vegetable consumption [11, 14, 18, 42]. However, there was no additional benefit conferred by variety. Therefore the effect of repeated exposure to a specific vegetable seems to depend on how it is presented (alone or mixed with other vegetables) and what other vegetables are present. In this context, intake of the target vegetable increased when offered to children on its own, but no change in intake was found when this was offered as part of a mixed vegetable snack. This finding is of particular interest as it suggests that variety per se is not sufficient to boost repeated exposure. The results also showed a significant increase in intake from baseline was achieved by the third exposure, suggesting that only a small number of exposures is needed to increase intake.

Children who were repeatedly exposed to a single vegetable snack did not increase their consumption of the 5-veg, mixed snack. Interestingly assignment to the single vegetable snack condition appeared to result in a decrease in intake of the vegetable mix, despite significantly higher intake of the mixed snack at baseline. This may suggest that children become familiar with the particular way that they have been introduced to this snack and it is familiarity of form rather than variety which stimulates intake.

Existing research has demonstrated a variety effect using vegetables [25, 36]. In contrast our findings fail to support the variety/choice effect and might be attributable to the target vegetables selected which were familiar [37], but not highly liked and not typically offered as a snack. It is suggested that the novelty of providing the mixed vegetable snack mitigated against the predicted increase in intake by variety.

The children included in this study were between the ages of two and five years old and evidence suggests that children experience food neophobia between two and six years of age [16]. Characterised by the avoidance and rejection of new and unfamiliar foods the neophobic response is reduced through repeated experiences with food [16, 17]. However, it has been suggested that animals, including humans, prefer inititial experiences with and ingestion of new foods individually to allow accurate associations to be made between the foods and any negative post-ingestive consequences and to ensure harmful foods are avoided in the future [43]. It follows that target vegetables selected for this experiment may have been novel and disliked by some children and so children were less willing to taste and consume the vegetables when they were offered mixed together compared with when they were offered separately. In addition Brown and colleagues [44] discuss the "contamination effect" whereby children will reject liked foods if they are presented with novel or disliked foods. This might contribute to explaining the low intake of the mixed vegetables. The fact that children in the RE condition, who increased their intake of their target vegetable, failed to eat any more of that target when it was offered as part of the variety snack post-intervention offers support for a contamination effect. Brown et al. [44] were also able to demonstrate that contamination effects were more likely to be observed in the youngest children that participated in their study (aged 4 years). The current sample also fall into this age group and would be considered to be at the peak of the neophobic stage [45-47].

As predicted, children assigned to the RE condition, who received no exposures to the mixed vegetable snack, did not increase consumption of the mixed vegetable snack. In addition to building children's familiarity with novel foods, the 'learned safety' hypothesis suggests that repeated exposure also allows individuals to trust that new foods are safe to consume [15]. It follows then that those children who were not exposed to the mixed vegetable snack did not increase intake, having lacked the opportunity to become familiar with the mixed format. It is assumed that the children in the RE condition were in fact surprised by the novel offering of 5 vegetables and so variety in itself did not increase intake. Alternatively, variety offers the opportunity for children to avoid some of the vegetables offered, and presents competition between more or less liked vegetables. Therefore, children are more likely to seek out their favoured vegetable and leave the remainder and so overall intake does not increase.

Children in the variety condition may not have consumed sufficient amounts of the individual vegetables to benefit from the effects of repeated exposure or may have required a greater number of exposures to produce comparable increases in intake. For instance, children in the RE group were consuming around 20g of their target vegetable, whereas the other children were consuming around 1 – 5g of each vegetable in the mixed bag.

