

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

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1 **VeggieSense: A non-taste multisensory exposure technique for**
2 **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*

63 1. Introduction

64 Only 18% of school-aged children in the UK eat the recommended five portions of fruit
65 or vegetables per day (NatCen Social Center, 2018) and a growing body of work suggests that
66 preschool children across Europe also fail to meet recommended levels of fruit and vegetable
67 intake (Angelopoulos, Kourlaba, Kondaki, Fragiadakis, & Manios, 2009; Huybrechts et al.,
68 2008; Manios et al., 2009). Preferences for sweet tastes in infants (Desor, Maller, & Andrews,
69 1975; Desor, Maller, & Turner, 1973) may well be of evolutionary origin (Wardle & Cooke,
70 2008), with the more bitter taste of vegetables (Chung & Fong, 2018) possibly accounting for
71 young children's greater dislike of vegetables compared to fruit (Cooke & Wardle, 2005;
72 Harnack et al., 2012). Given that the eating behaviours that are established during the early
73 years often last into adulthood (Coulthard, Harris, & Emmett, 2010; Harris, 2008), it is perhaps
74 not surprising that adults also fail to consume recommended levels of vegetables (Pomerleau,
75 Lock, Knai, & McKee, 2005).

76 Fortunately, however, children's food preferences are not solely determined by their
77 initial taste preferences and continue to develop as a result of the child's experiences with food.
78 Research has drawn on the known influence of the child's early food environment to devise
79 new strategies for increasing vegetable acceptance during the preschool years. Repeated taste
80 exposure – which involves offering the child between 10 and 15 exposures to a food's taste –
81 is a well-evidenced tactic for increasing acceptance of a disliked vegetable (Birch & Marlin,
82 1982; Gerrish & Mennella, 2001; Wardle, Cooke, et al., 2003; Wardle, Herrera, Cooke, &
83 Gibson, 2003). Yet, whilst this approach is highly effective when implemented, in practice
84 most parents will only offer their child a disliked food three to five times before giving up
85 (Carruth, Ziegler, Gordon, & Barr, 2004), which limits the likelihood of successful dietary
86 change through taste exposure alone.

87 Investigations of practical alternatives to repeated taste exposures have found that both
88 short-term and longer-term acceptance of vegetables and other healthy foods (as indexed by
89 measures of willingness to taste (WTT) and intake) can be increased by non-taste sensory
90 exploration of a food's visual (De Droog, Buijzen, & Valkenburg, 2014; Heath, Houston-Price,
91 & Kennedy, 2014; Houston-Price et al., 2009; Owen, Kennedy, Hill, & Houston-Price, 2018;
92 Rioux, Lafraire, & Picard, 2018) or olfactory (Luisier, Petitpierre, Clerc Béro, Garcia-Burgos,
93 & Bensafi, 2019) properties. The effectiveness of visual familiarity as a means of increasing
94 vegetable acceptance has been investigated using children's books, which show the child what
95 vegetables look like and where they come from. Repeated readings of such books have been

96 found to increase children's WTT, intake and liking of vegetables and to support parents in the
97 process of introducing vegetables at mealtimes (Heath et al., 2014; Houston-Price, Owen,
98 Kennedy, & Hill, 2019; Owen et al., 2018). In other work, Luisier et al. (2019) examined the
99 effect of familiarity with a food's odour on the food choices of children with autism. When
100 presented with two identical foods, one with a control odour and one with an odour with which
101 the child was familiar, 68% of children chose the food with the familiarised odour, suggesting
102 that familiarity with a food's smell plays a role in food preferences. Less is known about the
103 effects of familiarisation with the tactile properties of foods, although Coulthard and Thakker
104 (2015) and Coulthard and Sahota (2016) have reported strong associations between children's
105 tactile sensitivity and enjoyment of tactile play with non-food items and their levels of food
106 neophobia (unwillingness to try new foods), suggesting that tactile familiarity may play a role.

107 In addition to these studies exploring the effects of familiarisation with individual
108 sensory attributes of foods, several studies have explored the effects of engaging in
109 multisensory food-related activities on food acceptance. There are theoretical grounds for
110 expecting multisensory familiarity to be beneficial; in other domains, multisensory
111 environments are more supportive of learning than unisensory environments (Shams & Seitz,
112 2008). Moreover, taste exposures to foods are necessarily multisensory experiences
113 (Coulthard, Harris, & Emmett, 2009; Forestell & Mennella, 2007; Kringelbach, 2015; Spence
114 & Piqueras-Fiszman, 2014), as the visual, tactile and smell properties of foods are all available
115 when they are eaten. This raises the question of whether food familiarisation techniques that
116 involve multiple non-taste senses might be more effective in inducing food acceptance than
117 exposure in a single sensory modality has been shown to be.

