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1 **Visual exposure and categorization performance positively influence 3- to 6-year-old**  
2 **children's willingness to taste unfamiliar vegetables**

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4  
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7  
8 **Abstract**

9 The present research focuses on the effectiveness of visual exposure to vegetables in reducing  
10 food neophobia and pickiness among young children. We tested the hypotheses that (1)  
11 simple visual exposure to vegetables leads to an increase in the consumption of this food  
12 category,(2) diverse visual exposure to vegetables (i.e., vegetables varying in color are shown  
13 to children) leads to a greater increase in the consumption of this food category than classical  
14 exposure paradigms (i.e. the same mode of presentation of a given food across exposure  
15 sessions) and (3) visual exposure to vegetables leads to an increase in the consumption of this  
16 food category through a mediating effect of an increase in ease of categorization. We  
17 recruited 70 children aged 3-6 years who performed a 4-week study consisting of three  
18 phases: a 2-week visual exposure phase where place mats with pictures of vegetables were set  
19 on tables in school cafeterias, and pre and post intervention phases where willingness to try  
20 vegetables as well as cognitive performances were assessed for each child. Results indicated  
21 that visual exposure led to an increased consumption of exposed and non-exposed vegetables  
22 after the intervention period. Nevertheless, the exposure intervention where vegetables  
23 varying in color were shown to children was no more effective. Finally, results showed that an  
24 ease of categorization led to a larger impact after the exposure manipulation. The findings  
25 suggest that vegetable pictures might help parents to deal with some of the difficulties

26 associated with the introduction of novel vegetables and furthermore that focusing on  
27 conceptual development could be an efficient way to tackle food neophobia and pickiness.

28 **Keywords:** children, food neophobia and pickiness, visual exposure, willingness to try  
29 vegetables, cognitive performance.

### 30 **Introduction**

31 Over the past years concern has arisen over the lack of children's dietary diversity,  
32 which is necessary for healthy development (Falciglia, Couch, Gribble, Pabst, & Frank,  
33 2000). This lack of variety is directly associated with poor intake of fresh products such as  
34 fruits and vegetables, far below the recommended intake of five portions a day (Coulthard &  
35 Blissett, 2009). Arguably, *food neophobia* (defined as the reluctance to eat new foods; Pliner  
36 & Hobden, 1992) and *food pickiness* (defined as the rejection of new foods and certain  
37 familiar foods; Taylor, Wernimont, Northstone, & Emett, 2015) are two strong barriers to  
38 children's higher consumption of fruits and vegetables (Birch & Fischer, 1998; Dovey,  
39 Staples, Gibson, & Halford, 2008; Galloway, Lee, & Birch, 2003; Lafraire, Rioux, Giboreau,  
40 & Picard, 2016). Because the impact of these two kind of food rejections extends well beyond  
41 childhood, as dietary habits acquired during this period partly determine dietary patterns in  
42 adulthood (Nicklaus, Boggio, Chabanet, & Issanchou, 2005), it is essential to design effective  
43 interventions that aim to overcome children's food neophobia and pickiness.

#### 44 *The impact of mere exposure on children's food acceptance: a role for visual exposure*

45 According to the "mere exposure" theory, the exposure to one instance of a given  
46 stimulus is sufficient to trigger a more positive attitude toward a subsequent instance of that  
47 particular stimulus (Zajonc, 1968). A considerable body of research has therefore investigated  
48 whether repeated taste exposure to fruits and vegetables might be employed to enhance  
49 children's acceptance and reduce rejections (for a review on food exposure see Cook, 2007;  
50 Keller, 2014). There is considerable support for the success of such repeated taste exposure in

51 controlled experimental settings (Birch & Marlin, 1982; Birch, Mcphee, Shoba, Pirok, &  
52 Steinberg, 1987) as well as in more ecological settings like home or school environments  
53 (Mustonen & Tuorila, 2010; Park & Cho, 2015). However these intervention programs often  
54 lead to a significant increase for children's fruit intake, but only minor changes for vegetable  
55 intake (Appelton et al., 2016; Evans, Christian, Cleghorn, Greenwood, & Cade, 2012).  
56 Additionally these strategies may have limited efficacy in reducing neophobia or pickiness  
57 since several studies revealed that 10 to 15 taste exposures to a new food item may be needed  
58 for its successful acceptance in preschool-aged children (Birch et al., 1987; Wardle, Carnell,  
59 & Cooke, 2005). This is a number greater than most parents are willing or able to provide  
60 (Carruth, Ziegler, Gordon, & Barr, 2004).

61         Because a neophobic reaction results in foods being rejected on mere sight (Cashdan,  
62 1998; Dovey, et al., 2008), it is reasonable to assume that *visual* exposure could actually be  
63 more effective to reduce food rejections than *taste* exposure. In addition, it could be more  
64 effortless for caregivers to provide visual exposure to food (e.g. through picture books),  
65 especially if it occurs outside mealtimes. There is in fact an encouraging body of evidence to  
66 support research into the impact of visual exposure on children's food rejections (De Droog,  
67 Buijzen, & Valkenburg, 2014; Heath, Houston-Price, & Kennedy, 2011; 2014; Houston-Price,  
68 Butler, & Shiba, 2009; Osborne & Forestell, 2012). For example, providing 2- to 6-year-old  
69 children with picture books about leeks and carrots, Heath and colleagues (2011) and De  
70 Droog and colleagues (2014) showed that toddlers consumed more of the vegetable they had  
71 seen in their picture book, compared to a matched control vegetable.

72 ***The impact of mere exposure on children's food acceptance: a role for diverse visual***  
73 ***exposure***

74           In the large majority of studies that investigate the effect of mere food exposure,  
75 children were exposed to the same mode of presentation of a given food across exposure  
76 sessions (Caton, Ahern, Remy, Nicklaus, Blundell, & Hetherington, 2013; Olsen, Ritz, Kraaij,  
77 & Moller, 2012). For instance, in Caton and colleagues' study (2013), infants received the  
78 same preparation of artichoke puree for ten days, prepared with commercialized baby food.  
79 However, a recent study conducted by Houston-Price, Burton, Hickinson, Inett, Moore,  
80 Salmon, and Shiba (2009) revealed that offering children different modes of presentation of a  
81 food could lead to greater interest in this food. They exposed toddlers for two weeks, either to  
82 picture books containing five *identical* pictures of a given fruit (e.g. apple), or to picture  
83 books containing five *different* pictures of the same fruit (e.g. an apple on a tree, an apple cut  
84 up on a plate etc.). They found that toddlers' looking interest in the exposed fruit was greater  
85 in the latter condition. They hypothesized that toddlers' more positive attitude toward the fruit  
86 after the "diverse" exposure intervention was driven by experiences that had allowed them to  
87 furnish an elaborate representation in mind of the exposed food.

