



HAL
open science

Food rejection and the development of food categorization in young children

Camille Rioux, Delphine Picard, Jérémie Lafraire

► **To cite this version:**

Camille Rioux, Delphine Picard, Jérémie Lafraire. Food rejection and the development of food categorization in young children. *Cognitive Development*, 2016, 40, pp.163 - 177. 10.1016/j.cogdev.2016.09.003 . hal-01464659

HAL Id: hal-01464659

<https://hal.science/hal-01464659>

Submitted on 2 May 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 Food rejection and the development of food categorization in young children

2
3 Camille Rioux^{a,b*}, Delphine Picard^b & Jérémie Lafraire^a

4
5 ^a Center for Food and Hospitality Research, Paul Bocuse Institute, Ecully, France

6 ^b Aix Marseille Université, PSYCLE EA3273, 13621 Aix en Provence, France

7 8 **1 Introduction**

9 Food is of central biological importance to humans, but while “trying new foods is at the core
10 of omnivorousness (...) so is being wary of them” (Rozin, 1976). As insightfully stated by
11 Rozin, humans, along with other omnivorous species, are caught on the horns of this
12 omnivore’s dilemma. Humans need to have a diverse diet to ensure their nutritional health,
13 survival, and reproduction. To satisfy this dietary diversity, they must therefore continually
14 sample new food resources, as they move away from a mono diet, namely their mother’s
15 milk, to a diverse food repertoire. However, this search for variety can prove hazardous, as
16 new substances may be toxic, and a single mistake in this search could potentially lead to
17 death, and thus hinder reproduction (generally associated with evolutionary success; Dawkins,
18 1976).

19 Two design features appear to have emerged through natural selection to solve this adaptive
20 problem¹. Grasping the first horn of the dilemma, a categorization system allowing for a
21 food/nonfood distinction and discrimination between different food items enables efficient
22 sampling of new food resources and enrichment of the food repertoire. Categorization is a
23 fundamental cognitive process that allows us to organize objects into groups (Vauclair, 2004).
24 Without such abilities, each item would be perceived as new, and it would be impossible to

¹ An adaptive problem is a problem, like this omnivore’s dilemma, whose solution can affect reproduction, and hence evolutionary success (Cosmides, Tooby, & Barkow, 1992).

25 generalize its properties (such as assuming that because a carrot is edible, other carrots will be
26 too; Murphy, 2002).

27 Grasping the second horn of the dilemma, *food neophobia* (defined as the reluctance to eat
28 novel food items; Pliner & Hobden, 1992) and *food pickiness* (defined as the rejection of a
29 substantial amount of familiar foods, the consumption of an inadequate amount of food, and
30 the rejection of certain food textures; Rydell, Dahl, & Sundelin, 1995; Smith, Roux, Naidoo,
31 & Venter, 2005; Taylor, Wernimont, Northstone, & Emmett, 2015) prevent individuals from
32 ingesting substances that are potentially poisonous (Cashdan, 1994; Pliner, Pelchat, &
33 Grasbski, 1993; Rozin, 1977). It has been reported that these rejection behaviors are mainly
34 targeting plants, fruits and vegetables (Dovey, Staples, Gibson, & Halford, 2008). This is in
35 line with recent evidence showing that infants as young as eight months old exhibit greater
36 reluctance to touch basil and parsley plants, compared to plastic artefacts in the absence of
37 social information (Wertz & Wynn, 2014a).

38 However, while these food rejection behaviors had an adaptive value in Pleistocene hunter-
39 gatherers' hostile food environment, in our modern societies, where food safety is controlled
40 in food supply chains, they are less useful. Indeed, as food rejection behaviors lead to a low
41 consumption of fruit and vegetables by young children (Dovey, et al., 2008), they are
42 responsible for a reduction in dietary variety (Birch & Fisher, 1998; Falciglia, Couch,
43 Gribble, Pabst, & Frank, 2000) needed for normal and healthy child development (Carruth,
44 Skinner, Houck, Moran, Coletta, & Ott, 1998; Cashdan, 1998).

45 The assumption that food rejection and food categorization processes are natural selection's
46 solutions to the omnivore's dilemma led us to compare the scientific literature on food
47 rejection and on children's cognitive development, in particular the development of a food
48 categorization system (Lafraire, Rioux, Giboreau, & Picard, 2016). This comparison, which

49 we expected to shed light on the mechanisms underlying food rejection behaviors from the
50 perspective of overcoming them, uncovered several interesting outcomes or hypotheses.
51 First, an increasing number of research studies have related eating disorders to abnormal
52 cognitive development, such as in autism spectrum disorder (Postorino et al., 2015; Rochedy
53 & Poulain, 2015; Stough, Gillette Roberts, Jorgensen, & Patton, 2015). Children with autism
54 are known to have cognitive deficits (Frith & Happé, 1994; Ozonoff, Pennington, & Rogers,
55 1991), and interestingly eating problems are common in this clinical population (Ahearn,
56 Castine, Nault, & Green, 2001). Approximately 80% of young children on the autism
57 spectrum are described as picky eaters, and 95% of them are reported by parents to be
58 resistant to trying new foods (Lockner, Crowe, & Skipper, 2008) while prevalence of picky
59 eating in young neurologically typical children usually ranges from 25% to 50% (Taylor et al.
60 2015). Moreover, Bandini et al. (2010) found that children with autism had more limited food
61 repertoires than typically developing children.

62 Second, the sensitive period for food rejection starts at around 2 years, when children become
63 mobile and begin to reason about food items other than through their caregivers² (Cashdan,
64 1994; Dovey et al., 2008; Lafraire et al., 2016). It is precisely at this point that a food
65 categorization system is assumed to take its place within the child's cognitive system. Before
66 the age of 2 years, infants exhibit very limited food categorization abilities. For instance,
67 using a sequential touching procedure, Brown (2010) found that 20-month infants did not
68 systematically distinguish between food and animal categories. In the same vein, using a
69 looking time procedure, Shutts, Condry, Santos, and Spelke (2009) showed that 9-month-old
70 infants direct their attention equally to domain-relevant properties (e.g., color and texture) and
71 to domain-irrelevant properties (e.g., shape of the food's container) when reasoning about

² Before this age, food reasoning and selection seem to be mainly driven by social information (Wertz & Wynn, 2014b). For example infants preferentially reach for food that had been endorsed by native speaker of their native language (Shutts, Kinzler, McKee & Spelke, 2009). See Lafraire et al. (2016), Lumeng (2013) and Shutts, Kinzler & DeJesus (2013) for reviews of the social influences on food selection.

72 food. However, a rapid change occurs between 2 and 3 years of age. Using a sorting task
73 procedure, Bovet, Vauclair, and Blaye (2005) found that 3-year-olds systematically
74 distinguished between toy items and food items, demonstrating that these toddlers had
75 developed a conceptual food category. Moreover, Brown (2010) established that, at this age,
76 children also differentiate between categories within the food domain, such as biscuit and
77 fruit. These results are in line with Nguyen and Murphy's claim that taxonomic categories³
78 are available to children quite early in development (Nguyen & Murphy, 2003).

79 Third, rejection usually occurs at the mere sight of the food (Carruth et al., 1998), leading
80 some authors to hypothesize that as children wish to recognize the foods they are given (to be
81 sure of the consequences of ingestion), there is a perceptual mismatch between the meal that
82 is presented and the prototypical food representations in their mind, possibly leading to food
83 rejection (Brown, 2010; Dovey et al., 2008). For instance, Dovey et al. (2008, p. 183)
84 hypothesized that "children build up schemata of how an acceptable food should look, and
85 perhaps smell, and so foods not sufficiently close to this stimulus set will be rejected".

86 Fourth and last, one important finding in the domain of food categorization is that children
87 from the age of 2-3 years attend to information about color or texture, rather than shape
88 (Landau, Smith, & Jones, 1988; Yoshida & Smith, 2003) when discriminating between edible
89 and inedible substances or between different kinds of foods (Lavin & Hall, 2001; Macario,
90 1991, Ross & Murphy, 1999; Shutts et al., 2009). For example, in a conflicting picture triad
91 procedure⁴, Macario (1991, Exp. 4) showed 3- to 4-year-old children a novel object, described
92 as either a thing to eat (*food* condition) or a thing to play with (*toy* condition). The children
93 were then introduced to two other novel objects: a *color match* with the target object; and a
94 *shape match* with the target object. When asked which one was like the target object, children

³ Taxonomic categories are based on common properties and are organized into hierarchies, such as apple-fruit-food (Nguyen & Murphy, 2003).

⁴ In a conflicting triad procedure, a target and two test items are pitted against each other. Children are required to match one of the test items with the target.

95 were more likely to choose the color-match object in the *food* condition, whereas they were
96 more likely to choose the shape-match object in the *toy* condition. These data speak in favor
97 of a domain specificity⁵ effect on categorization, and this domain specificity effect is relevant
98 not only in nonlinguistic categorization tasks, as Macario established, but also in children's
99 novel word extensions (Lavin & Hall, 2001).