In line with existing research, the results of this study suggest that the effects of repeated exposure can be observed following a small number of experiences with novel vegetables [11, 48]. To date the most notable shifts in vegetable consumption have been produced by studies which have employed soups and purees as target foods [11, 12, 49] with exposure to raw vegetables producing less substantial increases [18, 50]. Such a distinction between intake of pureed or liquidised vegetables and that of vegetables in solid form is not surprising given the difference in texture and the resulting effort involved in consumption. A recent study in adults demonstrated that texture and viscosity can influence the speed and volume consumed [51]. Compared to vegetable soups and purees, consuming raw vegetables requires more effort and times to orally process, thus resulting in reduced intake. This might account for the relatively lower vegetable intake compared to other studies. It is possible that the combination of raw vegetables offered as snacks with the extra effort involved in consuming raw/solid vegetables may necessitate a greater number of exposures before comparable changes in intake are observed.

The absence of individual measures of vegetable familiarity and liking for participants presents a limitation of this study. For instance results suggest that repeated exposure may be more effective for some vegetables (e.g. red pepper and celery) than others (e.g. baby sweet corn) but without individual measures it is difficult to make inferences about why this might be the case. Another limitation of this study was the loss of data to follow-up at 1m after the intervention, with only 40 children participating at this time point. This was due to testing being conducted during summer, when fewer children attended nursery. However, an important strength is that the experiment was conducted in nursery settings according to the usual snack time routine by nursery staff familiar to participating children thus increasing ecological validity and generalizability. The lack of a variety effect may have been related to the types of vegetables offered and to the age of the current sample, considered to be at the peak of the neophobic stage. Future studies might look to explore this effect further by broadening the sample to include both younger and older age groups; and selecting vegetables which might be more acceptable (so providing a familiarization procedure before comparing variety and repeated exposure).

The results of this study suggest that offering a variety of vegetables does not confer an advantage over simple, repeated exposure to a single vegetable. However, the results provide further evidence of the beneficial effects of repeated exposure and its effectiveness in promoting vegetable consumption in preschool children. As a possible strategy for increasing intake, a simple repeated exposure technique is easy to implement and may be more effective than offering variety in view of its positive impact on preference. The current findings also suggest that for potentially food neophobic children, new vegetables may be best introduced separately in order to encourage 'learned safety' and to avoid possible contamination effects.

References

1. Public Health England, National Diet and Nutrition Survey Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009 – 2011/2012). 2014: London.

2. Nekitsing, C., et al., Systematic review and meta-analysis of strategies to increase vegetable consumption in preschool children aged 2-5 years. Appetite, 2018. **127**: p. 138-154.

3. Poelman, A.A.M. and C.M. Delahunty, The effect of preparation method and typicality of *colour on children’s acceptance for vegetables.* Food Quality and Preference, 2011. **22**(4): p. 355-364.

4. Poelman, A.A.M., C.M. Delahunty, and C. de Graaf, Cooking time but not cooking *method affects children’s acceptance of Brassica vegetables.* Food Quality and Preference, 2013. **28**(2): p. 441-448.

5. Zeinstra, G.G., et al., *The influence of preparation method on children’s liking for* vegetables. Food Quality and Preference, 2010. **21**(8): p. 906-914.

6. Mennella, J.A., et al., Variety is the spice of life: strategies for promoting fruit and vegetable acceptance during infancy. Physiol Behav, 2008. **94**(1): p. 29-38.

7. Cooke, L.J., et al., Eating for pleasure or profit: the effect of incentives on children's enjoyment of vegetables. Psychol Sci, 2011. **22**(2): p. 190-6.

8. Corsini, N., et al., Rewards can be used effectively with repeated exposure to increase liking of vegetables in 4-6-year-old children. Public Health Nutr, 2013. **16**(5): p. 942-51.

9. Horne, P.J., et al., Increasing pre-school children's consumption of fruit and vegetables. A modelling and rewards intervention. Appetite, 2011. **56**(2): p. 375-85.

10. Ahern, S.M., et al., The root of the problem: increasing root vegetable intake in preschool children by repeated exposure and flavour flavour learning. Appetite, 2014. **80**: p. 154-60.