88           This kind of "diverse" exposure could be greatly beneficial for children with high food  
89 neophobia and pickiness. In a recent study Rioux, Lafraire, and Picard (*under revision*)  
90 showed that 2- to 6-year-old neophobic and picky children tended to generalize knowledge to  
91 novel foods based on color similarity instead of category membership (see Murphy, 2002, pp.  
92 371-375 for a summary of the development of induction in childhood). For instance when  
93 taught a new fact about a red tomato, they tended to generalize it to a red apple rather than to  
94 a green tomato. Food rejections exhibited by certain children may discourage caregivers from  
95 presenting fruit and vegetables to their children. This would lead to fewer learning  
96 opportunities and to poor representation of fruit and vegetable categories tied to perceptual  
97 properties, such as color, explaining poor category-based induction abilities (see Lavin &  
98 Hall, 2001 and Macario, 1991, for the importance of color over shape in the food domain). In

99 this instance “diverse” exposure that allows children to furnish an elaborate mental  
100 representation of the food, as in Houston-Price and colleagues’ study (2009), should greatly  
101 benefit neophobic and picky children. These children, who relied heavily on color similarity  
102 for induction in Rioux and colleagues’ experiment, should benefit from exposure intervention  
103 and learning opportunities that expose them to diverse colors for given food items. They could  
104 learn that color similarity should be disregarded, in favor of labels, when making predictions  
105 and consumption choices about food items. It is therefore worth exploring further the  
106 potential for visual exposure, with various presentations of the same food across exposure  
107 sessions.

### 108 *The mechanisms behind mere exposure*

109 Surprisingly, while a large body of research has investigated the potential effect of  
110 exposure, the accepted mechanistic explanation remains elusive. One of the mechanisms by  
111 which exposure is assumed to engender a positive attitude toward a stimulus is thought to be  
112 “learned safety” (Kalat & Rozin, 1973; Zajonc, 2001). Exposure removes our natural fear of  
113 new stimuli through a process of conditioning. Indeed repeated ingestion of an unfamiliar  
114 food without negative consequences will lead to increased acceptance of this food (Cook,  
115 2007). Nevertheless, the recent evidence that mere visual exposure could also enhance the  
116 acceptance of unfamiliar food items (De Droog et al., 2014; Osborne & Forestell, 2012) casts  
117 doubt on whether the “learned safety” hypothesis entirely explains the positive effect of  
118 exposure. Additionally, since rejections usually occur at the mere sight of the food (Dovey et  
119 al., 2008), there are valid grounds for assuming that food appearances might play a more  
120 central role than the absence of post-ingestion consequences, in a child’s decision to consume  
121 a novel food item (Heath, et al., 2011).

122 An alternative explanation, which embodies a cognitive approach to the mere exposure  
123 effect, was offered by Bornstein and D’Agostino (1994). By increasing the amount of

124 experience an individual has with any stimulus, repeated exposure increases the ease and  
125 speed with which the stimulus is categorized, leading to a positive attitude toward the  
126 stimulus (Bornstein & D'Agostino, 1994; Seamon, Williams, Crowley, Langer, Orne, &  
127 Wishengrad, 1995). Categorization is a fundamental cognitive process that allows us to  
128 organize objects into groups (Vauclair, 2004). When a food item is first presented to a child it  
129 is organized into categories relating to its characteristics (Murphy, 2002; Vauclair, 2004; see  
130 also Lafraire, Rioux, Roque, Giboreau, & Picard, 2016). Knowledge gained through this first  
131 encounter allows for easier and faster categorization, when subsequently presented with the  
132 same or a similar food item (Aldridge, Dovey, & Halford, 2009).

133         According to this cognitive approach, this ease in categorization of a given food item  
134 should lead to a reduction of food neophobia and pickiness. A recent study supports this  
135 hypothesis. Rioux, Picard, and Lafraire (2016) showed that categorization performance  
136 predicted food neophobia and pickiness. The authors asked children to sort pictures of fruits  
137 and vegetables into two different boxes according to their categories, and found that children  
138 with poor categorization performance were likely to be highly neophobic and picky. Hence,  
139 they proposed that food acceptance depends upon categorization (Rioux et al., 2016; see also  
140 Brown, 2010; Dovey et al., 2008).

141         Nevertheless it is important to note that within this cognitive approach it remains to be  
142 seen if positive effects are restricted to the exposed stimulus (e.g. a carrot) or are  
143 generalizable to other instances of the category of the exposed stimulus (e.g. other vegetables  
144 like tomato). Evidence for this in the literature is not clear: in one study, it was observed that  
145 changes were restricted to the target food (Mennella, Nicklaus, Jagolino, & Yourshaw, 2008)  
146 while transfer effects were observed in another studies (Birch, Gunder, Grimm-Thomas, &  
147 Laing, 1998; Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). For instance, Mennella  
148 and colleagues (2008) found that repeated exposure to pureed potatoes did not enhance

149 acceptance of pureed carrots. Conversely, Birch and colleagues (1998) found that repeated  
150 exposure to bananas enhanced intake of pears.

151 It was originally proposed by Borstein and D'Agostino (1994) that exposure to a  
152 stimulus facilitates categorization only for that given stimulus. It is also plausible that positive  
153 effects are due to an enrichment of the content of the category at hand and then facilitate  
154 subsequent categorization for other instances of the same category (Lafraire et al., 2016).  
155 Indeed, the richer the experienced content of the category, the higher the probability of an  
156 acceptable similarity between a non-exposed stimulus and representations in mind (Murphy,  
157 2002).

### 158 *The present study*

159 The goal of the present study was to explore further the potential for visual exposure  
160 and to investigate the mechanisms responsible for its impact. We tested the effectiveness of an  
161 intervention among children who were exposed to different pictures of vegetables, compared  
162 with a control group of children, who were not exposed these pictures. Based on the  
163 theoretical framework described above, we had three main hypotheses:

164 (1) Simple visual exposure to vegetables leads to an increase in the consumption of  
165 this food category.

166 (2) Diverse visual exposure to vegetables (i.e., vegetables varying in color are shown  
167 to children) leads to a greater increase in the consumption of this food category than  
168 classical exposure paradigms (i.e. the same mode of presentation of a given food  
169 across exposure sessions).

170 (3) Visual exposure to vegetables leads to an increase in the consumption of this food  
171 category through a mediating effect of an increase in ease of categorization.

172

### 173 **Materials and method**



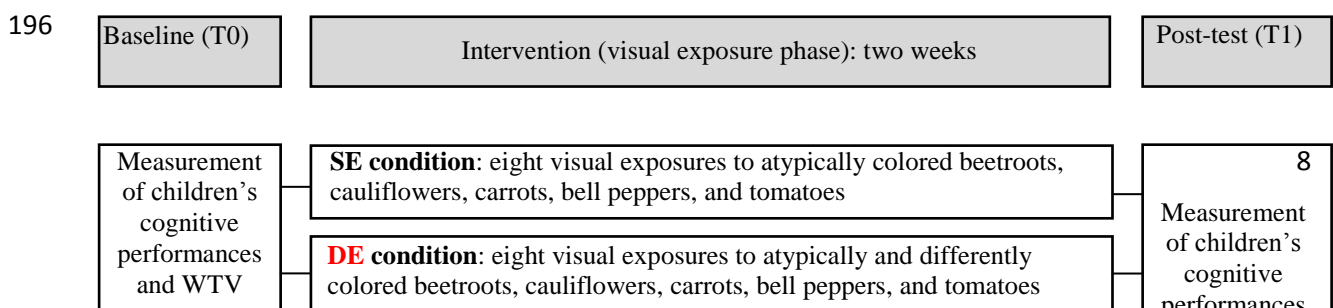
174 **Participants**

175 The participants were 70 children, aged 34 to 68 months (40 girls and 30 boys, mean  
176 age = 51.43 months, *SD* = 8.62). They were all-day pupils eating lunch in the cafeteria at three  
177 preschools in Lyon (France) and came from middle-class communities (as defined by the city  
178 of Lyon, principally based on the number of pupils with scholarships and average parental  
179 incomes). Prior to the study, the parents of each child filled out the Child Food Rejection  
180 Scale (CFRS; Rioux, Lafraire, & Picard, 2017) to assess his or her food neophobia and  
181 pickiness. CFRS scores could range from 11 to 55 with high scores indicating high food  
182 neophobia and pickiness. Parents were also asked to indicate their child’s liking for the 6  
183 types of vegetables in the study (beetroots, bell peppers, cauliflowers, carrots, tomatoes, and  
184 zucchini) on a 7-point Likert scale (from *hate* to *love*, with a high score indicating high  
185 liking). Finally, parents were asked to indicate at which frequency each colored vegetable  
186 (green tomatoes, red tomatoes, red bell peppers, etc.) was consumed at home using a 5-point  
187 Likert scale (from *never* to *more than once a week*, with a high score indicating high  
188 frequency of consumption).