100 Thus, if food rejection is a behavioral consequence of an immature food categorization system
101 (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016) and food categorization is mainly
102 color-dependent (Lavin & Hall, 2001; Macario, 1991), then some food colors should trigger
103 food rejection. There is already some evidence to support this idea. Compared with orange
104 vegetables (Gerrish & Mennella, 2001), green vegetables are often rejected more (Harris,
105 1993), and their acceptance is more difficult to foster (Mennella, Nicklaus, Jagolino, &
106 Yourshaw, 2008). Additionally, Macario (1991) reported that many parents have anecdotally
107 noted that their children can reject all foods of a particular color. To explain these
108 mechanisms, Macario (1991, Exp. 2-3) showed 2- to 4-year-old children two photographs of
109 familiar foods: one normally colored (e.g., a green lettuce) and one anomalously colored (e.g.,
110 a purple lettuce). The children were then asked which one was not for people to eat, and
111 consistently chose the anomalously colored photograph. The author concluded that the
112 toddlers had a hypothesis about the predictive validity of color in the food domain, and
113 rejected foods were those that were not the color they were supposed to be.

114 To summarize, our comparison of the scientific literature on food rejection and the
115 development of a food categorization system uncovered the following three outcomes and
116 hypotheses:

117 (i) Children's ability to perform categorization in the food domain appears to improve from
118 the age of 2-3 years. However, further studies are greatly needed, as there is still far too little

⁵ According to Fodor (1983), many aspects of cognition are supported by specialized and specified learning devices.

119 research on food categorization in children, especially children over 3 years, when the food
120 categorization system is thought to develop;

121 (ii) Food rejection may be a manifestation of a developing food categorization system that
122 generates a large number of mismatches between food items and early food categories.
123 Nevertheless, though promising, the explanation that food is rejected on account of its visual
124 properties, through a mismatch between a prototypical category and a particular food item
125 (proposed by Brown, 2010, and Dovey et al., 2008) needs further elaboration and refinement.
126 These authors seemed to rely on the prototype theory of categorization proposed by Rosh and
127 Mervis (1975), as they used notions proposed by this theory, such as *schemata* and *prototype*
128 (Murphy, 2002). However, in this theory, a category is represented by a unified and summary
129 representation of the different exemplars, rather than by separate representations for each
130 member of the category (Murphy, 2002; Rosh & Mervis, 1975). Therefore, there is
131 necessarily a mismatch between a new item and the prototype of the category (since it is not
132 an exemplar but rather a feature list), and acceptance of a new item in the category is
133 therefore based not on an exact match but rather on an acceptable similarity to the prototype
134 (Murphy, 2002);

135 (iii) Food categorization is mainly color dependent, and some food colors trigger food
136 rejection. However the precise mechanism linking food color and food rejection has yet to be
137 identified. In our view, color is important mainly because it conveys information about the
138 typicality of a given food exemplar contrary to shape or texture (which vary more across
139 recipes and preparations). We would expect atypical items of a given category to be
140 frequently excluded from that category (Murphy, 2002), and the anomalously colored
141 photographs in Macario's experiments described above (1991), which were atypical items,
142 were indeed excluded from the food category.

143 The present study was designed to investigate these three interesting outcomes and the gaps in
144 these fields that would be well worth filling in, so as to shed light on the mechanisms
145 underlying food rejection behaviors and possibly overcome them. The literature described
146 above led us to formulate the following three hypotheses:

147

148 H1 = Children's abilities to perform categorization in the food domain start improving at age
149 2-3 years. More specifically, discrimination abilities in the food domain should improve
150 between 2-4 years and 4-6 years, and up to adulthood.

151

152 H2 = Food rejection in young children is closely intertwined with the development of a food
153 categorization system, with food rejection being the behavioral consequence of an immature
154 food categorization system. From this perspective, we would expect children with poor
155 discrimination abilities in the food domain to demonstrate higher food rejection tendencies
156 than children with high discrimination abilities.

157

158 H3 = Food categorization is mainly color dependent, but color is not important per se. Rather,
159 it conveys information about the typicality of a given food exemplar. As a result, we would
160 expect food items with atypical colors to be more prone to categorization errors than food
161 items with typical colors.

162

163 To investigate these three hypotheses, we conducted a food categorization task with children
164 aged 2-4 and 4-6 years (plus an additional control group of adults), involving the use of fruit
165 and vegetable categories. We chose these categories because by this age, children have
166 usually encountered several exemplars of these food items and developed the corresponding
167 taxonomic categories (Nguyen & Murphy, 2003). Fruit and vegetables were also chosen

168 because they are likely to be rejected by children in this age range. Moreover, to gain a
169 sensitive measure of children's categorization abilities, we needed two categories that were
170 not too distant from each other, regarding false relatedness effects (it is more difficult to
171 answer "No" to the question "Is a vegetable a fruit?" than to the question "Is a vegetable a
172 car?"; see Smith & Medin, 1981). It has been argued that from an early age, children
173 distinguish accurately between natural items (e.g., food) and artificial items (Mandler &
174 McDonough, 1993) and between categories within the food domain such as biscuit and fruit
175 (Brown, 2010).

176 **2 Methods**

177 **2.1 Participants**

178 The participants were 79 children: 40 children aged between 27 and 46 months ($M = 36.1$
179 months, $SD = 5.7$; 24 girls and 16 boys) and 39 children aged between 48 and 78 months ($M =$
180 63.7 months, $SD = 8.7$; 20 girls and 19 boys). The children were pupils at a preschool in the
181 Lyons urban area (France), and were predominately European and recruited from middle-
182 class communities. Prior to the study, the children's parents filled out a questionnaire about
183 their food rejection (Child Food Rejection Scale⁶, CFRS; Rioux, Lafraire, & Picard,
184 submitted) and exposure to the fruits and vegetables presented to the children during the
185 experiment. The children's scores on the CFRS ranged from 16 to 50 ($M = 33.5$, $SD = 7.8$),
186 and were normally distributed (Shapiro-Wilk test, $W = 0.98$, $p = 0.42$). These scores obtained
187 via parental report were used as the predictive measure of children's own food rejection
188 tendencies. Their exposure scores ranged from 3 to 10⁷ ($M = 8.4$, $SD = 1.5$) and were not
189 normally distributed ($W = 0.8$, $p < 0.05$). Neither of these scores (CFRS and exposure scores)

⁶ The Child Food Rejection Scale is a short and easy-to-administer scale, in which caregivers respond for their child. It was developed to enable the assessment of food neophobia and pickiness in children aged 2-7 years, and includes two subscales: one measuring children's food neophobia and one measuring their pickiness.

⁷ Children's scores on the Child Food Rejection Scale can range from 11 to 55. Their exposure scores can range from 0 to 10.

190 were correlated with age (Pearson's correlation, $r = -0.13$, $p = 0.24$, and Spearman's
191 correlation $r = 0.06$, $p = 0.6$) and neither varied according to sex (as attested by a Student's t
192 test, both $ps > 0.06$). It is interesting to note that the absence of any influence of age on food
193 rejection scores within this age range (2-6 years old) is consistent with previous findings
194 (Adessi, Galloway, Visalberghi & Birch, 2005; Cook, Wardle & Gibson, 2003; Koivisto &
195 Sjöden, 1996; Rioux et al. submitted). It suggests that food rejections increase rapidly around
196 the age of two years, when children are liable to ingest toxic compounds because of their
197 growing mobility, remains quite stable until 6-7 years and slowly decrease thereafter when
198 fewer foods are novel to children.

199 A control group of adults ($n = 30$) also performed the categorization task (Adult sample 1).
200 These participants were either recruited from a university or were preschool employees. Two
201 additional adult samples (Sample 2: $n = 79$ (children's parents); and Sample 3: $n = 10$) were
202 used to rate the kind and color typicality of our food set.

203 **2.2 Stimuli**

204 Following Macario's lead (1991, Exp. 2 and 3), we tested the children with photographs of
205 some familiar fruit and vegetables. Some photographs had typical colors (e.g., a purple
206 beetroot), while some had atypical, but still real, colors (e.g., a yellow beetroot). The main
207 difference between Macario's experiment and the present study was the use of only real food,
208 that is to say, even if yellow is an atypical color for a beetroot, this variety can still be found
209 in supermarkets and greengrocer's stores. None of our colors were anomalous for a given type
210 of food.

211 To generate our set of foods, we first visited a school canteen to see which foods were
212 available to children, and which recipes were usually proposed. On this basis, we selected six
213 vegetables that were commonly served and were available in different colors (carrots,

214 tomatoes, eggplants, beetroots, bell peppers and zucchinis), and three fruits (apples, pears and
 215 citrus fruits)⁸. Next, to control for fruit and vegetable typicality, as several authors have
 216 demonstrated that typical items are easier to recognize and categorize (Hayes & Taplin, 1993;
 217 Mervis & Pani, 1980; Murphy, 2002), we followed Barsalou (1985)'s and Chrea, Valentin,
 218 Sulmont-Rossé, Hoang Nguyen & Abdi (2005)'s methodologies. The parents of the children
 219 in our sample (Adult sample 2) were therefore asked to indicate on a 7-point scale for each of
 220 the nine food items whether they were good examples of the fruit or vegetable category in
 221 question. No pictures were used for this procedure. For example, we asked adult participants
 222 to imagine a carrot and then rate its typicality compared to other vegetables on the 7-point
 223 scale. The purpose of this first assessment was to determine whether in general, carrots were
 224 judged to be more typical than beetroots for instance. The results are set out in Table 1 and
 225 showed for instance, that carrots were judged to be more typical vegetables than beetroots
 226 because typicality's rating for carrot was judged to be 6.30 while it was judged to be 3.91 for
 227 beetroots.