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

127 Another approach to engaging children in multisensory activities has been to involve
128 them in 'hands on' activities such as gardening and cooking (DeCosta, Møller, Frøst, & Olsen,
129 2017). A systematic review of gardening interventions with children and adolescents (Savoie-

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

141 Several recent interventions have sought to provide multisensory exposure in preschool
142 settings via 'sensory play' activities, in which children engage with foods via multiple senses
143 prior to tasting them as snacks or during mealtimes (Coulthard, Palfreyman, & Morizet, 2016;
144 Coulthard & Sealy, 2017; Dazeley & Houston-Price, 2015; Dazeley, Houston-Price, & Hill,
145 2012; Hoppu, Prinz, Ojansivu, Laaksonen, & Sandell, 2015; Kähkönen, Rönkä, Hujo,
146 Lyytikäinen, & Nuutinen, 2018). For example, Dazeley and Houston-Price (2015) trained
147 nursery staff to deliver a range of engaging activities that provided toddlers aged 12 to 36
148 months with non-taste sensory exposures to fruit and vegetables. Each day's activities focused
149 on one sensory domain (sound, smell, sight or touch) and over the course of 4 weeks, children
150 gained repeated exposures to the raw and cooked foods in each sensory modality. Results
151 suggested that the sensory activities increased the children's willingness to touch and taste the
152 vegetables with which they had been familiarised. Coulthard and Sealy (2017) also investigated
153 the effects of non-taste sensory exposures to a variety of fruit and vegetables. Children were
154 allocated to one of three conditions: 1) a tactile-visual condition, in which children created a
155 picture on a plate using fruit and vegetables; 2) a visual-only condition, where children watched
156 a researcher create a picture using the same foods; 3) a control group, who created a picture
157 using non-food items. Children in the tactile-visual condition tried significantly more fruit and
158 vegetables in a subsequent taste test than children in the visual-only and control conditions.
159 While this finding suggests that multisensory exposure is more effective at increasing WTT
160 than exposure in a single modality, it is also compatible with the possibility that tactile
161 familiarity plays the primary role in food acceptance.

162 Thus, although previous studies suggest that there is likely to be value in developing
163 practical non-taste multisensory exposure methods for increasing children's acceptance of

164 vegetables, it has not yet been established whether exposure via multiple senses is cumulative
165 in its effects. Moreover, while visual exposure has been shown to have a lasting impact on food
166 acceptance if exposure is repeated over several days or weeks (e.g. Owen et al., 2018), it
167 remains unknown whether more immediate effects following a single exposure session might
168 be demonstrated if the exposure activities engages multiple senses. If multisensory exposure
169 has a more immediate impact on children's food acceptance of a food, parents' (or nursery
170 staff's) tendency to cease offering children a new food following its initial rejection (e.g.
171 Carruth et al., 2004) is less likely to pose a barrier to the food's successful introduction.

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

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

192 **2. Method**

193 **2.1. Participants & Design**

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

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

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

208

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

210

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

216

221 2.2. Materials and measures

222 2.2.1. Vegetables and containers

223 Six different vegetables were used, selected to vary in colour, shape and smell (broccoli,
 224 fennel, leek, parsnip, radish & swede). Vegetables were prepared in a university nutrition
 225 laboratory in adherence to Food Standards Agency regulations (2018b). For exposures to
 226 whole, raw vegetables, the six vegetables were washed and placed into separate containers. For
 227 exposures to prepared foods, the six vegetables were peeled (if necessary), chopped into
 228 bitesize pieces of varying shapes (e.g. circles of leek, florets of broccoli) and either steamed
 229 (broccoli, fennel, leek, parsnip & swede) or chilled (radish). Six pieces of each of the prepared
 230 vegetables were placed in separate containers. Containers were transparent plastic pots that
 231 were covered with black material to allow control over when the contents could be seen. For

232 the smelling activities, a mesh cloth covered the opening to the container to allow the vegetable
233 to be smelled without being seen when the lid was removed. For children in the control
234 condition, two examples of each of six non-food items (e.g. toy cars, Lego blocks) were placed
235 in the same type of container used in exposure conditions.