189 **Study design**

190 This 4-week study consisted of three phases: a *visual exposure phase* where place mats  
191 were set on tables in the cafeteria of the three schools participating in the study, and *pre and*  
192 *post intervention phases* where Willingness to Try Vegetables (WTV) as well as cognitive  
193 performances were assessed for each child. An overview of the study design is shown Fig 1.  
194 The design was approved by a local ethical committee.

195 Figure 1: Overview of the experimental design.



197

198

199

200 *Note.* SE : simple exposure, CE : diverse exposure, C : control. WTV: Willingness to Try Vegetables.

201 ***Visual exposure phase***

202 In this 2-week intervention phase, the three schools participating in the study were  
203 randomly assigned to one of the three experimental conditions: *simple exposure* condition  
204 ( $n_2 = 24$ ; 13 girls and 11 boys, mean age = 52.21 months,  $SD = 9.45$ ), *diverse exposure*  
205 condition ( $n_3 = 26$ ; 17 girls and 9 boys, mean age = 54.08 months,  $SD = 8.08$ ) and *control*  
206 condition ( $n_1 = 20$ ; 10 girls and 10 boys, mean age = 46.56 months,  $SD = 6.25$ ). The choice of  
207 using separate schools for the different conditions resulted from the need to avoid allowing  
208 children from different conditions to exchange information about the intervention. However,  
209 the three schools were located in the same neighborhood to avoid any socio-demographic  
210 confounding effects.

211 In each of the three schools, place mats were set every day on cafeteria tables, for two  
212 consecutive weeks, therefore children were exposed to these mats eight times (as cafeterias  
213 are closed on Wednesdays). Each place mat was printed on a laminated card measuring 21 x  
214 29.7 cm and contained five color pictures. The five pictures printed on the mats depended on  
215 the intervention condition assignment:

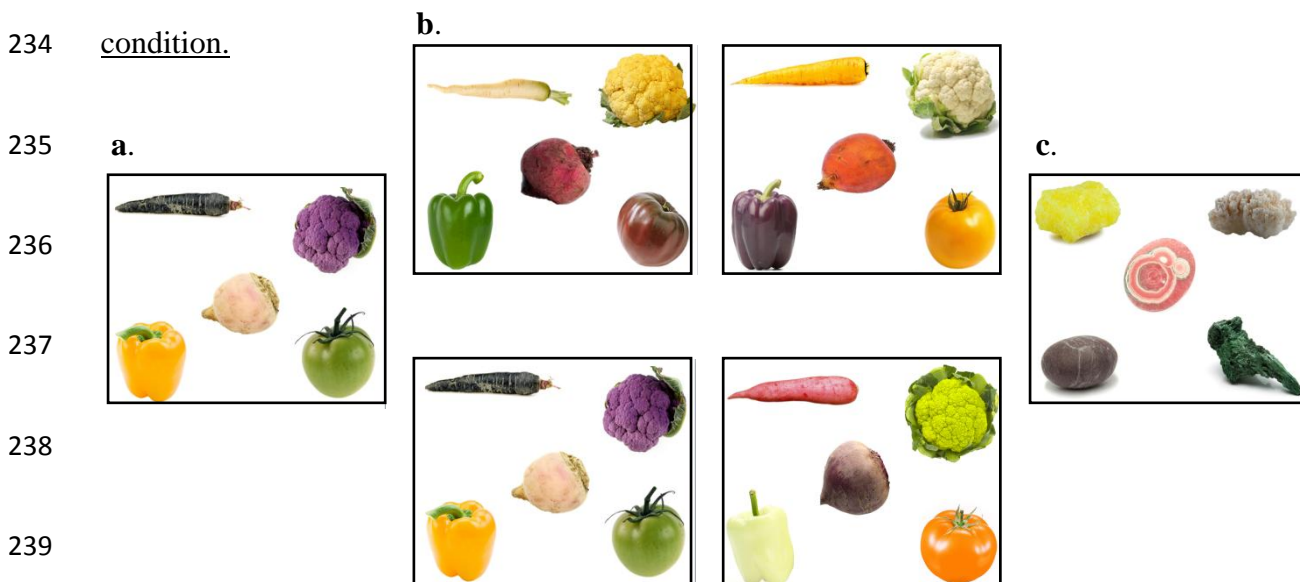
216 (1) *Simple exposure condition (SE)*. In this school, the *same* place mat with five  
217 unfamiliar vegetables was presented to children eight times. The main difference between the  
218 present study and previous studies of exposure's effect on willingness to try unfamiliar  
219 vegetables was the source of unfamiliarity. Indeed in our study, the vegetables themselves

220 were commonly served in the school canteen but the unfamiliarity came from the atypical  
221 color of the vegetables: green tomato, purple cauliflower, white beetroot, yellow bell pepper,  
222 and purple carrot (see Figure 1a).

223 (2) *Diverse exposure condition (DE)*. In this school, place mats presented the same  
224 kinds of vegetables as in the previous condition. However, contrary to the *simple exposure*  
225 condition where one vegetable was always presented in the same color, in this condition each  
226 of the five vegetables was presented in four different atypical and unfamiliar colors (see  
227 Figure 1b). Therefore in this condition four different mats were presented to children, for two  
228 successive days each.

229 (3) *Control condition (C)*. In this school, the same place mats with pictures of five  
230 stones were presented to children (see Figure 1c). The five stones were selected to match for  
231 unfamiliarity and color diversity with the vegetables printed on the mat of the *simple exposure*  
232 condition.

233 Figure 2. Place mats of simple (a) and diverse (b) exposure conditions and control (c)  
234 condition.



241 *Baseline and post-test*

242 Both at baseline (T0) and post-test (T1) phases, children were seen individually for  
243 approximately 15 minutes in a quiet room at their school on a Friday afternoon. They sat at a  
244 table with an experimenter by their side and performed in a constant order a forced-sorting  
245 task and a category-based induction task to assess their cognitive performances and then a  
246 Willingness to Try Vegetables task (WTV).