228 Table 1 (single column fitting image): Typicality rated by adults (on a 7-point scale) for the
 229 entire food set.

Food items	Typicality rating	Typicality ranking
carrot	6.30	1
zucchini	6.14	2
tomato	5.33	3
bell pepper	4.60	4
eggplant	4.41	5
beetroot	3.91	6
apple	6.55	1
pear	6.29	2
citrus fruit	5.12	3

230 *Note.* For citrus fruit, we averaged the typicality rates for orange and grapefruit.

⁸ We chose the citrus fruit family (and not just orange or grapefruit) because of the limited availability of fruits in different colors in the season the experiment was conducted.

231 For each of the six vegetables and three fruits, we chose four varieties differing in color. We
 232 then asked 10 adults (Adult sample 3) to indicate the typicality (either *typical* or *atypical*) of
 233 the color chosen for each vegetable and fruit (the typicality of the color for each food item
 234 was independent of its kind typicality assessed with the adult sample 2).⁹. From this
 235 assessment we were able to know that the orange carrot was *typically colored* while the
 236 purple carrot was *atypically colored* for instance.

237 Finally, to control for shape effects, each food item was cut either into quarters, slices or
 238 cubes, ensuring that the chosen shape was the one in which a given vegetable/fruit was most
 239 commonly served in the school canteen we visited (e.g., beetroots were commonly served cut
 240 into small cubes, so this was the shape we chose for this vegetable; see Table 2). We decided
 241 to use cut fruit and vegetables instead of whole food items to gain in ecological validity.
 242 Indeed, as the purpose of the study was to understand how children perceived and categorized
 243 their food in the plate and to determine the factors that trigger rejections, we wanted to
 244 present them with food they actually can encounter in everyday life, for example in school
 245 canteens. In such settings, children encounter starters composed of beetroots cut in small
 246 cubes rather than whole beetroots for instance, and sometimes they don't know what the
 247 whole vegetable resembles.

248 Table 2 (1.5 column fitting image): Description of the entire food set.

Zucchini (slice)	Carrot (slice)	Tomato (quarter)	Bell pepper (quarter)	Eggplant (cube)	Beetroot (cube)
Green (T)	Orange (T)	Red (T)	Green (T)	Dark purple (T)	Purple (T)
Dark green (T)	Dark orange (T)	Dark red	Yellow (T)	Light purple	White
Light green	Yellow	Yellow	Red (T)	White	Pink

⁹ We chose a 7-point scale to assess fruit and vegetable typicality because we wanted to arrange the items according to their typicality in the different blocks of pictures. However, we followed Macario's lead and assessed color typicality with a binary scale, in order to gain an initial impression of the role of color typicality in food categorization.

Yellow Purple Green Orange Green Yellow

Apple (quarter)	Pear (cube)	Citrus fruit (slice)
Green (T)	Yellow (T)	Green (T)
Red (T)	Green (T)	Yellow (T)
Brown	Brown	Pink (T)
Yellow (T)	Red	Orange (T)

249 *Note.* (T) = typical color. The colors reported here are the skin colors of each fruit or
 250 vegetable.

251

252 The different foods were then cooked (but not peeled, as we wanted to retain the differences
 253 in colors) and photographed, controlling for contrast and luminosity. The visual stimuli were
 254 then printed separately on cards measuring 10 x 15 cm (see Appendix for the 36 food
 255 pictures), and divided into three blocks of 12 pictures each (eight vegetable pictures and four
 256 fruit pictures per block; see Table 3).

257 Table 3 (single column fitting image): Characteristics of the three blocks of food pictures.

Block A	Block B	Block C
4 carrots (1)	4 zucchinis (2)	4 tomatoes (3)
4 bell peppers (4)	4 eggplants (5)	4 beetroots (6)
4 pears (2)	4 apples (1)	4 citrus fruits (3)

258

259 *Note.* The numbers in brackets are the typicality rankings for each type of vegetable and fruit.

260 Each block contained the same number of food items, cut in quarters, slices or cubes. For
 261 example, in Block A the four colored varieties of carrots were cut into slices, the varieties of
 262 bell peppers were cut into quarters, and the varieties of pears were cut into cubes. Moreover,
 263 in each block, the two kinds of vegetables differed considerably in typicality. Twelve
 264 additional stimuli, which were neither fruit nor vegetables, were used in a practice session

265 (four pictures of cats, four pictures of dogs, and four pictures of cars, differing in terms of
266 their overall colors).

267 2.3 Procedure

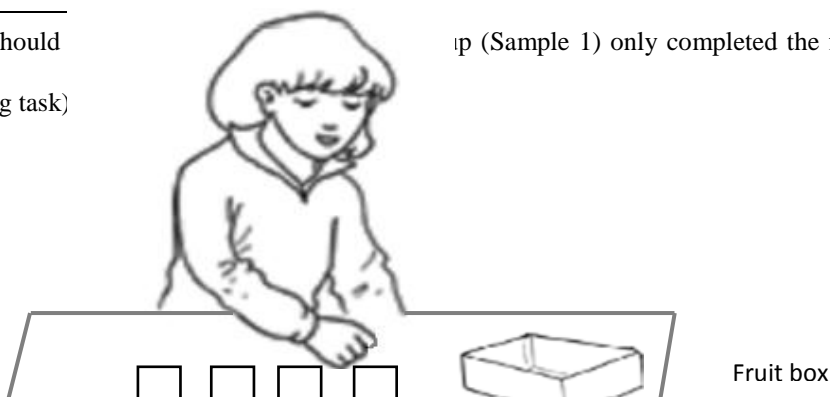
268 Children were tested individually for approximately 15 minutes in a quiet room at their
269 school. They sat at a table, with the experimenter on their left side. There were three parts to
270 the experiment, run successively and in a constant order for all the children.¹⁰

271 *Part 1- Forced sorting task.* The experimenter explained to the child that they were going to
272 play a game with pictures and the rule was to sort them into two different boxes according to
273 their categories. The game began with a familiarization phase where eight pictures of animals
274 and four pictures of cars were shown simultaneously to the children (see Fig. 1). The
275 experimenter explained that the child first had to find the animal pictures, and put them in the
276 same box. Then the car pictures had to go in the other box. During this familiarization phase,
277 the experimenter gave the children feedback and corrected their mistakes. Afterwards, the
278 experimenter introduced the fruit and vegetable pictures, and asked the child to find the
279 vegetable pictures first and put them in the same box, and then put the fruit pictures in the
280 other box. Each child carried out this sorting task for two blocks of food pictures without any
281 feedback from the experimenter. The order in which the pictures were placed on the table was
282 randomized for each participant. Additionally, the order in which the blocks were provided
283 was counterbalanced across participants (e.g., Participant 1 sorted blocks A and B, while
284 Participant 2 sorted blocks A and C, etc.).

285 Figure 1 (single column fitting image): Arrangement of cards on the table.

¹⁰ It should
sorting task)

ip (Sample 1) only completed the first part of the study (forced



286

287

288

289

290

291

292 *Note.* This arrangement allowed the children to see all the pictures rapidly without having to
293 make large exploratory eye or body movements. This drawing was realised based on
294 illustrations from « Clic images 2.0 - Canopé académie de Dijon » : [http://www.cndp.fr/crdp-](http://www.cndp.fr/crdp-dijon/clic-images/)
295 [dijon/clic-images/](http://www.cndp.fr/crdp-dijon/clic-images/).

296 The experimenter recorded the type of response for each vegetable (hit or miss) and for each
297 fruit (correct rejection or false alarm). We then assigned to each participant a hit score (i.e.,
298 number of cards placed in the vegetable box when the picture was a vegetable) and a false
299 alarm score (i.e., number of cards placed in the vegetable box when the picture was a fruit).
300 Hit scores could vary between 0 and 16, and false alarm scores between 0 and 8. Both these
301 scores were important to take into account to evaluate children performances to the task. For
302 example a child who would have placed the twelve pictures of block A in the vegetable box
303 would have a high hit score (because she put in the right box all the vegetables from block A).
304 However her categorization performances would be nevertheless poor as she would have put
305 also all the fruit pictures from block A in the vegetable box and it will be indicated by a high
306 rate of false alarms. Based on these two scores (hit and false alarm), we measured an index of
307 discriminability (A'), and an index of the child's decision criterion (B'') (these indexes are
308 widely used within the signal detection theory, see Grier, 1971; Stanislaw & Todorov, 1999).
309 A' ranged from 0 to 1, with .50 indicating responses at chance level, and 1 indicating
310 maximum discriminability. B'' ranged from -1 to +1, with -1 indicating a liberal criterion

311 (e.g., children tending to place cards in the vegetable box whatever the pictures), and 1
312 indicating a conservative criterion (e.g., children tending to place cards in the fruit box
313 whatever the picture). Both indices were computed according to Grier's formulas (Grier,
314 1971): $A' = \frac{1}{2} + [(y - x)(1 + y - x) / 4y(1 - x)]$, and $B'' = [y(1 - y) - x(1 - x)] / [(y(1 - y) + x(1 -$
315 $x)]$ where y stood for the probability of a hit and x corresponded to the probability of a false
316 alarm.

317 *Part 2- Food rejection task.* In the second part of the experiment, children were shown a third
318 block of food pictures (arranged in a manner similar to that of the sorting task). In this task,
319 children were asked to put the different foods they were unwilling to taste in the bin. The
320 main objective of this task was to associate food rejection behaviors with performances on the
321 sorting task. In order to make the test more tangible to the children, we used an actual small
322 bin that was already present in the room and therefore familiar to them. For each child, the
323 number and type of items placed in the bin was recorded by the experimenter.