11. Caton, S.J., et al., Repetition counts: repeated exposure increases intake of a novel vegetable in UK pre-school children compared to flavour-flavour and flavour-nutrient learning. Br J Nutr, 2013. **109**(11): p. 2089-97.

12. de Wild, V.W., C. de Graaf, and G. Jager, Effectiveness of flavour nutrient learning and mere exposure as mechanisms to increase toddler's intake and preference for green vegetables. Appetite, 2013. **64**: p. 89-96.

13. Anzman-Frasca, S., et al., Repeated exposure and associative conditioning promote preschool children's liking of vegetables. Appetite, 2012. **58**(2): p. 543-53.

14. Hausner, H., A. Olsen, and P. Moller, Mere exposure and flavour-flavour learning increase 2-3 year-old children's acceptance of a novel vegetable. Appetite, 2012. **58**(3): p. 1152-9.

15. Kalat, J.W. and P. Rozin, "Learned safety" as a mechanism in long-delay taste-aversion learning in rats. J Comp Physiol Psychol, 1973. **83**(2): p. 198-207.

16. Birch, L.L., et al., What kind of exposure reduces children's food neophobia?: Looking vs. tasting. Appetite, 1987. **9**(3): p. 171-178.

17. Loewen, R. and P. Pliner, Effects of prior exposure to palatable and unpalatable novel foods on children's willingness to taste other novel foods. Appetite, 1999. **32**(3): p. 351-66.

18. Wardle, J., et al., Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. Appetite, 2003. **40**(2): p. 155-162.

19. Lakkakula, A., et al., Repeated taste exposure increases liking for vegetables by low-income elementary school children. Appetite, 2010. **55**(2): p. 226-231.

20. Hetherington, M.M., et al., Understanding variety: Tasting different foods delays satiation. Physiology & Behavior, 2006. **87**(2): p. 263-271.

21. Gerrish, C.J. and J.A. Mennella, Flavor variety enhances food acceptance in formula-fed infants. American Journal of Clinical Nutrition, 2001. **73**(6): p. 1080-1085.

22. Mennella, J.A., et al., Variety is the spice of life: Strategies for promoting fruit and vegetable acceptance during infancy. Physiology & Behavior, 2008. **94**(1): p. 29-38.

23. Sorensen, L.B., et al., Effect of sensory perception of foods on appetite and food intake: a review of studies on humans. Int J Obes Relat Metab Disord, 2003. **27**(10): p. 1152-66.

24. Meengs, J.S., L.S. Roe, and B.J. Rolls, Vegetable variety: an effective strategy to increase vegetable intake in adults. J Acad Nutr Diet, 2012. **112**(8): p. 1211-5.

25. Roe, L.S., et al., Serving a variety of vegetables and fruit as a snack increased intake in preschool children. Am J Clin Nutr, 2013. **31**: p. 31.

26. Hetherington, M. and R.C. Havermans, Sensory-specific satiation and satiety., in Satiation, satiety and the control of food intake: theory and practice, J.E. Blundell and F. Bellisle, Editors. 2013, Woodhead Publishing Ltd: Cambridge. p. 253-269.

27. Havermans, R.C., et al., Food liking, food wanting, and sensory-specific satiety. Appetite, 2009. **52**(1): p. 222-5.

28. Patrick, H., et al., The benefits of authoritative feeding style: caregiver feeding styles and children's food consumption patterns. Appetite, 2005. **44**(2): p. 243-249.

29. Blissett, J., Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood. Appetite, 2011. **57**: p. 826-831.

30. Scaglioni, S., M. Salvioni, and C. Galimberti, Influence of parental attitudes in the development of children eating behaviour. British Journal of Nutrition, 2008. **99**(SupplementS1): p. S22-S25.

31. Crombie, I.K., et al., What maternal factors influence the diet of 2-year-old children living in deprived areas? A cross-sectional survey. Public Health Nutrition, 2009. **12**(08): p. 1254-1260.