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

239

240 **2.2.2. Matching game posters**

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

246

247 **2.2.3. Measures of immediate acceptance**

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

255

256 **2.3. Procedure**

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

264

265 **2.3.1. Exposure Sessions**

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

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

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

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

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

299 **2.3.2. Taste Test**

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

308 **3. Results**

309 **3.1. Data analysis**

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

320

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

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

Intake

<i>Control</i> ^a	1.25 ^{cd}	3.07	3.31	0	11
<i>Visual</i> ^b	1.5 ^{cd}	3.55	3.98	0	12
<i>Smell-Visual</i> ^c	4.5 ^{ab}	5.63	4.07	0	12
<i>Smell-Touch-Visual</i> ^d	7 ^{ab}	6.71	4.32	0.5	12

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3.2. WTT

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

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3.3. Intake

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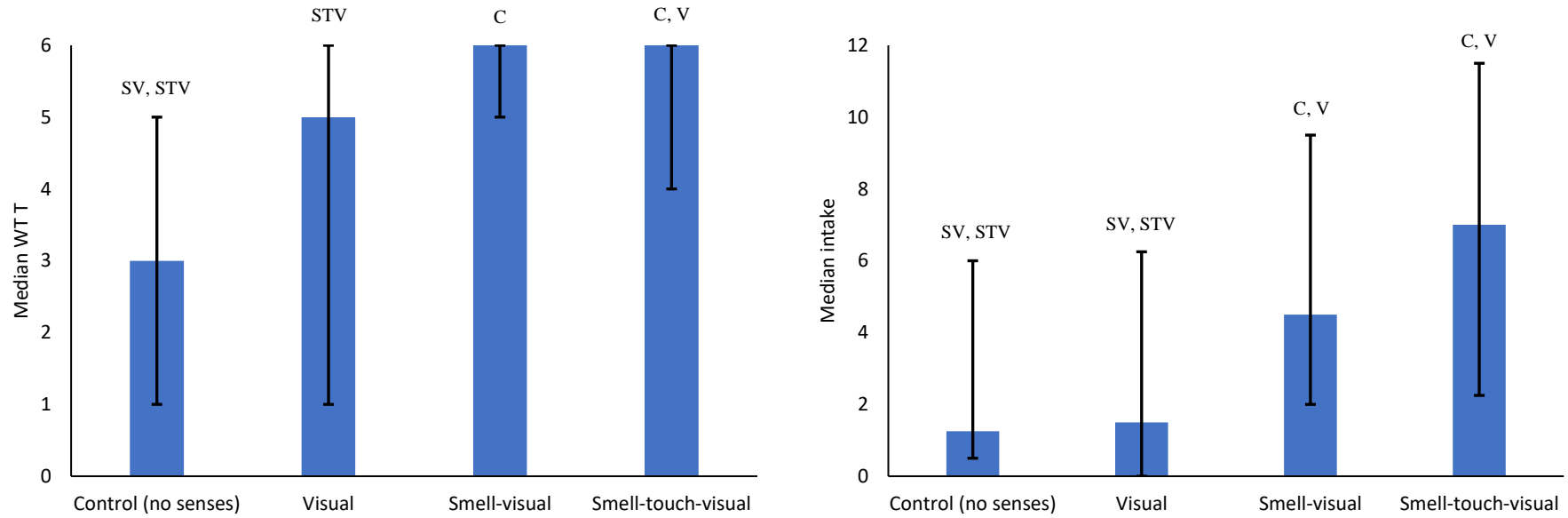
351

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

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357 **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
358 above bars indicate a significant difference between that condition and the labelled conditions (C = Control, V = Visual-only, SV = Smell-Visual, STV =
359 Smell-Touch-Visual).

360

361

362 4. Discussion

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

369 These findings confirm recent reports that non-taste sensory exposure activities can
370 support children's short-term acceptance of vegetables (Coulthard et al., 2016; Coulthard &
371 Sealy, 2017; Dazeley & Houston-Price, 2015; Houston-Price et al., 2019; Johannessen et al.,
372 2018; Mustonen & Tuorila, 2010; Owen et al., 2018). However, it is worth noting that unlike
373 previous studies that have reported positive outcomes from exposure in a single sensory
374 domain, most frequently visual familiarisation alone (Coulthard & Sealy, 2017; De Droog et
375 al., 2014; Dulay, Masento, Harvey, Messer, & Houston-Price, 2020; Heath et al., 2014;
376 Houston-Price et al., 2009; Owen et al., 2018; Rioux et al., 2018), the current study found no
377 significant differences in acceptance between the Visual-only and Control conditions. The most
378 likely explanation for this discrepancy in findings lies in the brevity of the *VeggieSense*
379 intervention used in the current study; children were exposed to foods during a short session
380 on a single day. In contrast, previous reports of positive effects of visual familiarisation to
381 foods have followed extended exposure periods. For example, Owen et al. (2018) asked parents
382 to look at picture books about foods with their toddler every day for a two-week period. To our
383 knowledge, no study to date has shown a change in food acceptance following a single visual
384 familiarisation episode. It is therefore feasible that visual exposure effects depend on multiple
385 exposures over an extended period, and that visual-only activities of the type used in
386 *VeggieSense* would be effective if repeated several times.