324 *Part 3- Color naming task.* Following Macario (1991, Exp. 2 and 3)'s work, the last part of
325 the experiment consisted of an examination of color naming abilities, so as to assess the
326 potential relationship between color naming and the categorization of colored vegetables.
327 Eleven monochrome pictures in colors extracted from the fruit and vegetable pictures (light
328 green, dark green, light purple, dark purple, red, dark red, yellow, orange, brown, pink and
329 white) were printed separately on 5 x 5-cm cards and shown to the child. In a color-word
330 production subtask, we asked the children to name each color. In a color-word comprehension
331 subtask, we told the children the name of a color and asked them to point out the
332 corresponding picture card. The order of the two subtasks was counterbalanced across
333 children. For each subtask, we credited a child with knowing a particular color word if she
334 produced or understood the correct color word (scoring 0 when the child did not know the
335 color word and 1 when the child did know it). Note that, for the color-word production

336 subtask children labeling the "light green" panel as just "green", or the "dark purple" panel as
 337 just "purple" were counted as correct responders. Each child could thus score between 0 and
 338 11 on the word production subtask and on the word comprehension subtask. As scores on the
 339 two subtasks were closely correlated (as attested with Spearman's coefficient: $r = 0.70$, $p <$
 340 0.001), we averaged these two scores. Each child was therefore assigned a single *color-word*
 341 *knowledge* score between 0 and to 11.

342 **3 Results**

343 **3.1 Sorting task**

344 To test the hypothesis that children's ability to perform categorization in the food domain
 345 improves with age, for each of the three age groups (2-4 years, 4-6 years, and adults), we
 346 assessed mean hit and false alarm responses, as well as A' and B'' (results set out in Table 4).

347 Table 4 (2- column fitting image): Type of response and signal detection indices for each age
 348 group.

Age group	Hit percentage	False alarm percentage	discriminability A'	Decision criterion B''
2-4 years	73.4	44.0	0.72	-0.07
4-6 years	75.6	29.1	0.81	-0.05
adults	88.1	9.2	0.94	0.12

349

350 3.1.1 Type of response

351 Overall, children had a high rate of hits ($M = .74$, $SD = .14$), and a moderate rate of false
 352 alarms ($M = .36$, $SD = .23$).

353 More specifically, the results set out in Table 4 indicate that the average hit rate for children
 354 aged 2-4 years was 0.73 ($SD = .08$), while the average hit rate for children aged 4-6 years was
 355 0.75 ($SD = .15$). The adults performed better on the task, with higher hit rates ($M = .88$, $SD =$

356 .08). An analysis of variance (ANOVA) on the percentage of hits, with age (3 groups) as a
357 predictive variable, indicated an effect of age ($F = 11.94, p < 0.0001$). A post hoc LSD
358 analysis revealed that hit rates for the two children's groups did not differ significantly,
359 whereas there was a significant difference between the 2- to 4-year-old children and the adults
360 ($p < 0.0001$), as well as between the 4- to 6-year-old children and the adults ($p = 0.0004$).

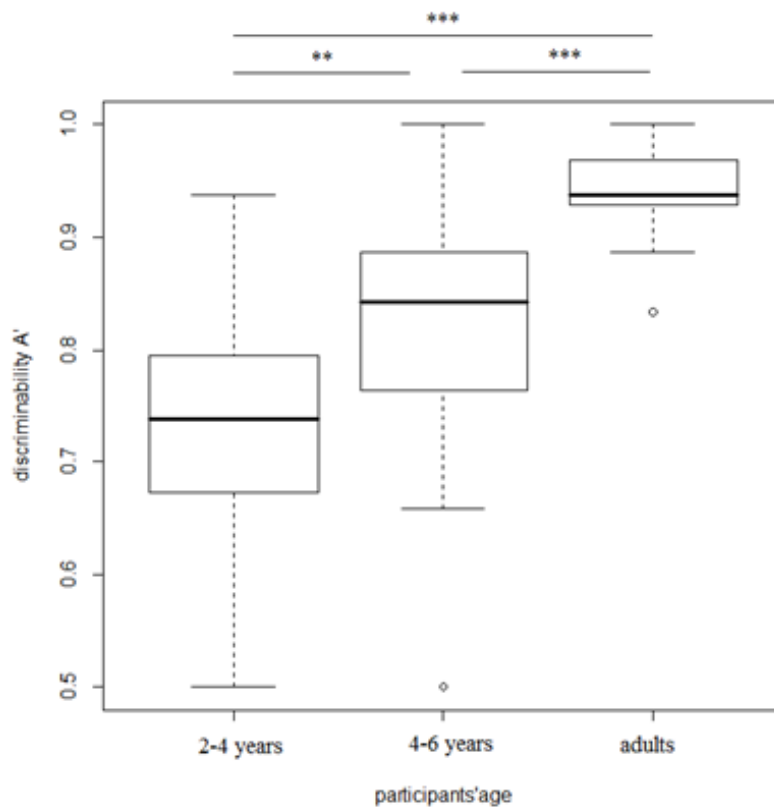
361 The mean false alarm rate for children aged 2-4 years was 0.44 ($SD = .14$), while the average
362 false alarm rate for children aged 4-6 years was 0.29 ($SD = .23$). The adults performed better
363 on the task, with lower false alarm rates ($M = .09, SD = .09$). A one-way ANOVA also
364 indicated an effect of age ($F = 28.96, p < 0.0001$). More specifically, a post hoc LSD analysis
365 revealed that false alarm rates differed significantly between the two children's groups ($p =$
366 0.002), as well as between the children and the adult participants ($p < 0.0001$ for 2-4 years vs.
367 adults, and $p < 0.0001$ for 4-6 years vs. adults).

368 3.1.2 Discriminability A'

369 A' for children was .77 ($SD = .13$; range = .50-1). Results (see Table 4) indicated that mean
370 A' for children aged 2-4 years was 0.72 ($SD = .11$), while the mean hit rate for children aged
371 4-6 years was 0.81 ($SD = .12$). The adults performed better on the task ($M = .94, SD = .04$).

372 An ANOVA on A' with age (3 groups) as a predictive variable indicated an effect of age ($F =$
373 $36.7, p < 0.0001$; Fig. 2). Post hoc LSD analysis revealed significant differences between the
374 groups ($p = 0.002$ between the two children's groups, $p < 0.0001$ between the adults and
375 younger children, and $p < 0.0001$ between the adults and older children).

376 Figure 2 (single column fitting image): Discriminability A' for each of the age groups.



377

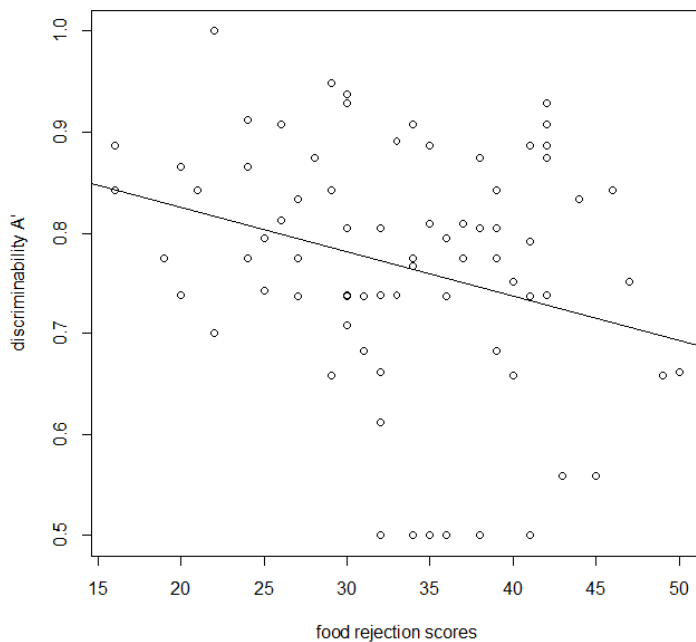
378 *Note.* Significant differences between the age groups are marked * for $p < 0.05$, ** for $p < 0.01$
 379 and *** for $p < 0.001$.

380 To identify the variables that were most predictive of discriminability variation among the
 381 children, we carried out a stepwise procedure using the AIC¹¹ as our criterion for model
 382 selection. The predictive variables we retained were sex (boy/girl), age (younger/older), order
 383 of block presentation (AB/AC/BA/BC/CA/CB), food rejection (scores obtained to the CFRS
 384 questionnaire possibly ranging from 11 to 55) and exposure to fruit and vegetables (scores
 385 possibly ranging from 0 to 11). The first variables were discontinuous, and the last two
 386 continuous. This model significantly predicted discriminability variation across our sample (p
 387 = 0.0003) and explained 26% of this variation, as demonstrated by the adjusted R^2 . It revealed
 388 effects of age ($F = 6.11$, $p = 0.016$) and rejection ($F = 4.99$, $p = 0.029$). As attested by post
 389 hoc LSD analyses, the older children performed significantly better than the younger children

¹¹ The Akaike information criterion (AIC) is a measure of the relative quality of different statistical models. The retained model is usually the one with the lowest AIC (Hu, 2007).

390 (see Fig. 2). Furthermore, the highly neophobic and picky children performed more poorly on
391 the task than the less neophobic and picky children (see Fig. 3).

392 Figure 3 (single column fitting image) : Discriminability A' as a function of children's food
393 rejection scores.



394

395 *Note.* The Pearson coefficient correlation indicated a significant and negative correlation
396 between the children's food rejection scores and discriminability A' ($r = -0.27, p = 0.014$).