#### 247 *Categorization task*

248 This task aimed to assess children's categorization performance. Following the same  
249 protocol as in Rioux and colleagues (2016), children were shown successively two blocks of  
250 twelve pictures each of fruit and vegetables printed separately on laminated cards measuring  
251 10 x 15 cm. Some vegetables had typical colors (e.g., a purple beetroot), while some had  
252 atypical colors (e.g., a yellow beetroot; see Table 2 for the description of the two blocks). For  
253 each block, the children were asked to find the vegetable pictures and place them in a box,  
254 and then place the other pictures in the other box (the other pictures were the fruit pictures but  
255 we did not tell the children they were fruits). The order in which the blocks were provided  
256 was counterbalanced across participants. The experimenter then assigned four scores to each  
257 participant:

- 258 (i) a hit score (i.e. number of cards placed in the vegetable box when the picture was  
259 indeed a vegetable).
- 260 (ii) A false alarm score (i.e., number of cards placed in the vegetable box when the  
261 picture was a fruit).
- 262 (iii) A miss score (i.e. number of cards placed in the fruit box when the picture was a  
263 vegetable).
- 264 (iv) A correct rejection score (i.e. number of cards placed in the fruit box when the  
265 picture was indeed a fruit).

266 Based on these scores we calculated an index of categorization A (ranging from -2.75 to 2.75,  
 267 with a high score indicating good categorization performance) derived from signal detection  
 268 theory (Macmillan & Creelman, 2005), but adapted to the needs of experiments with low  
 269 numbers of stimuli (successfully used in Morin-Audebrand, Mojet, Chabanet, Issanchou,  
 270 Møller, Köster, & Sulmont-Rossé, 2011).

271 Categorization index  $A = \log \left[ \frac{N_H+0.5}{N_M+0.5} \right] - \log \left[ \frac{N_{FA}+0.5}{N_{CR}+0.5} \right]$

272 with  $N_H$ ,  $N_M$ ,  $N_{FA}$  and  $N_{CR}$  respectively corresponding to the numbers of hits, misses, false  
 273 alarms and correct rejections). With regard to performance, a categorization index higher than  
 274 zero means that participants answered more often “vegetables” for the vegetable pictures than  
 275 for the fruit pictures.

276 Table 2. Description of the two blocks of fruit and vegetable pictures.

<b>Block 1</b>		<b>Block 2</b>			
<b>Bell pepper (quarter)</b>	<b>Zucchini (slice)</b>	<b>Pear (cube)</b>	<b>Eggplant (cube)</b>	<b>Tomato (quarter)</b>	<b>Citrus fruit (slice)</b>
Green (T)	Green (T)	Yellow	Dark purple (T)	Red (T)	Green
Red (T)	Dark green (T)	Green	Light purple (T)	Dark red (A)	Yellow
Yellow (A)	Light green (A)	Brown	White(A)	Yellow(A)	Pink
Orange (A)	Yellow (A)	Red	Green(A)	Green(A)	Orange

277 *Note.* (T) = typical color. (A) = atypical color assessed in Rioux et al. (2016). The colors reported here are the  
 278 skin colors of each fruit or vegetable. In each block, there was the same number of food items cut in quarters,  
 279 slices and cubes.

280 *Category-based induction task*

281 This task aimed to assess children’s use of taxonomic categories to generalize  
 282 knowledge. Following the same protocol as in Rioux and collaborators (*under revision*)  
 283 children were successively shown eight sets of three color pictures: one vegetable target  
 284 picture and two test pictures (each triad set was printed on a laminated card measuring 21 x  
 285 29.7 cm, see Table 3 for a description of the eight sets). For each set, children were told an  
 286 invented property about the target vegetable picture (such as “contains zuline”, to ensure they  
 287 did not use prior knowledge to draw induction; Fisher, Godwin, Matlen & Unger, 2015). Then

288 they were asked to generalize this property to one of the two test pictures: one fruit similar in  
 289 color to the target vegetable (*Test picture 1*) or one other vegetable dissimilar in color to the  
 290 target vegetable (*Test picture 2*)<sup>1</sup>. To heighten the conflict between category membership and  
 291 color similarity, the labels of the pictures (which can facilitate category recognition) were not  
 292 provided (the experimenter said “Look at *this*. It contains zuline”). The experimenter recorded  
 293 participants’ responses to the task, assigning a score of 1 to category-consistent responses  
 294 (i.e., if the participant generalized the property to the other vegetable) and a score of 0 to  
 295 perceptual-consistent responses (i.e., if the participant generalized the property to the similar-  
 296 in-color fruit). The scores were then summed across all the sets to obtain the number of  
 297 category-consistent responses for each participant. This number was divided by the total  
 298 number of test sets (8) to obtain the child’s category-based induction score (ranging from 0 to  
 299 1, with a high score indicating good category-based induction performances).

300 Table 3. Description of the eight sets of fruit and vegetable pictures.

<b>Target food (vegetable)</b>	<b>Test picture 1 (fruit similar in color)</b>	<b>Test picture 2 (vegetable dissimilar in color)</b>
<b>Red tomato (T)</b>	Red apple	(1) Yellow bell pepper (T) (2) Purple bell pepper (A)
<b>Green tomato (A)</b>	Green apple	(3) Yellow bell pepper (T) (4) Purple bell pepper (A)
<b>Green zucchini (T)</b>	Green banana	(5) purple eggplant (T) (6) white eggplant (A)
<b>Yellow zucchini (A)</b>	Yellow banana	(7) purple eggplant (T) (8) white eggplant (A)

301 *Note.* (T) = typically colored vegetable; (A) = atypically colored vegetable.

302 *Willingness to try vegetables task (WTV)*

303 This task aimed to assess children’s willingness to try unfamiliar vegetables.  
 304 Following the principle of the seminal food choice task by Pliner and Hobden (1992) eight  
 305 pieces of vegetables arranged in four pairs were presented to children. Within each pair the

<sup>1</sup> This protocol used by Rioux and colleagues (*under review*) was based on research on category-based induction (Badger & Shapiro, 2012; Fisher, Godwin, & Matlen, 2015; Gelman & Markman, 1986).

306 same vegetable was presented in two colors: one typical (e.g. orange carrot) and one atypical  
307 (e.g. purple carrot). The four pairs of vegetables were as follows: (1) orange and purple carrot,  
308 (2) red and green tomato, (3) red and orange bell pepper, and (4) green and yellow zucchini.  
309 The typically colored vegetables were *a priori* familiar food items while the atypically  
310 colored vegetables were *a priori* unfamiliar vegetables and data collection from the parents  
311 supported this assumption: the four atypically colored vegetables were eaten less than once a  
312 month on average (all means < 2.3) while the four typically colored vegetables were eaten  
313 almost once a week on average (all means > 3). The frequency of consumption of each  
314 atypically colored vegetables was significantly lower than its typically colored match (all *ps* >  
315  $10^{-7}$ ).

316 It is important to note that while at baseline (T0) the four atypically colored vegetables  
317 had the same status (i.e. *unfamiliar*), after the intervention (T1) they had different status  
318 because:

319 (i) Purple carrot and green tomato were present on the place mats in both *exposure*  
320 conditions (see Figure 1a and 1b), and are hereinafter referred to as the *color-*  
321 *exposed vegetables*.

322 (ii) Orange bell pepper was not present on the place mats in the two *exposure*  
323 conditions, however pictures of differently colored bell peppers (e.g. yellow bell  
324 pepper) were printed on the mats in both *exposure* conditions (see Figure 1a and  
325 1b). Bell pepper is hereinafter referred to as the *kind-exposed vegetable*.

326 (iii) Yellow zucchinis were not presented on the place mats and neither were  
327 differently colored zucchinis (see Figure 1a and 1b). Zucchini is hereinafter  
328 referred to as the *non-exposed vegetable*.