387 However, while one day of visual exposure to a vegetable appears to be insufficient to
388 bring about acceptance, the current study shows that one day of multisensory exposure can be
389 effective, at least in the short-term. Children who were exposed to foods via two or three
390 sensory modalities were more likely to taste the exposed vegetables than children in the Control
391 group, and those exposed in all three modalities were also more likely to taste the exposed
392 foods than those in the Visual-only group. Children in both multisensory exposure conditions
393 went on to consume more of the exposed vegetables than those in both the Control and Visual-

394 only conditions. No significant differences were seen between the two- and three-sense
395 conditions, likely due in part to ceiling effects, particularly in the WTT data, where most
396 children in these groups tasted all the foods offered. However, the analyses overall suggest that
397 children who engaged in activities involving all three senses showed the greatest benefit of
398 taking part. Only this group consumed significantly more of the foods than children in the
399 unisensory (Visual-only) exposure condition and, importantly, a positive linear trend was
400 found across conditions.

401 Results therefore suggest a ‘sensory accumulation effect’ in the impact of multisensory
402 exposure activities, whereby acceptance increases with the number of senses engaged. Such an
403 account is congruent with ‘perceptual fluency’ accounts of exposure effects (Bornstein &
404 D’Agostino, 1992), whereby the more perceptual information that is accrued about a stimulus,
405 the easier it is to process that item when it is subsequently encountered, and the more positively
406 disposed we are towards the stimulus as a result (Coulthard & Sealy, 2017; Shams & Seitz,
407 2008; cf. Spence & Piqueras-Fiszman, 2014). However, there are several alternative accounts
408 of how the multisensory conditions in our design might have enabled additional perceptual
409 information to be accrued, and these require further investigation. One possibility is that the
410 ‘sensory accumulation effect’ is simply driven by the additive impact of information provided
411 in several sensory domains. That is, accruing information about a food’s smell and feel as well
412 as its visual appearance strengthens the representation of the food in such a way as to induce a
413 more positive evaluation of it. A second possibility is that multisensory conditions also afford
414 the opportunity to construct perceptual representations of the food that integrate information
415 across modalities, enabling learning about how the sensory domains are related to one another
416 (e.g. foods that look knobbly feel rough to the touch). Such an account would be congruent
417 with previous demonstrations of learning being facilitated by situations that provide
418 ‘intersensory redundancy’, where information overlaps across sensory domains (Bahrick &
419 Lickliter, 2000). Yet another explanation is that it is not the number of senses that induces the
420 positive effects, but the total sensory exposure time; in this study, exposure in more senses also
421 meant longer overall exposure time. These accounts are not mutually exclusive, of course; it
422 is plausible that benefits accrue from greater exposure time, opportunities to experience foods
423 in multiple sensory domains, and from opportunities to integrate these experiences; further
424 research is needed to tease apart these possibilities empirically.

425 It is also worth noting that results are also supportive of familiarity with a food’s smell
426 playing a key role in its acceptance. The two and three sense conditions in this study were
427 distinguished from the unisensory and control conditions by the inclusion of olfactory

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

443 It would also be valuable to consider both age-related differences and individual
444 differences in children’s visual, tactile and olfactory sensitivity in relation to the effectiveness
445 of different exposure activities, to establish whether sensory sensitivity is relevant to the
446 success of an intervention involving sensory exploration. Previous research has established
447 developmental change in attention to sensory information. For example, in a sample of 7- to
448 11-year olds, Coulthard et al. (2016) found that younger children were more likely to rate a
449 novel vegetable as looking strange, while older children were more likely to rate the same
450 vegetable as smelling strange. Familiarisation techniques may be optimised for different groups
451 of children by providing exposures in domains that carry more weight for them.

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

462 **4.1. Conclusions**

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

473
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477
478 **Author Contributions**

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

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

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

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

485

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