32. Ryan, R.M. and E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. Am Psychol, 2000. **55**(1): p. 68-78.

33. Zeinstra, G.G., et al., Offering choice and its effect on Dutch children's liking and consumption of vegetables: a randomized controlled trial. Am J Clin Nutr, 2010. **91**(2): p. 349-56.

34. Hendy, H.M., K.E. Williams, and T.S. Camise, "Kids Choice" school lunch program increases children's fruit and vegetable acceptance. Appetite, 2005. **45**(3): p. 250-63.

35. Hendy, H.M., Comparison of five teacher actions to encourage children's new food acceptance. Ann Behav Med, 1999. **21**(1): p. 20-6.

36. Rohlfs Domínguez, P., et al., *Providing choice increases children’s vegetable intake.* Food Quality and Preference, 2013. **30**(2): p. 108-113.

37. Ahern, S.M., et al., Eating a rainbow. Introducing vegetables in the first years of life in 3 European countries. Appetite, 2013. **71**: p. 48-56.

38. Hammond, J., et al., Validation of a food frequency questionnaire for assessing dietary intake in a study of coronary heart disease risk factors in children. Eur J Clin Nutr, 1993. **47**(4): p. 242-50.

39. Pliner, P. and K. Hobden, Development of a scale to measure the trait of food neophobia in humans. Appetite, 1992. **19**(2): p. 105-20.

40. Pliner, P., Development of measures of food neophobia in children. Appetite, 1994. **23**(2): p. 147-63.

41. Wardle, J., et al., Development of the Children's Eating Behaviour Questionnaire. J Child Psychol Psychiatry, 2001. **42**(7): p. 963-70.

42. de Wild, V.W.T., C. de Graaf, and G. Jager, Effectiveness of flavour nutrient learning *and mere exposure as mechanisms to increase toddlerâ€™s intake and preference for green* vegetables. Appetite, 2013. **64**(0): p. 89-96.

43. Cashdan, E., Adaptiveness of food learning and food aversions in children. Social Science Information, 1998. **37**(4): p. 613-632.

44. Brown, S.D., et al., Disliked food acting as a contaminant in a sample of young children. Appetite, 2012. **58**(3): p. 991-6.

45. Dovey, T.M., et al., Food neophobia and `picky/fussy' eating in children: A review. Appetite, 2008. **50**(2-3): p. 181-193.

46. Addessi, E., et al., Specific social influences on the acceptance of novel foods in 2 5-year-old children. Appetite, 2005. **45**(3): p. 264-271.

47. Cashdan, E., A sensitive period for learning about food. Human Nature, 1994. **5**(3): p. 279-291.

48. Wardle, J., et al., Modifying children's food preferences: the effects of exposure and reward on acceptance of an unfamiliar vegetable. European Journal of Clinical Nutrition, 2003. **57**(2): p. 341-348.

49. Remy, E., et al., Repeated exposure of infants at complementary feeding to a vegetable puree increases acceptance as effectively as flavor-flavor learning and more effectively than flavor-nutrient learning. J Nutr, 2013. **143**(7): p. 1194-200.

50. Remington, A., et al., Increasing food acceptance in the home setting: a randomized controlled trial of parent-administered taste exposure with incentives. The American Journal of Clinical Nutrition, 2012. **95**(1): p. 72-77.

51. de Graaf, C. and F.J. Kok, Slow food, fast food and the control of food intake. Nat Rev Endocrinol, 2010. **6**(5): p. 290-3.