329 These different statuses were created to investigate whether exposure effects may generalize  
330 to other unexposed stimuli.

331 To comply with the usual presentation of these vegetables in school cafeterias,  
332 zucchini and bell peppers were served cooked while carrots and tomatoes were served raw  
333 and zucchini and carrots were sliced while tomatoes and bell peppers were cut into wedges.  
334 None of the vegetables were peeled.

335 At the beginning of the task a small piece of each vegetable was placed on small white  
336 plastic plates (pairs were presented simultaneously in a counterbalanced order). Children were  
337 told many foods were available and they could taste them all if they wanted in order to help  
338 the experimenter select food items that they liked for the cafeteria menu the following week.  
339 Each time the participant looked at or came closer to a pair of vegetables, the experimenter  
340 said “These are carrots (for instance), would you like to try them?”. We labeled the different  
341 vegetables in this task to prime the corresponding category for children in order to investigate  
342 whether they were willing to accept a novel mode of presentation within a known category.  
343 As the four vegetables in the study are commonly served at school canteens, and because  
344 menus are announced verbally each day to the children by the cafeteria personnel, all children  
345 were familiar with their labels. The experimenter simply recorded for each child the number  
346 of tasted vegetables (i.e. put in the child’s mouth, swallowed or not).

#### 347 *Statistical analysis*

348 To test our first and second hypotheses (H1, H2), a linear mixed model was used with  
349 the number of atypically colored vegetables eaten as the outcome measure, because the  
350 intervention phase consisted of exposing children to atypically colored vegetables. The  
351 predictive variables of primary interest in this model were time (T0,T1), status of the  
352 vegetable (*color-exposed, kind-exposed, non-exposed*), condition (*C,SE,DE*), and CFRS  
353 scores. Interaction between time and other primary variables, as well as interaction between  
354 CFRS scores and other primary variables were also added in the model as primary variables.



355 Age, frequency of consumption and liking scores were predictive variables of secondary  
 356 interest.

357 To test our third hypothesis (H3), a regression analysis was used with the difference  
 358 between the number of atypically colored vegetables eaten at T1 and T0 as an outcome  
 359 measure. The predictive variables of primary interest in this model were categorization scores,  
 360 category-based induction scores, and CFRS scores and their interactions. Age and liking  
 361 scores were predictive variables of secondary interest.

362 The significance level was set to 5% ( $p < 0.05$ ). All statistical analyses were  
 363 performed with the software R. 3. 2. 4., using the package “nlme”.

364

## 365 **Results**

### 366 *Evaluation at baseline*

367 The characteristics at baseline (T0) of the children who fully completed the study are  
 368 presented in Table 4. Children in the *control* condition were significantly younger than those  
 369 in the other two conditions. Additionally, children in the *diverse exposure* condition ate  
 370 atypically colored vegetables significantly less often at home, compared to the two other  
 371 conditions.

372 Table 4. Characteristics of the study population at baseline.

	<i>Control condition</i> (n=20)	<i>Simple exposure</i> <i>condition</i> (n=24)	<i>Diverse exposure</i> <i>condition</i> (n=26)
<b>Female/male (n)</b>	10/10	13/11	17/11
<b>Age (mo)</b>	46.56 ( $\pm 6.45$ ) <sup>a</sup>	52.21 ( $\pm 9.45$ ) <sup>b</sup>	54.08 ( $\pm 8.08$ ) <sup>b</sup>
<b>Liking</b>	4.7 ( $\pm 0.84$ )	4.46 ( $\pm 1.56$ )	4.48 ( $\pm 1.06$ )
<b>Frequency of consumption at home</b>	2.11 ( $\pm 0.79$ ) <sup>b</sup>	2.19 ( $\pm 0.64$ ) <sup>b</sup>	1.55 ( $\pm 0.51$ ) <sup>a</sup>
<b>CFRS scores</b>	31.80 ( $\pm 7.10$ )	31.96 ( $\pm 8.94$ )	31.69 ( $\pm 8.85$ )
<b>Categorization performance</b>	0.44 ( $\pm 0.62$ )	0.48 ( $\pm 0.81$ )	0.45 ( $\pm 0.62$ )
<b>Induction performance</b>	0.46 ( $\pm 0.35$ )	0.52 ( $\pm 0.30$ )	0.54 ( $\pm 0.31$ )

373  
374 *Note: values are means ± SD. Means with a different common letter differ,  $p < 0.05$ .*  
375  
376

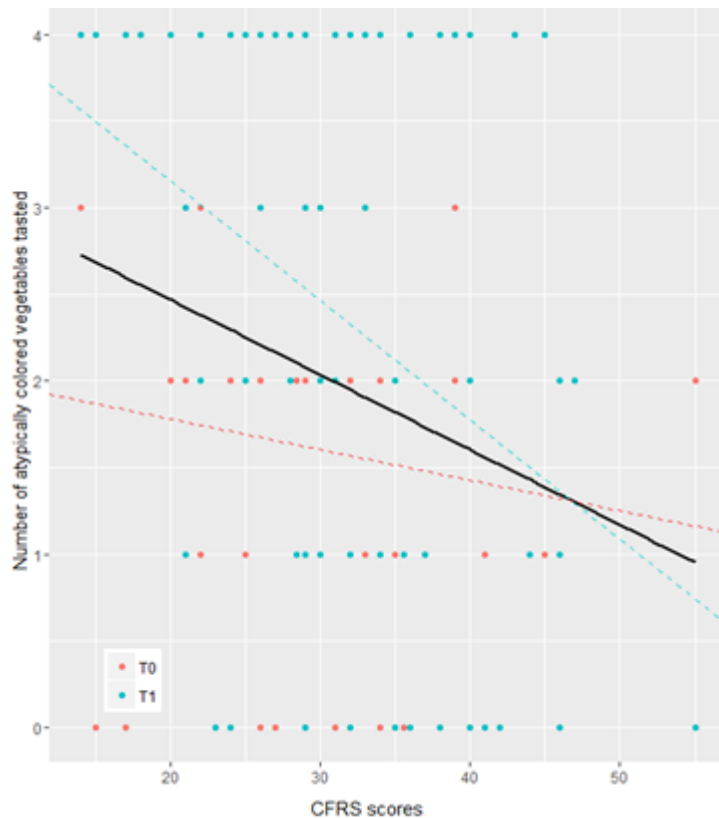
377 ***Does simple and diverse visual exposure to vegetables lead to an increase in the***  
378 ***consumption of this food category (H1 and H2)?***

379 A linear mixed model was used with the number of atypically colored vegetables eaten  
380 (ranging from 0 to 4) as the dependent variable, time (T0, T1) and status of the vegetable  
381 (*color-exposed, kind-exposed, non-exposed*) as within-participants factors, and condition (*C,*  
382 *SE, DE*), age, CFRS score (measuring neophobia and pickiness), frequency of consumption,  
383 and liking scores as between-participants factors.

384 This analysis revealed a main effect of time,  $F = 31.21, p < 0.0001$ . Children were  
385 more willing to taste atypically colored vegetables at T1 ( $M = 2.34, SD = 1.61$ ) than T0 ( $M =$   
386  $1.57, SD = 1.38$ ). No effect of the status of the vegetables was found (i.e. children ate the  
387 same amount of *color-exposed, kind-exposed, and non-exposed* vegetables).