397

398 3.1.3 Decision criterion B''

399 The mean B'' for children was $-.06$ ($SD = .037$; range = -1 to 1), meaning that overall, the
400 children were neither liberal nor conservative in their responses. Results (see Table 4)
401 indicated that the mean B'' for children aged 2-4 years was -0.07 ($SD = .41$), while the mean
402 B'' for children aged 4-6 years was -0.05 ($SD = .34$). The adults' mean B'' was quite similar
403 ($M = .12, SD = .63$), indicating that, like the children, they were neither liberal nor
404 conservative in their responses. An ANOVA on B'', with age (3) as the predictive variable,
405 did not indicate any age effect.

406 As with A', to select the predictive variables that best explained variations in B'' across our
407 child sample, we carried out a stepwise procedure using the AIC as the criterion for model
408 selection. The sole predictive variable we retained was food rejection score (possibly ranging
409 from 11 to 55). However, this model did not significantly predict variation in B'' ($p = 0.069$).
410 Unlike A', therefore, neither the children's characteristics nor the experimental setting
411 affected B''.

412 3.1.4 Influence of A' and B'' on food rejection scores

413 To test the hypothesis that food rejection is the behavioral consequence of an immature food
414 categorization system, we conducted a regression analysis with A' and B'' as predictive
415 variables, and food rejection score obtained from the CFRS questionnaire as the predicted
416 variable¹². This model significantly predicted variation in the food rejection score across our
417 child sample ($p = 0.019$), but explained rather a low proportion (7.5%) of this variability, as
418 demonstrated by the adjusted R^2 . Results revealed an effect of A' on food rejection scores (F
419 $= 4.79$, $p = 0.031$). This effect indicated that children who performed poorly on the sorting
420 task were more neophobic and picky than children who performed well on it (see Fig. 2).

421 **3.2 Food rejection task**

422 Spearman's correlation coefficients failed to reveal any significant correlation between the
423 number of pictures binned during the food rejection task and either children's food rejection
424 scores obtained from the CFRS questionnaire ($r = 0.06$, ns) or their fruit and vegetable
425 exposure scores ($r = 0.10$, ns). To assess the potential influence of picture characteristics on
426 the decision to place them in the bin, we ran an ANOVA (with post hoc LSD analysis) on the

¹² A' represented children's sensitivity to stimulus differences, that is to say, their ability to distinguish between fruit and vegetables in the present experiment (MacMillan & Creelman, 2005). By contrast, B'' reflected their leaning toward one response or the other, that is to say, their inclination to favor the vegetable box over the fruit box in the present experiment (MacMillan & Creelman, 2005). These indices therefore captured the degree of maturity of their food categorization system and the types of classification strategy that might be involved.

427 binning percentage for each picture, with category (2), shape (3), color (11) and color
428 typicality (2) as predictive variables. This model did not significantly predict the proportion of
429 times a picture was binned and did not reveal any effect of picture characteristics.

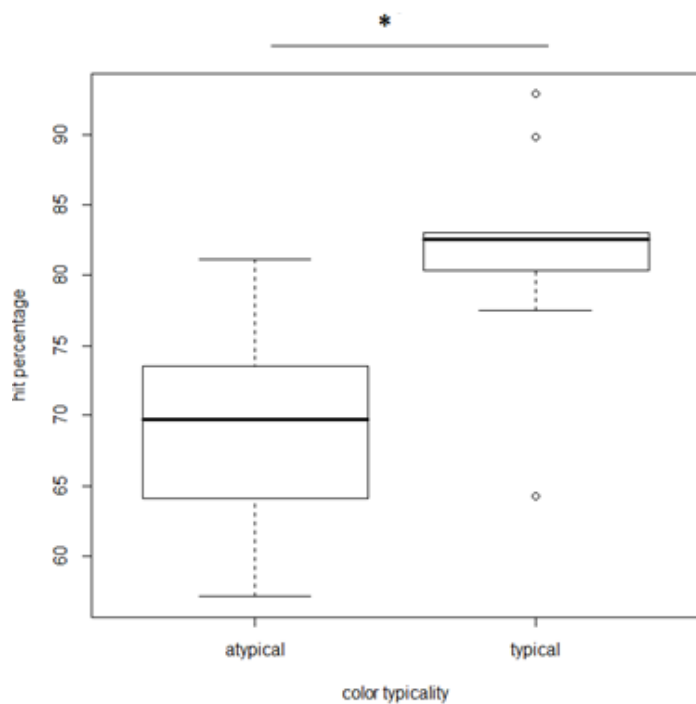
430 **3.3 Color naming task**

431 Overall, children were quite familiar with the names of the colors of the 11 color pictures they
432 were shown. The children's mean color name score was 8 ($SD = 1.48$; range: 3-11). Their
433 color name knowledge varied according to age, as attested by the Mann-Whitney test between
434 the two age groups ($W=226.5$, $p < 0.0001$), but not according to sex ($W = 693$, $p = 0.53$).
435 Moreover, the children's color name knowledge was not correlated with their food rejection
436 scores (as attested by Spearman's coefficient, $r = -0.09$, *ns*).

437 **3.4 Categorization performance based on vegetable characteristics.**

438 To test the hypothesis that, in food categorization, color is important mainly because of the
439 information it conveys about the typicality of a given food exemplar, we calculated the
440 percentage of hits for each vegetable across the children (see Appendix). To assess the
441 potential influence of each vegetable's characteristics on the decision to categorize it as a
442 vegetable, we ran an ANOVA (with post hoc LSD analysis) on the percentage of hits for each
443 vegetable across children, with shape (3), color (11), color typicality (2) and vegetable kind
444 typicality (6) as predictive variables. This model significantly predicted variations in the
445 percentage of hits for vegetable pictures among children ($p = 0.002$) and explained 76% of
446 this variability, as demonstrated by the adjusted R^2 . Results indicated a color typicality effect
447 ($F = 6.99$, $p = 0.024$), and a color effect ($F = 4.1$, $p = 0.01$). As shown in Figure 4, typically
448 colored vegetables were significantly better categorized than atypically colored ones (hit
449 percentage 81.6% vs. 69.3%).

450 Figure 4 (single column fitting image): Hit percentages for atypically and typically colored
451 vegetables.



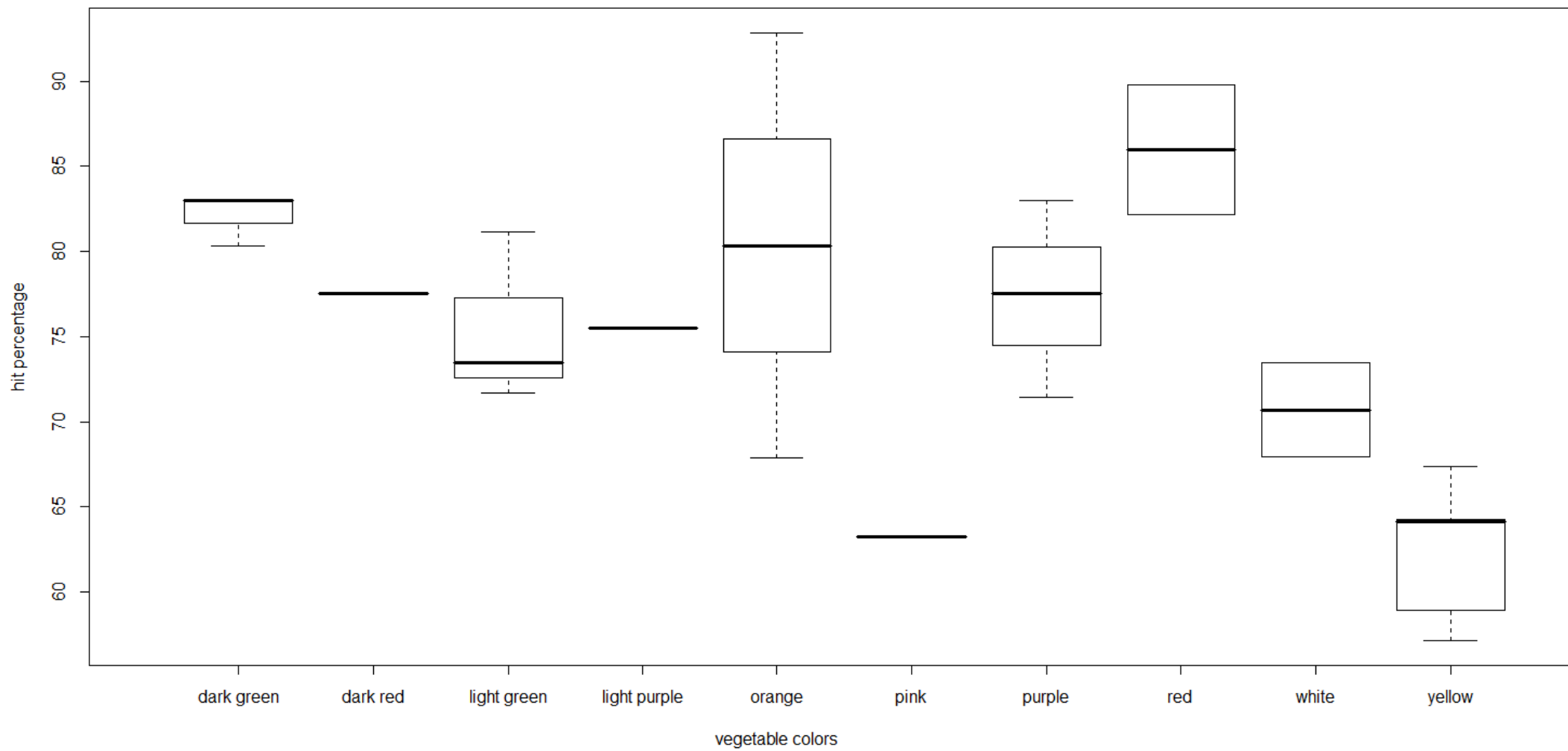
452

453 *Note.* * $p < 0.05$, ** $p < 0.01$.