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Table 1. Participant characteristics (n=95)

	Condition			
	Total (n = 95)	Variety (n = 37)	RE (n = 58)	p-value
Age (months)	43.44 ± 0.87	40.00 ± 1.51	45.64 ± 0.94	0.001
Range (months)	25-55	25-54	25-55	-
Male/Female	53/42	21/16	32/26	0.53
BMI z-score	0.85 ± 0.15 (n = 75)	1.25 ± 0.14 (n = 32)	0.55 ± 0.24 (n = 43)	0.02

Figure legends

Figure 1: Schematic overview of the study protocol: RE = repeated exposure to a single vegetable (baby sweet corn, celery or red pepper), Variety = repeated exposure to the 5-vegetable snack (baby sweet corn, celery, red pepper, green pepper and radish). E1 etc. denotes exposure number. Please note that the order of these exposures was counterbalanced.

Figure 2: Absolute intake (g) of each vegetable by snack type at baseline (pre-test, 2a) and post intervention (post-test, 2b). Values are means, with their standard errors represented by vertical bars. ***Mean value was significantly different from that at baseline ($p<0.001$)

Figure 3: Absolute intake (g) at baseline (pre-test) and post-intervention (post-test) of the 1-veg and 5-veg snacks in each condition (RE vs variety). Values are means, with their standard errors represented by vertical bars. ***Mean values were significantly different from baseline to post-intervention ($p<0.001$)

Figure 4: Mean snack intake (g) across six exposures (both conditions combined). Values are means, with their standard errors represented by vertical bars. * Mean value was significantly different from that at exposure number 1 ($p<0.05$). ANCOVA demonstrated a main effect of exposures ($p<0.01$) and intake increased significantly by exposure 3 ($p<0.05$).

Figure 5: Mean snack intake (g) at baseline (pre-test), immediately post-intervention (post-test) and 1 month after intervention (follow-up) by condition (Variety/RE) and snack type (1-veg, 5-veg)

Figure 1

	Pre-test Week 1			**Exposure period** Week 2		Week 3		Week 4			**Post-test** Week 5			**Follow-up** Week 10	
Day	1	2		3 (E1)	4 (E2)	5 (E3)	6 (E4)	7 (E5)	8 (E6)		9	10		11	12
RE (*n*=87)	1-veg snack	5-veg snack	**2-5 days**	1-veg snack	1-veg snack	1-veg snack	1-veg snack	1-veg snack	1-veg snack	**2-5 days**	1-veg snack	5-veg snack		1-veg snack	5-veg snack
Variety (*n*=97)				5-veg snack	5-veg snack	5-veg snack	5-veg snack	5-veg snack	5-veg snack						

n= number of children recruited and assigned to each condition (total *n*=184)

Figure 2a (top panel) and 2b (bottom panel)

Figure 2a.

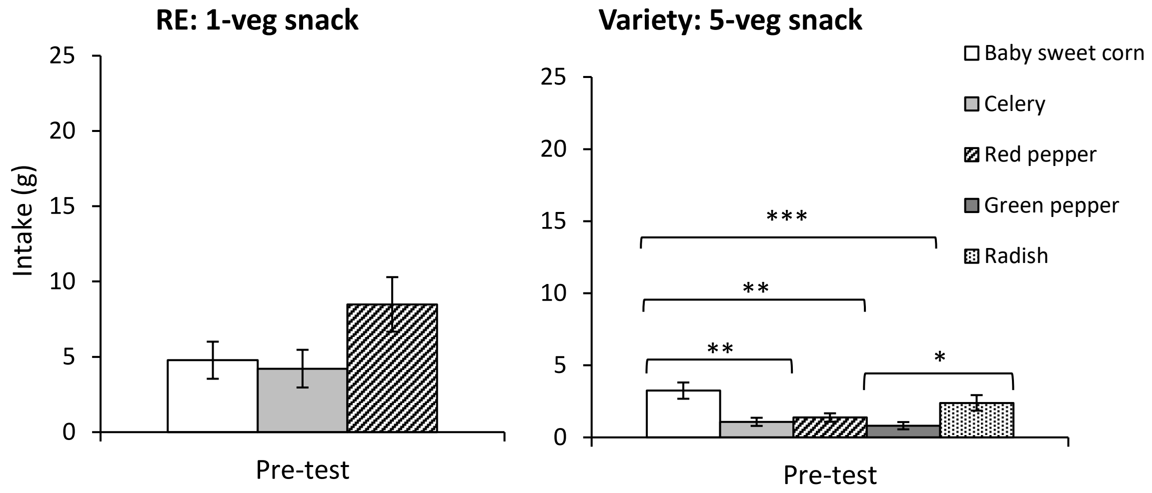


Figure 2b.