388 An effect of the CFRS scores was also found,  $F = 7.54, p = 0.0078$ . Highly neophobic  
389 and picky children ate significantly fewer atypically colored vegetables than their counterparts  
390 (Spearman's correlation coefficient:  $r = -0.22, p = 0.0067$ , see Fig. 3, black continuous line).  
391 An interaction between CFRS scores and time was also found,  $F = 12.30, p = 0.00060$ , see  
392 Fig.3 dashed lines). The increase of eaten vegetables between post-test (T1) and baseline (T0)  
393 was greater for non-neophobic and non-picky children, than for highly neophobic and picky  
394 children (see Fig. 3, dashed lines).

395 *Figure 3. Children's willingness to taste atypically colored vegetables as a function of their*  
396 *food neophobia and pickiness scores (CFRS scores).*



397

398 *Note.* The Spearman coefficient correlation indicated a significant and negative correlation between children's  
 399 eating patterns and their food neophobia and pickiness levels ( $r = -0.22, p = 0.0067$ ) across time (black line). The  
 400 correlation was not significant at T0 ( $r = -0.11, ns$ , red dashed line) and significant at T1 ( $r = -0.33, p = 0.0045$ ,  
 401 blue dashed line).

402

403 In support of the first hypothesis (H1), a main effect of the condition was revealed,  $F =$

404  $7.69, p = 0.0010$ , and more interestingly so was an interaction between condition and time,  $F =$

405  $6.07, p = 0.0027$  (see Fig. 4). A post hoc analysis indicated that at T0 the number of

406 atypically colored vegetables tasted in each condition did not differ significantly ( $ps > 0.05$ ).

407 The post hoc analysis also revealed that in support of our first hypothesis, in the *simple*

408 *exposure condition* the number of atypical vegetables tasted at T1 ( $M = 3.09, SD = 1.44$ ) was

409 significantly greater than at T0 ( $M = 1.75, SD = 1.42, p = 0.019$ ).

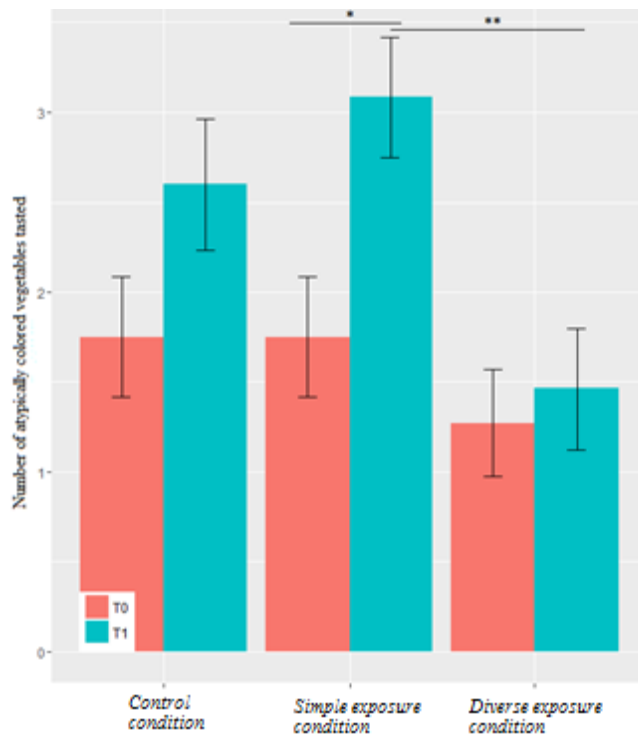
410 However, contrary to the second hypothesis (H2), this post hoc analysis revealed that

411 post-test (T1), the children in the *simple exposure condition* ate significantly more atypical

412 vegetables ( $M = 3.09, SD = 1.44$ ) than children did in the *diverse exposure condition* ( $M =$

413 1.46,  $SD = 1.53$ ,  $p = 0.0014$ ). Children in the *diverse exposure condition* did not significantly  
414 increase their consumption at T1 from T0.

415 Figure 4. Children's willingness to taste atypically colored vegetables as a function of  
416 experimental condition and time.



417

418 *Note.* Significant differences between the age groups are marked \* for  $p < 0.05$  and \*\* for  $p < 0.001$ .

419 Lastly, the analysis also revealed a main effect of the liking for the four vegetables in  
420 the tasting task,  $F = 4.19$ ,  $p = 0.049$ . Children ate more atypically colored vegetables when  
421 they liked those vegetables (as attested by a positive and significant Spearman's coefficient,  $r$   
422  $= 0.25$ ,  $p = 0.0026$ ).

423 ***Does visual exposure to vegetables lead to an increase in the consumption of this food***  
424 ***category through a mediating effect of the increase in ease of categorization (H3)?***

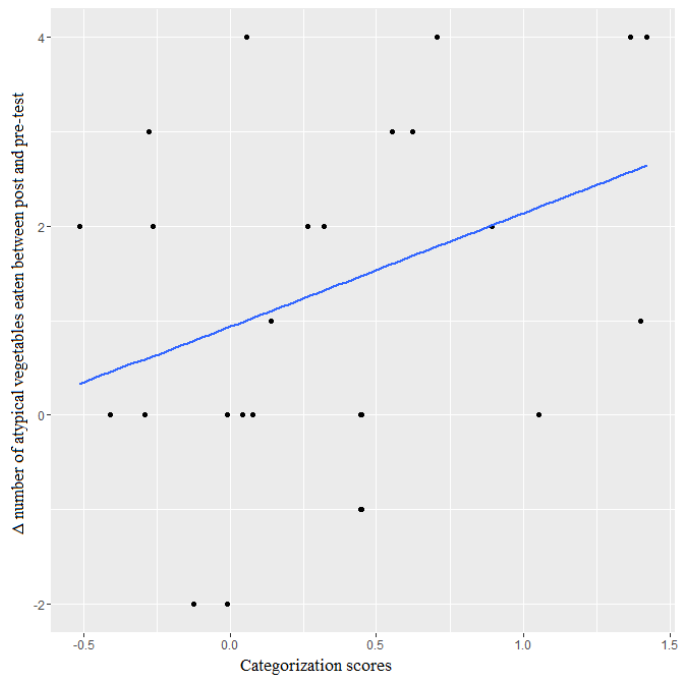
425 Contrary to hypothesis 3, no significant increase in the cognitive performances of  
426 children between baseline and post-test were found ( $ps > 0.05$  for both categorization

427 performance and category-based induction performance as attested by paired Wilcoxon's  
428 signed-rank test). Additionally, within each experimental condition, we did not find any  
429 significant increase in the cognitive performances of children between baseline and post-test  
430 (all  $ps > 0.05$ ). As categorization and category-based induction performances at baseline were  
431 significantly correlated with performances post-test (as attested with Spearman's coefficients  
432 both  $ps < 0.05$ ), we averaged the scores across time. Each child was therefore assigned a  
433 single *categorization score* ( $M = 0.35, SD = 0.49$ ) and a single *category-based induction*  
434 *score* ( $M = 0.48, SD = 0.28$ ).

435 We evaluated the moderator effect of cognitive performances on the increase in  
436 willingness to try atypically colored vegetables in the *simple exposure condition*. We ran a  
437 linear regression analysis with the difference in number of atypically colored vegetables eaten  
438 at T1 and T0 (ranging from -4 to 4) as the dependent variable, and with categorization and  
439 category-based induction scores, CFRS scores, age, and liking scores as predictive variables.