454 Concerning the color effect, yellow, white and pink vegetables were poorly categorized (see
455 Fig. 5), compared with, red, orange and dark green vegetables. However, post hoc LSD
456 analysis revealed that none of the colors was significantly less well recognized as a potential
457 color for vegetables.

458 Figure 5 (2-column fitting image): Hit percentage for each vegetable color.

459



461 **4 Discussion**

462 The present study had a threefold aim: (i) investigate 2- to 6-year-old children's ability to
463 distinguish between fruit and vegetable items in a categorization task; (ii) find evidence for
464 the putative relationship between food rejection and food categorization performance in
465 young children; and (iii) shed light on the mechanisms behind the central role of color in food
466 categorization. To our knowledge, it was the first study to investigate the potential
467 relationship between food rejection and the typical development of the food categorization
468 system, as well as the first attempt to examine the role of color typicality in children's food
469 categorization.

470 **4.1 Do children's food categorization performances improve with age?**

471 Results indicated that children as young as 2 years were able to distinguish fairly efficiently
472 between different food categories (mean discriminability for 2- to 4-year-olds: .73), even with
473 complex food stimuli that varied in shape and color. This result proved that our methodology
474 was appropriate for this age range, and extended the findings reported by Nguyen and
475 Murphy (2003), who reported that children can acquire both fruit and vegetable taxonomic
476 categories as early as 3 years. However, while the younger children (2-4 years) displayed a
477 high rate of hits (73%), they also displayed a high rate of false alarms (44%). As Cashdan
478 pointed out (1994), this meant that their food categorization system was rather crude and still
479 under construction. Results also indicated a clear developmental effect. The children's ability
480 to correctly categorize items on the basis of their basic visual properties increased with age.
481 While both younger and older children had hit rates of around 0.74, there was a clear and
482 significant fall in the mean false alarm rate for older children (0.44 for 2- to 4-year-olds vs.
483 0.29 for 4- to 6-year-olds). Consequently, discriminability was greater at 4-6 years (as shown
484 in Fig. 2), suggesting that categorization abilities improve between the ages of 2 and 6 years.

485 This finding is consistent with previous studies of food categorization development in
486 children (see Bovet et al., 2005; Nguyen & Murphy, 2003). However, the food categorization
487 system was still under construction at 4-6 years, as attested by the adults' significantly better
488 performances (both hit and false alarm rates were significantly higher for adults, and
489 consequently discriminability as well). As food taxonomic categorization does not take place
490 solely at a perceptual level (where items are classified according to their physical
491 resemblance), but rather at a conceptual level (where items are classified according to
492 functional or conceptual knowledge, with little perceptual resemblance between category
493 members; Rosch & Mervis, 1975; Tomikawa & Dodd, 1980), we can assume that the children
494 had not yet completely developed taxonomic categories within the food domain and mostly
495 used perceptual cues to categorize items.

496 Across the children, we did not observe a clear response bias toward one answer ("It's a
497 vegetable") rather than another ("It's a fruit"), as attested by a mean B'' of -0.06. Moreover
498 we failed to observe any changes with age: no difference in mean B'' between either the two
499 age groups (2-4 and 4-6 years) or the children and adult controls. As a consistent pattern was
500 found in adults and children, we can reasonably rule out the possibility that children's
501 responses in our study were elicited by the mere presence of the experimenter and social
502 desirability effects, as can be the case in studies with young children (Lavin & Hall, 2001).

503 **4.2 Is food rejection the behavioral consequence of an immature food categorization** 504 **system?**

505 Our findings showed that children's food rejection scores and sorting task performances were
506 significantly correlated (Pearson's correlation coefficient: $r = -0.27$, $p = .014$; see Fig. 3).
507 Further statistical analyses indicated that highly neophobic-picky children performed more
508 poorly than the other children on the sorting task (as attested by the retained model predicting
509 A' variation among children), suggesting that the children's level of food rejection partly

510 predicted their performance on the fruit and vegetable categorization task. From this
511 perspective, we could argue that food neophobia and pickiness acted as restraining factors on
512 food discriminability, that is to say, they behaved as dampers on the development of the food
513 categorization system. At a given age, strongly neophobic and picky children will thus have
514 poorer food category content than other children, because they do not accept new items in the
515 food category as easily and have fewer learning opportunities with food categories. Indeed
516 caregivers of children who display high food rejection tendencies, are often discouraged to
517 present fruit and vegetables to their children (Heath, Houston-Price & Kennedy, 2011),
518 leading to fewer experiences and it is known that children's categorization abilities differ as a
519 function of their experience (Chi, Hutchinson & Robin in 1989). This claim was supported by
520 the fact that neophobic-picky children performed the same as the younger children in terms of
521 hit and false alarm rates (mean hit and false alarm rates for neophobic-picky children: 0.76
522 and 0.41). Furthermore, the non-neophobic-picky children performed just as well as the older
523 children in terms of hit and false alarm rates (mean hit and false alarm rates for non-
524 neophobic-picky children: 0.77 and 0.31). These results were especially striking, given that
525 food rejection scores were not correlated with age.

526 Statistical analyses also revealed that children with a poor ability to distinguish between fruits
527 and vegetables (i.e., low A') tended to be more neophobic and picky than the children with
528 high discrimination abilities (as attested by the model predicting variations in food rejection
529 scores across children). This additional finding indicated that children's discrimination
530 abilities were predictive of their level of food rejection, thus supporting the premise that food
531 rejection is partly the behavioral consequence of an immature food categorization system
532 (Brown, 2010; Lafraire et al., 2016). This finding possibly accounts for the recognized
533 positive effect of visual food exposure on food rejection and attitudes towards food (Birch,
534 McPhee, Shoba, Pirok, & Steinberg, 1987; Birch & Fisher, 1998). Exposure would facilitate

535 the recognition process (Lafraire et al., 2016; Zajonc, 1968), by enriching food category
536 content and food prototypes and therefore reduces the probability that food items will not be
537 judged as food category members because they are not close enough to the food prototype.
538 Finally, we could be facing a vicious circle: food rejections seem to be the behavioral
539 consequences of a developing categorization system. Consequently, caregivers may be
540 discouraged to present fruit and vegetables to their children, leading to fewer learning
541 opportunities and to hinder the development of the food categorization system. Focusing on
542 conceptual development could then be an efficient manner to tackle food rejections behaviors
543 as demonstrated by a recent study from Grishover and Markmann (2013). Indeed, in their
544 research they compared usual educational programs about nutrition to a *knowledge based-*
545 *approach* nutritional education program (which provided children with a rich conceptual
546 framework about food) and found that, children who attended to the latter program ate more
547 vegetables at snack time.

548 However, contrasting with these promising results linking food rejection to categorization
549 development in children, scores on the food rejection scale were not correlated with their
550 binning behaviors, leading us to conclude that, contrary to parental reports, the food rejection
551 task was not a relevant measure for associating food rejection behaviors with sorting
552 performances. Two main reasons may explain this negative result. First, this task was often
553 regarded as a game by the children, as they were allowed to throw food away-a behavior
554 banned in the school canteen. Moreover, some of the comments made during this task by
555 nursery staff indicated that the children did not display their normal food rejection behaviors
556 (e.g., while one child was throwing away almost all the pictures into the garbage, a staff
557 member told the experimenter that this child usually ate nearly everything). Secondly another
558 reason to have some doubt regarding the reliability of the binning behaviors as an appraisal of
559 the food rejection behaviors is that, we assessed the predictive validity of the food rejection

560 questionnaire in a previous study (Rioux, et al. submitted) and found that caregivers were
561 relevant predictors of their children's behaviors toward foods.

562 **4.3 Is color important because it conveys information about the typicality of a given food** 563 **item?**

564 Our results replicated Macario's findings (1991) about the importance of color in food
565 categorization. Indeed, contrary to shape, color information was a salient variable predicting
566 the hit percent of a given vegetable (as attested by the model we retained predicting the
567 variation in the hit percentage across vegetables). Possibly explaining this result is that within
568 the food domain, shape usually changes across serving and recipes for a given food item,
569 while color is a more constant feature.

570 Results also indicated that colors are important in food categorization mainly because they
571 convey information on typicality. Indeed, among the children, color typicality was the most
572 salient variable predicting the hit percentage of a given vegetable (as attested by the model we
573 retained predicting the variation in the hit percentage across vegetables). Moreover, the effect
574 of color *per se* described above may also have been partly explained by typicality. Yellow,
575 pink and white vegetables were the least well recognized vegetables (i.e., lowest hit
576 percentages for these vegetables; see Appendix). Interestingly, in our vegetable sample
577 (carrots, tomatoes, eggplants, beetroots, bell peppers and zucchinis), white, pink and yellow
578 were the only colors that were never typical for a given vegetable (compared with dark green,
579 red or orange, for example, which were typical for zucchinis, tomatoes and carrots).