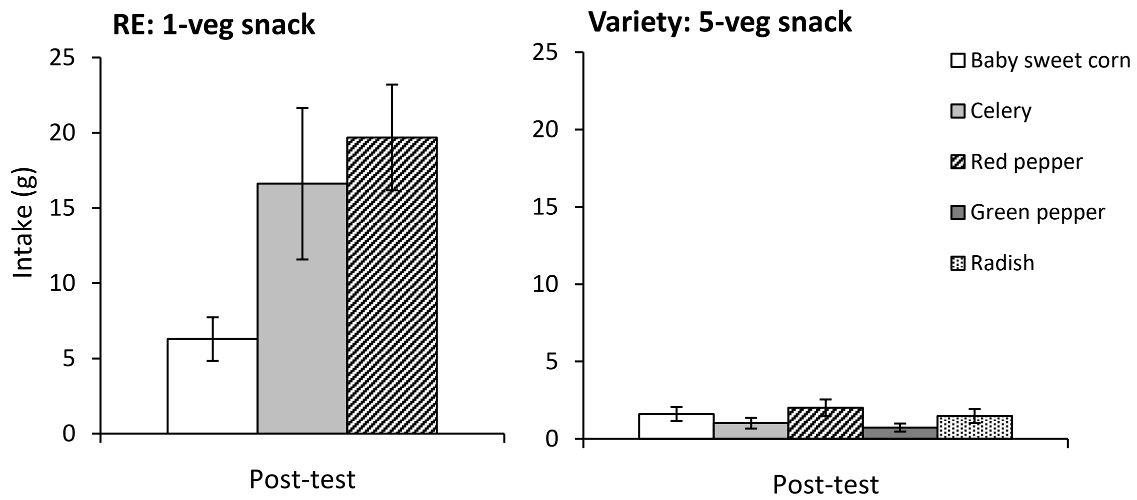


Figure 3

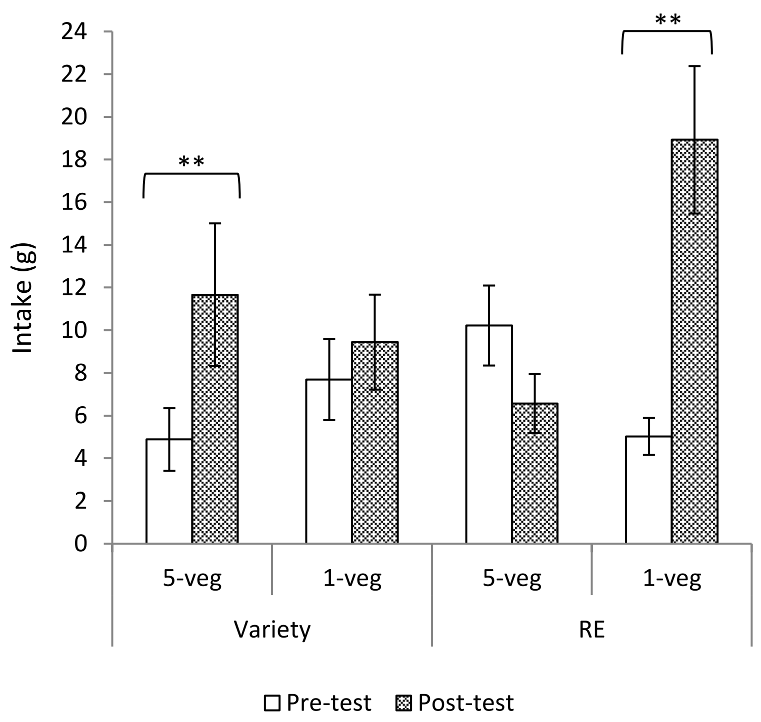
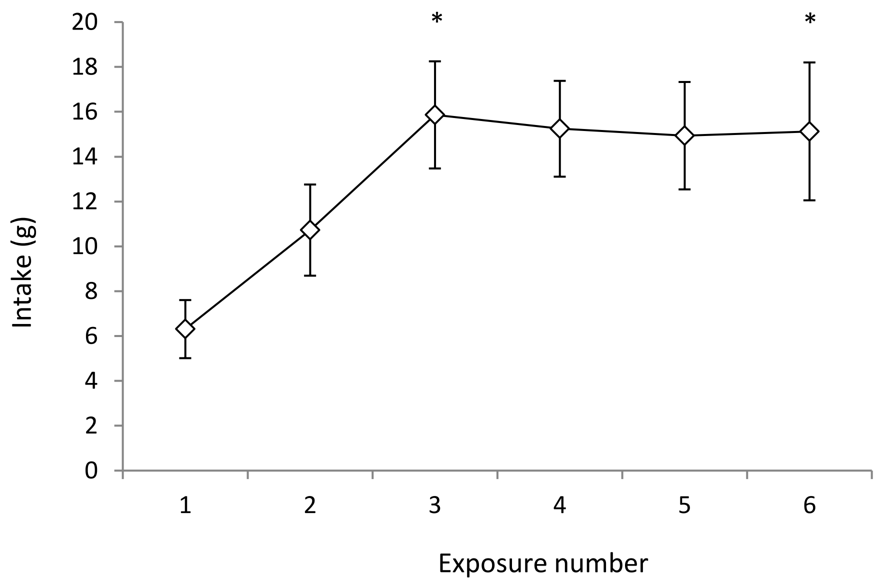