440 This model only revealed a significant effect of categorization scores,  $F = 4.22, p =$   
441  $0.054$  (see Fig. 5). As presented in Fig. 5, the partial correlation between categorization  
442 performance and the difference in number of atypically colored vegetables eaten at T1 and  
443 T0, corrected for age, was significant (as attested by Spearman's partial correlation  
444 coefficient,  $r = 0.42, p = 0.032$ ). We corrected for age, because there are age differences in  
445 categorization performance on this kind of forced-sorting task (Rioux et al., 2016).

446 Figure 5. Children's change in willingness to taste atypically colored vegetables between T1  
447 and T0 as a function of categorization score.



448

449 *Note.* The Spearman coefficient correlation indicated a nearly significant and positive correlation between  
 450 categorization performance and the difference in number of atypically colored vegetables eaten, between T1 and  
 451 T0 ( $r = 0.42, p = 0.032$ ).

452

453 **Discussion**

454 The goal of the present study was to explore further the potential for visual exposure  
 455 and to investigate the mechanisms responsible for its impact. We tested the effectiveness of an  
 456 intervention among children, who were exposed to different pictures of vegetables, compared  
 457 with a control group of children, who were not exposed these pictures.

458 ***Does simple visual exposure to vegetables lead to an increase in the consumption of this***  
 459 ***food category (H1)?***

460 In support of our first hypothesis, results indicated that children in the *simple exposure*  
 461 condition did increase their consumption of exposed vegetables after the intervention period.  
 462 Indeed, in this condition, children consumed significantly more atypically colored vegetables  
 463 at post-test than at baseline (see Fig. 4). This finding is in line with the claims of Houston-  
 464 Price and colleagues (2009) and Osborne and Forestell (2012): looking at food pictures  
 465 increases children willingness to taste these particular foods.

466           Interestingly, we also found that visual exposure effects were not tied to the exposed  
467 stimuli themselves. Indeed, we did not find any significant effect of the status of the  
468 vegetables. Children in the *simple exposure* condition, significantly increased their  
469 consumption of *color-exposed vegetables* (green tomatoes and purple carrots) as well as *kind-*  
470 *exposed vegetables* (orange bell peppers) or even *non-exposed vegetables* (yellow zucchinis),  
471 between pre and post-test. Therefore, they ate not only more *exposed vegetables* but also more  
472 atypically colored (and thus novel) vegetables in general, and visual exposure effects  
473 generalized to other, unexposed stimuli. This result is in line with Birch and colleagues’  
474 finding (1998) and Tuorila and colleagues’ finding (1994), since these authors observed that  
475 changes due to exposure were not restricted to the target food. It suggests to us that the  
476 changes we observed in children’s eating behaviors may be associated with their more mature  
477 representations of the exposed category rather than the exposed instance *per se*. For instance,  
478 it is possible that because we presented children with novel colors of familiar kinds of  
479 vegetables, they understood that the same food may undergo perceptual feature changes  
480 between servings.

481           However, in contrast to these promising results, we found an effect of children’s  
482 CFRS scores. Highly neophobic and picky children ate significantly fewer atypically colored  
483 vegetables than their counterparts. Additionally, we found that the increase in eaten  
484 vegetables between post-test (T1) and baseline (T0) was greater for non-neophobic and non-  
485 picky children, compared to highly neophobic and picky children (see Fig. 3, dashed lines).  
486 This is consistent with numerous studies showing significant negative correlation between  
487 neophobia assessed through questionnaires and willingness to try novel foods (Laureati,  
488 Bergamaschi, & Pagliarini, 2015; Lowen & Pliner, 2000; Pliner, 1994). At first glance, this  
489 result reinforces findings indicating that children with high food neophobia and pickiness are  
490 less responsive to exposure interventions (Caton, Ahern, & Hetherington, 2011; De Wild,

491 Cees de Graaf, & Jager 2016; Zeinstra, Kooijman, & Kremer, 2016). Nevertheless, within the  
492 *simple exposure* condition, the significant increase in atypically colored vegetables eaten was  
493 not affected by children's CFRS scores (as attested by the second regression analysis). This  
494 suggests that visual exposure interventions are suitable for these children. It is important to  
495 note that we observed the same pattern of results for liking. Indeed, while across conditions  
496 children ate more atypically colored vegetables as a function of their liking for the vegetables,  
497 the success of the intervention in the *simple exposure* condition was irrespective of children's  
498 liking (as attested by the second regression analysis). Taken together, these promising  
499 findings suggest that, in line with our first hypothesis, children (both with high and low food  
500 neophobia and pickiness) might be more easily persuaded to try a new vegetable if they have  
501 seen a picture of this vegetable, or another vegetable, first.

502 ***Does diverse visual exposure to vegetables lead to a greater increase in the consumption of***  
503 ***this food category (H2)?***

504 Contrary to our second hypothesis, results indicated that children in the *diverse*  
505 *exposure* condition did not increase their consumption of atypically colored vegetables after  
506 the intervention period. This absence of any significant increase in vegetable consumption  
507 was not in line with the recent study conducted by Houston-Price and colleagues (2009)  
508 which showed that offering children different presentations of a food could lead to greater  
509 interest in that food.

510 We assumed that this condition would be more effective to increase vegetable  
511 consumption because neophobic children tend to rely on color similarity to draw induction in  
512 the food domain (Rioux et al., *under revision*). They should then benefit from an exposure  
513 intervention that exposes them to diverse colors for given food items. They would learn that  
514 color similarity should be disregarded, in favor of labels, when making predictions and  
515 consumption choices about food items. We have two hypotheses to explain the absence of a



516 significant increase in vegetable consumption. First, in each condition, children saw the place  
517 mats for only eight days to avoid boredom effects (Wadhera & Capaldi-Phillips, 2014). Thus  
518 children in the *diverse exposure* condition only saw each instance of atypically colored  
519 vegetables twice (i.e. they saw green tomatoes for two consecutive days, then they saw yellow  
520 tomatoes for two days etc.). Comparatively, children in the *simple exposure* condition saw  
521 each vegetable eight times (i.e. they saw the green tomatoes for eight days). There is no  
522 consensus on the number of exposures needed to increase the consumption of a food item,  
523 especially for visual exposure. For instance, Houston-Price and colleagues (2009b) did not  
524 find any enhanced interest for exposed food after 2-5 or 6-8 readings of a food picture book.  
525 However, most studies argue in favor of a number greater than two for toddlers (Birch et al.,  
526 1987; Sullivan & Birch, 1990). It is possible that eight exposures for each instance of colored  
527 vegetables would have led to positive effects on consumption as well in the *diverse exposure*  
528 condition.