580 Concerning the color naming task, we did not replicate Macario's finding (1991, Exp. 3),
581 which associated children's ability to name colors with their discrimination of anomalously
582 colored objects, as we failed to find any significant correlations between color name
583 knowledge and sorting task performances across children. However, as even young children

584 were quite familiar with color names (mean color name knowledge for the youngest group of
585 children: 7/11), it was maybe not possible to distinguish between children on this basis.
586 Moreover, some comments made during this task by nursery staff indicated that the very
587 young children often did know almost every color they were shown, but were too shy or
588 intimidated by the experimenter to name them (it should be recalled that this was the only part
589 of the experiment where the children had to talk), thereby artificially lowering their color
590 knowledge scores.

591 **4.4 Conclusion and perspectives**

592 In conclusion, our results validated the three experimental hypotheses, by providing evidence
593 in favor of (i) an improvement in children's food categorization abilities from the age of 2-3
594 years, (ii) a negative correlation between food rejection and food categorization performances
595 in young children; and (iii) the central role of typicality in explaining the importance of color
596 in food categorization.

597 Nonetheless, our study had several limitations. First, we did not control for color preferences
598 or fruit/vegetable preferences, whereas Carey (2009) and Murphy (2002) pointed out that a
599 priori preferences for one of the categories tested in categorization task should be assessed.
600 Second, color typicality was assessed by an external sample of 10 adults, rather than by the
601 children themselves. In future, it would be worthwhile assessing children's preferences and
602 opinions about color typicality. When children are as young as 2 years, it is rather difficult to
603 ask them directly if they think that a color is typical for a given vegetable, as we did for
604 adults. It might therefore be helpful to implement a puppet procedure (e.g., Lavin & Hall,
605 2001), by asking children to describe a tomato to a puppet that does not know what it is, and
606 noting which colors the children use to describe it. Third, the blocks of food pictures
607 contained different numbers of typically and atypically colored food items, as we used real

608 fruit and vegetables for our stimulus sample and were therefore constrained by the availability
609 of fruit and vegetable varieties at the time of the experiment. It would thus be interesting to
610 balance typically and atypically colored food items more evenly in future experiments testing
611 this effect on children's food categorization.

612 Despite these limitations, we believe that the present experiment opened up promising new
613 avenues of research, and shed light on the cognitive mechanisms underlying different kinds of
614 food rejection (neophobia and pickiness), as well as on the central role of color in food
615 categorization processes. However these are only preliminary conclusions and more research
616 is needed to gain a better understanding of the mechanisms that come into play. For instance,
617 it will be of interest to investigate children categorization performances with other food
618 categories that are less prone to rejections (such as starchy foods) and investigate whether the
619 negative correlations between categorization performances and food rejections scores
620 continue to exist. Another line of research would be to investigate category-based induction in
621 children in relation to their level of food rejection. As it is often stated that "one important
622 function of categories is to allow inferences that extend beyond surface appearances"
623 (Gelman & O'Reilly, 1988, p. 876) and highly neophobic and picky children in our study
624 performed poorly on the food categorization task, category-based induction and food
625 rejections scores may as well be correlated. Finally, it would be worth exploring the effect of
626 visual food exposure (in an ecological setting such as a school canteen, where food rejection
627 behaviors are commonly observed) on pupils' attitudes towards foods in the light of the
628 present experiment's results. If food rejection acts as a damper on the development of the
629 food categorization system, and if exposure to food variety (foods differing in color, shape,
630 texture, etc.) enriches food category content and facilitates the recognition process (Lafraire et
631 al., 2016), highly neophobic-picky children with weak discriminability and recognition
632 abilities should greatly benefit from this type of exposure.

633 **Acknowledgments**

634 The authors would like to acknowledge the financial support they received from the Daniel
635 and Nina Carasso Foundation. We would also like to thank Thomas Arciszewski (PsyCLE
636 research center) for his help with the color photographs used in the study. We are also grateful
637 to the nursery staff, the children and their parents for their helpful collaboration. Finally, we
638 would like to thank E. Wiles-Portier who proofread our article.

639

640 **References**

- 641 Addressi, E., Galloway, A. T., Visalberghi, E., & Birch, L. L. (2005). Specific social
642 influences on the acceptance of novel foods in 2–5-year-old children. *Appetite*, *45*(3),
643 264-271.
- 644 Ahearn, W. H., Castine, T., Nault, K., & Green, G. (2001). An assessment of food acceptance
645 in children with autism or pervasive developmental disorder-not otherwise specified.
646 *Journal of Autism and Developmental Disorders*, *31*, 505-511.
- 647 Bandini L. G., Anderson S. E., Curtin C., Cermak S., Evans E. W., Scampini R., Maslin M.,
648 & Must A. (2010). Food selectivity in children with autism spectrum disorders and
649 typically developing children. *Journal of Pediatrics*, *157*(2), 259-264.
- 650 Barsalou, L. W. (1985). Ideals, central tendency, and frequency of instantiation as
651 determinants of graded structure in categories. *Journal of Experimental Psychology:*
652 *Learning, Memory, and Cognition*, *11*, 629-654.
- 653 Birch, L. L., & Fisher, J. O. (1998). Development of eating behaviors among children and
654 adolescents. *Pediatrics*, *101*(3), 539-549.
- 655 Birch, L. L., McPhee, L., Shoba, B. C., Pirok, E., & Steinberg, L. (1987). What kind of
656 exposure reduces children's food neophobia? Looking vs. tasting. *Appetite*, *9*(3),
657 171-178.
- 658 Bovet, D., Vauclair, J., & Blaye, A. (2005). Categorization and abstraction abilities in 3-year-
659 old children: A comparison with monkey data. *Animal Cognition*, *8*(1), 53-59.
- 660 Brown, S. D. (2010). *The rejection of known and previously accepted foods in early*
661 *childhood*. (Doctoral Dissertation). University of Birmingham Research Archive.

- 662 Carey, S. (2009). *The origin of concepts*. New York, NY: Oxford University Press.
- 663 Carruth, B. R., Skinner, J. D., Houck, K., Moran, J., Coletta, F., & Ott, D. (1998). The
664 phenomenon of “picky eater”: A behavioral marker in eating patterns of toddlers.
665 *Journal of the American College of Nutrition*, *17*, 180-186.
- 666 Cashdan, E. (1994). A sensitive period for learning. *Human Nature*, *5*(3), 279-291.
- 667 Cashdan, E. (1998). Adaptiveness of food learning and food aversions in children. *Social*
668 *Science Information*, *37*(4), 613-632.
- 669 Chi, M. T. H., Hutchinson, J., & Robin, A. F. (1989). How inferences about novel domain-
670 related concepts can be constrained by structured knowledge. *Merrill-Palmer Quarterly*,
671 *35*, 27–62
- 672 Chrea, C., Valentin, D., Sulmont-Rossé, C., Hoang Nguyen, D., & Abdi, H. (2005). Odeurs et
673 catégorisation: Notre représentation mentale des odeurs est-elle universelle ou
674 dépendante de notre culture ? *Actes de la 3ème Journée du Sensolier, Paris*.
- 675 Cooke, L., Wardle, J., & Gibson, E. L. (2003). Relationship between parental report of food
676 neophobia and everyday food consumption in 2–6-year-old children. *Appetite*, *41*(2),
677 205–206.
- 678 Cosmides, L., Tooby, J., & Barkow, J. H. (1992). Introduction: Evolutionary psychology and
679 conceptual integration. In L. Cosmides, J. Tooby, & J. H. Barkow (Eds.), *The adapted*
680 *mind* (pp. 3-15). Oxford: Oxford University Press.
- 681 Dawkins, R. (1976). *The selfish gene*. Oxford: Oxford University Press.
- 682 Dovey, T. M., Staples, P. A., Gibson, E. L., & Halford, J. C. G. (2008). Food neophobia and
683 “picky/fussy” eating in children: A review. *Appetite*, *50*(2-3), 181-193.

684 Falciglia, G. A., Couch, S. C., Gribble, L. S., Pabst, S. M., & Frank, R. (2000). Food
685 neophobia in childhood affects dietary variety. *Journal of the American Dietetic*
686 *Association, 100*(2), 1474-1481.

687 Fodor, J. A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.

688 Frith, U., & Happé, F. (1994) Autism: Beyond “theory of mind”. *Cognition, 50*, 115-132.

689 Gelman, S. A., & O’Reilly, A. W. (1988). Children’s inductive inferences within
690 superordinate categories: The role of language and category structure. *Child*
691 *Development, 59*, 876–887.

692 Gerrish, C. J., & Mennella, J. A. (2001). Flavor variety enhances food acceptance in formula-
693 fed infants. *The American Journal of Clinical Nutrition, 73*, 1080-1085.

694 Grier, J. B. (1971). Nonparametric indexes for sensitivity and bias: Computing formulas.
695 *Psychological Bulletin, 75*, 424-429.

696 Gripshover, S. J., & Markman, E. M. (2013). Teaching young children a theory of nutrition
697 conceptual change and the potential for increased vegetable consumption.
698 *Psychological Science, 24*(8), 1541–1553.

699 Harris, G. (1993). Introducing the infant’s first solid food. *British Food Journal, 95*(9), 7-10.

700 Hayes, B. K., & Taplin, J. E. (1993). Developmental differences in the use of prototype and
701 exemplar-specific information. *Journal of Experimental Child Psychology, 55*, 329-352.

702 Heath, P., Houston-Price, C., & Kennedy, O. (2011). Increasing food familiarity without the
703 tears: a role for visual exposure? *Appetite 57*, 832–838.