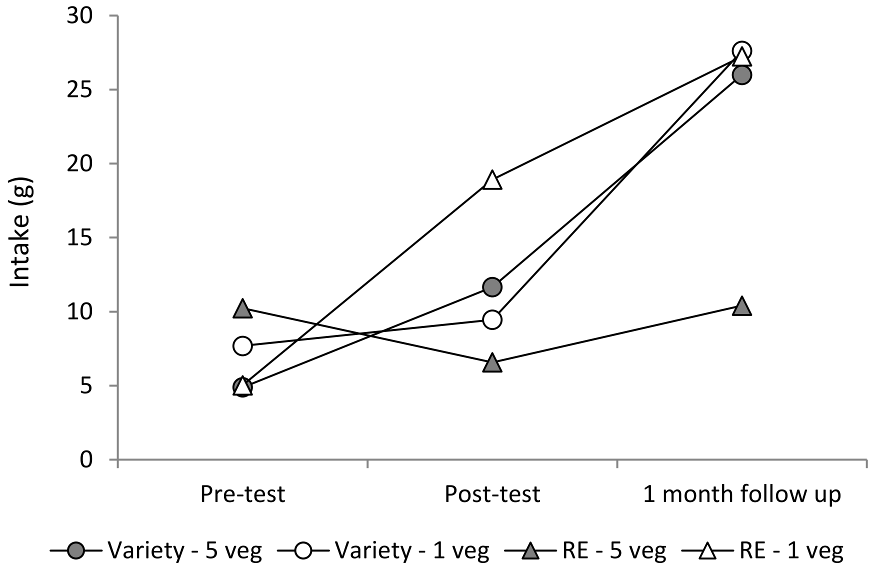


Figure 4




30
25
20
15
10
5
0
Intake (g)
Pre-test
Post-test
1 month follow up
Variety - 5 veg
Variety - 1 veg
RE - 5 veg
RE - 1 veg