529 Another plausible explanation is that, by revealing to children that vegetables can have  
530 different colors, we did succeed in lowering the predictive value of color for inductive  
531 reasoning in the food domain. However, as vegetables were not labeled during the  
532 intervention phase, we failed to provide alternative reliable cues, such as labels, to support  
533 categorization and category-based induction. Indeed, during the 2-week exposure  
534 intervention, the place mats were simply set on the table in the cafeteria. An experimenter was  
535 present to ascertain whether children paid attention to the mats by telling them “Look at the  
536 different vegetables you have on the mats! Look they have different colors!”, but did not  
537 name the five vegetables depicted on the mats. Even if we named the vegetables during the  
538 individual WTV task, it is possible that by lowering the predictive power of color during the  
539 intervention, we unwittingly increased the children’s state of uncertainty about the atypically  
540 colored vegetables. As a possible consequence children picked the vegetables that were

541 familiar to them at post-test, namely the typically colored ones, to be sure of the consequences  
542 of ingestion. Tuorila and colleagues (1994) accordingly found that label information reduces  
543 uncertainty about the identity of a novel food and initially reduced negative responses to this  
544 food. Similarly Morizet, Depezay, Combris, Picard, & Giboreau (2014) found that 8- to 11-  
545 year-old children more often chose the familiar presentation of a familiar vegetable when no  
546 label information was given. Conversely, the availability of a label led to an increase in  
547 consumption of the new presentation of a familiar vegetable (Morizet et al., 2014). The  
548 greater correlation between CFRS scores and the number of atypically colored vegetables  
549 eaten at *post-test, compared to baseline* (see Fig.3, red dashed line) may support this  
550 hypothesis. Neophobic and picky children, who supposedly reject a particular food item  
551 because there is not an acceptable similarity between the item and its representation in their  
552 mind (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; Rioux et al., 2016), were  
553 therefore negatively impacted by this increased uncertainty about the predictive power of  
554 color. Whether this type of diverse exposure intervention would be effective if the labels were  
555 provided during the exposure manipulation remains to be seen.

556 ***Does visual exposure to vegetables lead to an increase in the consumption of this food***  
557 ***category through a mediating effect of an increase in ease of categorization (H3)?***

558 Contrary to our third hypothesis, no significant increase in the cognitive performances  
559 of children (categorization and inductive performances) between baseline and post-test were  
560 found. We have two interpretations for this non-significant result. First, it is very likely that a  
561 2-week exposure intervention was too short to significantly increase children's category  
562 content and categorization performance. Another explanation could be that our cognitive tasks  
563 were not sensitive or powerful enough to detect changes in children's cognitive performances.  
564 Therefore we can't draw conclusions about the potential mediating role of an improvement in

565 cognitive performances on the enhanced consumption of vegetables in the *simple exposure*  
566 condition.

567           Nevertheless, results revealed a moderator effect of categorization performance on the  
568 increased consumption of vegetables. Indeed, in the *simple exposure* condition, in which we  
569 found a positive effect of visual exposure, children with better categorization performance  
570 increased their consumption between pre and post-test significantly more. For instance, the  
571 children with the highest categorization scores ate three more atypically colored vegetables at  
572 post-test than at baseline (see Fig. 5). Comparatively, the children with the lowest  
573 categorization scores ate roughly the same number at baseline and post-test (see Fig. 5). This  
574 result is in line with Rioux and colleagues' study, showing that children with good  
575 categorization performance had low food neophobia and pickiness (Rioux et al., 2016). This  
576 finding also reinforces the cognitive approach of the mere exposure effect (Bornstein &  
577 D'Agostino, 1994; Lafraire et al., 2016): even if we failed to increase the ease with which  
578 these vegetables are categorized with our exposure manipulation, we nonetheless showed that  
579 an ease of categorization led to a larger impact of the exposure manipulation, that resulted in a  
580 greater consumption of the four novel vegetables in the simple exposure condition. We are  
581 confident that with other visual types of exposure manipulations (for instance more active  
582 exposure or for a longer period) an ease in categorization could be revealed. Indeed in a recent  
583 study conducted by Mustonen, Rantanen, and Tuorila (2009), ameliorations of young  
584 children's cognitive performances (assessed via odor recognition and naming) were found,  
585 after a several-month sensory education program that exposed children to different food  
586 odors.

587           Finally, it is interesting to note that, children's categorization performance moderated  
588 their increase in vegetable consumption, but their inductive performance did not. The present  
589 result added a piece to the puzzle of the cognitive mechanisms underlying food neophobia and

590 pickiness. Food neophobia and pickiness occur mainly at the mere sight of foods. This led  
591 some authors to hypothesize that rejections of fruits and vegetables are partly the  
592 consequences of an immature categorization system (Brown, 2010; Dovey et al., 2008;  
593 Lafraire et al., 2016; Rioux et al., 2016) that does not support the shift toward a focus on  
594 category membership for induction (Rioux et al., *under revision*). Two of the hallmarks of a  
595 mature categorization system are the ability to (i) recognize and organize into categories the  
596 stimuli in our environment and (ii) to make category-based inductions based on the  
597 knowledge that different items belong to the same or related categories. The present result  
598 suggests that food rejection behaviors seem to arise from an immature categorization system  
599 that does not recognize and organize into categories the stimuli in our environment. Focusing  
600 on the ease of categorization could be an efficient manner to tackle food neophobia and  
601 pickiness and to enhance the positive impact of visual food exposure.

### 602 *Limits and perspectives*

603         There are a number of shortcomings that could usefully be addressed in future  
604 research. First, our study did not include any long term follow-up. Therefore it is not clear  
605 whether the improvement in children's consumption was sustained over time. This is a  
606 question of importance as a recent review pointed out that few existing interventions are  
607 effective enough to increase vegetable consumption in children, especially in the long run  
608 (Appelton et al., 2016). Second, the number of exposures was chosen based on the existing  
609 literature and for practical reasons, but it may have led to the absence of positive effects in the  
610 color exposure condition. Further research is needed to establish how many picture encounters  
611 are required to trigger a positive attitude toward an exposed food. Finally, in the present  
612 study, children underwent a passive and short exposure experience. An experimenter was  
613 present to draw children's attention to the mats, but they were visible for a short period of  
614 time, namely just before lunch started and during dessert, because a plate was hiding the

615 pictures for the rest of the lunch. It will be of interest to investigate the effect of a more active  
616 exposure manipulation, for instance if the children use the place mats for coloring. Such a  
617 strategy is in line with recent findings (De Droog et al., 2014; De Droog, Van Nee, Govers, &  
618 Buijzen, 2017). Indeed De Droog and colleagues (2014; 2017) found that picture books were  
619 particularly effective to increase the consumption of exposed vegetables when children were  
620 actively involved in the reading sessions (answering questions about the story etc.).

621 On the other hand, particular strengths of the intervention include its simplicity and its  
622 effectiveness with highly neophobic and picky children, while several other exposure  
623 manipulations failed to increase the consumption of novel foods for this population (De Wild  
624 et al., 2016; Zeinstra et al., 2016). In addition to the measurable effects, the intervention  
625 appealed to school and cafeteria staff members because they were present during the exposure  
626 intervention and helped us design this study. It is recognized that some feeding strategies  
627 seem counterproductive (e.g. the use of food reward, see Decosta, Moller, Frost, & Olsen,  
628 2017) and school and cafeteria staff members who play an important role in children's  
629 development could profit from exchange with scientists working on children's food  
630 behaviors.

### 631 ***Conclusion***

632 Our findings added to the rising body of evidences in favor of the positive effect of  
633 mere visual exposure. Vegetable pictures might help parents to deal with some of the  
634 difficulties associated with the introduction of novel vegetables (or novel preparations of  
635 familiar vegetables). Our findings also suggested that focusing on conceptual development  
636 could be an efficient manner to tackle food neophobia and pickiness and to enhance the  
637 positive impact of visual food exposure, as demonstrated by the moderator effect of  
638 categorization performance on vegetable consumption.

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