704 Hu, S. (2007). Akaike information criterion. Retrieved from
705 <http://www4.ncsu.edu/~shu3/Presentation/AIC.pdf>

706 Koivisto, U. K., & Sjöden, P. O. (1996). Food and general neophobia in Swedish families:
707 Parent–child comparisons and relationships with serving specific foods. *Appetite*, *26*,
708 107–118.

709 Lafraire, J., Rioux, C., Giboreau, A., & Picard, D. (2016). Food rejections in children:
710 Cognitive and social/environmental factors involved in food neophobia and picky/fussy
711 eating behavior. *Appetite*, *96*, 347-357.

712 Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical
713 learning. *Cognitive Development*, *3*, 299-321.

714 Lavin, T. A., & Hall, D. G. (2001). Domain effects in lexical development: Learning words
715 for foods and toys. *Cognitive Development*, *16*(4), 929-950.

716 Lockner, D. W., Crowe, T. K., & Skipper, B. J. (2008). Dietary intake and parents' perception
717 of mealtime behaviors in preschool-age children with autism spectrum disorder and in
718 typically developing children. *Journal of the American Dietetics Association*, *108*,
719 1360-1363.

720 Lumeng, J. C. (2013). Food as a unique domain of social cognition. In M. R. Banaji & S. A.
721 Gelman (Eds.), *Navigating the social world* (pp. 245-249). Oxford University Press.

722 Macario, J. F. (1991). Young children's use of color in classification: Foods and canonically
723 colored objects. *Cognitive Development*, *6*(1), 17-46.

724 MacMillan, N. A., & Creelman, C. D. (2005). *Detection theory: a user's guide (second*
725 *edition)*.

726 Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive*
727 *Development*, *8*, 291-318. London : Lawrence Erlbaum associates Press.

728 Mennella, J. A., Nicklaus, S., Jagolino, A. L., & Yourshaw, L. M. (2008). Variety is the spice
729 of life: Strategies for promoting fruit and vegetable acceptance during infancy.

730 *Physiology and Behavior*, 94(1), 29-38.

731 Mervis, C. B., & Pani, J. R. (1980). Acquisition of basic object categories. *Cognitive*
732 *Psychology*, 12, 496-522.

733 Murphy, G. L. (2002). *The big book of concepts*. Cambridge: MIT Press.

734 Nguyen, S. P., & Murphy, G. L. (2003). An apple is more than just a fruit: Cross-
735 classification in children's concepts. *Child Development*, 74(6), 1783-1806.

736 Ozonoff, S., Pennington, B., & Rogers, S. J. (2015). Executive function deficits in high-
737 functioning autistic individuals: Relationship to theory of mind. *Journal of Child*
738 *Psychology and Psychiatry*, 32(7), 1081-1105.

739 Pliner, P., & Hobden, K. (1992). Development of a scale to measure the trait of food
740 neophobia in humans. *Appetite*, 19(2), 105-120.

741 Pliner, P., Pelchat, M., & Grabski, M. (1993). Reduction of neophobia in humans by exposure
742 to novel foods. *Appetite*, 20, 111-123.

743 Postorino, V., Sanges, V., Giovagnoli, G., Fatta, L. M., De Peppo, L., Armando, M., ...
744 Mazzone, L. (2015). Clinical differences in children with autism spectrum disorder with
745 and without food selectivity. *Appetite*, 92, 126-132.

746 Rioux, C., Lafraire, L., & Picard, D. (submitted). Development and validation of a new scale
747 to assess food neophobia and pickiness among 2- to 7-years old French children.

748 Rochedy, A., & Poulain, J.-P. (2015). Approche sociologique des néophobies alimentaires
749 chez l'enfant. *Dialogue*, 209, 55-68.

750 Rosch, E., & Mervis, C. B. (1975). Family resemblance: Studies in the internal structure of
751 categories. *Cognitive Psychology*, 7, 573-605.

752 Ross, B. H., & Murphy, G. L. (1999). Food for thought: Cross-classification and category
753 organization in a complex real-world domain. *Cognitive Psychology*, 38, 495-553.

754 Rozin, P. (1976). The selection of food by rats, humans and other animals. In J. S. Rosenblatt,
755 R. A. Hinde, E. Shaw, & C. Beers (Eds.), *Advances in the study of behavior* (pp 21-76).
756 New York: Academic Press.

757 Rozin, P. (1977). The use of characteristic flavorings in human culinary practice. In C. M.
758 Apt (Ed.), *Flavor: Its chemical, behavioural, and commercial aspects* (pp. 101-127).
759 Boulder, CO: Westview Press.

760 Rydell, A.-M., Dahl, M., & Sundelin, C. (1995). Characteristics of school children who are
761 choosy eaters. *The Journal of Genetic Psychology: Research and Theory on Human*
762 *Development*, 156(2), 217-299.

763 Shutts, K., Condry, K. F., Santos, L. R., & Spelke, E. S. (2009). Core knowledge and its
764 limits: The domain of food. *Cognition*, 112(1), 120-140.

765 Shutts, K., Kinzler, K. D., McKee, C. B., & Spelke, E. S. (2009). Social information guides
766 infants' selection of foods. *Journal of Cognition and Development*, 10, 1-17.

767 Shutts, K., Kinzler, K. D., & DeJesus, J. M. (2013). Understanding infants' and children's
768 social learning about foods: previous research and new prospects. *Developmental*
769 *Psychology*, 49(3), 419-425.

770 Smith, E. E., & Medin, D. L. (1981). *Categories and concepts*. Cambridge, MA: Harvard
771 University Press.

772 Smith, A. M., Roux, S., Naidoo, N. T., & Venter, D. J. L. (2005). Food choices of tactile
773 defensive children. *Nutrition*, 21(1), 14-19.

774 Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures.
775 *Behavior Research Methods, Instruments, & Computers*, *31*, 137-149.

776 Stough, C. O., Gillette, M. L. D., Roberts, M., C., Jorgensen, T. D., & Patton, S. R. (2015).
777 Mealtime behaviors associated with consumption of unfamiliar foods by young children
778 with autism spectrum disorder. *Appetite*, *95*, 324-333.

779 Taylor, C. M., Wernimont, S. M., Northstone, K., & Emmet, P. M. (2015) Picky/fussy eating
780 in children: Review of definitions, assessment, prevalence and dietary intakes. *Appetite*,
781 *95*, 349-359.

782 Tomikawa, S. A., & Dodd, D. H. (1980). Early word meanings: Perceptually or functionally
783 based? *Child Development*, *51*, 1103-1109.

784 Vauclair, J. (2004). *Développement du jeune enfant : Motricité, perception, cognition*. Paris:
785 Belin.

786 Wertz, A. E., & Wynn, K. (2014a). Thyme to touch: Infants possess strategies that protect
787 them from dangers posed by plants. *Cognition*, *130*(1), 44-49.













788 Wertz, A. E., & Wynn, K. (2014b). Selective social learning of plant edibility in 6- and 18-
789 month-old infants. *Psychological Science*, *25*(4), 874-882.

790 Yoshida, H., & Smith L. B. (2003). Known and novel noun extensions: Attention at two
791 levels of abstraction. *Child Development*, *74*(2), 564-577.

792 Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social*
793 *Psychology*, *9*(2), 1-27.

Appendix . Color photographs of the 36 pictures and hit or false alarm rate for each of them.

Hit rates concern the vegetable pictures and false alarm rates concern the fruit pictures.

Block A			
<p>Dark purple carrot Hit rate : 71.4</p> 	<p>Orange carrot Hit rate : 92.5</p> 	<p>Orange carrot Hit rate : 80.3</p> 	<p>Yellow carrot Hit rate : 58.9</p> 
<p>Orange bell pepper Hit rate : 67.8</p> 	<p>Yellow bell pepper Hit rate : 64.2</p> 	<p>Red bell pepper Hit rate : 82.1</p> 	<p>Dark green bell pepper Hit rate 80.3</p> 
<p>Light green pear False alarm rate : 58.9</p> 	<p>Red pear False alarm rate : 44.6</p> 	<p>Brown pear False alarm rate : 44.6</p> 	<p>Yellow pear : False alarm rate : 39.3</p> 

Block B

Light green eggplant
Hit rate : 81.1



Light purple eggplant
Hit rate : 75.5



Dark purple eggplant
Hit rate : 83.0



White eggplant
Hit rate : 67.9



Yellow zucchini
Hit rate : 64.1



Dark green Zucchini
Hit rate : 83.0



Light green zucchini
Hit rate : 71.7



Dark green zucchini
Hit rate : 83.0



Red apple
False alarm rate : 13.2



Brown apple
False alarm rate : 17.0














Yellow apple
False alarm rate : 30.2



Light green apple
False alarm rate : 35.8



Block C

<p>Red tomato Hit rate : 89.8</p> 	<p>Dark red tomato Hit rate : 77.5</p> 	<p>Light green tomato Hit rate : 73.5</p> 	<p>Yellow tomato Hit rate : 57.1</p> 
<p>Pink beetroot Hit rate : 63.2</p> 	<p>White beetroot Hit rate : 73.5</p> 	<p>Yellow beetroot Hit rate : 67.3</p> 	<p>Dark purple beetroot Hit rate : 77.5</p> 
<p>Yellow lemon False alarm : 32.5</p> 	<p>Dark green lime False alarm : 71.4</p> 	<p>Red grapefruit False alarm rate : 30.6</p> 	<p>Orange False alarm : 20.4</p> 