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1 **Food rejections in children: Cognitive and social/environmental**
2 **factors involved in food neophobia and picky/fussy eating behavior**

3

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5

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8

9 Abstract

10

11 Food neophobia and picky/fussy eating behavior are presented as the two main forms of
12 children's food rejections responsible for a reduction of their dietary repertoire. We review
13 the key factors, presented in the literature, that are involved in food rejections during
14 childhood. We first consider a range of "cognitive factors", such as food perception, mental
15 representations, categorization of food items, and emotions and feelings toward food. We then
16 focus on "social and environmental factors", as these might also significantly influence and
17 modulate children's food rejections. We then summarize the findings to provide a
18 comprehensive view of the factors involved in children's food rejections. Finally, we discuss
19 the need for future studies on food rejections, regarding (i) the distinction between food
20 neophobia and picky/fussy eating, and (ii) the potential link between food categorization
21 abilities and children's food neophobia and pickiness.

22

23 Keywords: Children; Food rejection; Food neophobia; "Picky/fussy" eating; Cognitive and
24 social factors.

25

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27

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47 **Introduction**

48

49 Food neophobia and picky/fussy eating behavior are presented as the two main forms of food
50 rejections in children, and mostly concern the rejection of healthy items like fruits and
51 vegetables (Brown, 2010; Cashdan, 1998; Carruth, Skinner, Houck, Moran, Coletta, & Ott,
52 1998; Jacobi *et al.*, 2003). Therefore they are responsible for the reduction of the child's
53 dietary variety (Birch & Fisher, 1998; Falciglia, Couch, Gribble, Pabst, & Frank, 2000), along
54 with a possible lack of essential micro-nutriments and fibers that are necessary for normal and
55 healthy child development (Carruth *et al.*, 1998).

56 A recent research review by Dovey, Staples, Gibson, and Halford (2008) provided an
57 interesting and comprehensive understanding of the concepts of food neophobia and
58 picky/fussy eating and how they affect children's dietary repertoire. However, despite
59 extensive research in the area, the mechanisms underlying these two types of food rejection in
60 children are still unclear, as the main factors influencing food rejection have not been clearly
61 identified yet. Our aim is to review a range of research studies on food neophobia and
62 picky/fussy eating so as to point to a series of factors that play a key role in food rejections in
63 childhood. Accordingly, and unlike previous available research reviews, we emphasize the
64 "cognitive factors" underlying food rejections in children. We use the notion of "cognitive
65 factors" in the broad sense of the term, that is to say we include the following: food
66 perception, mental representations and categorizations of food items, and emotions and
67 feelings toward food. We also include a range of "social and environmental factors" as they
68 might also significantly influence and modulate children's food rejections. To that end, a
69 search of published research papers on children's food rejections was conducted using the
70 ScienceDirect, PubMed, and JSTOR databases. We used a combination of keywords to
71 compile peer-reviewed articles on the two constructs of interest (food neophobia and
72 picky/fussy eating), and on the factors that influence these behaviors. Accordingly, "food
73 neophobia", "picky-fussy eating", "food aversion", and "food rejection" were used jointly
74 with "infants", "toddlers", and "children" as keywords, to circumscribe our research within
75 the sensitive period of food neophobia (i.e., from 18 months to six years of age; see Cashdan,
76 1994). We additionally included studies on adults and nonhuman primates when they
77 potentially revealed interesting aspects of food rejections.

78 We start with a brief summary of food neophobia and picky/fussy eating behavior
79 regarding their definitions, measure assessments, developmental trends, and negative
80 consequences on children's dietary repertoire. We then review a range of cognitive factors

81 that potentially influence and explain food rejections in children. In the subsequent section we
82 review social and environmental factors that may affect and modulate food rejections in
83 children. We then summarize the findings to provide a comprehensive view of the factors
84 involved in children's food rejections. We conclude by suggesting new lines of research.

85

86 **Food neophobia and picky/fussy eating behavior in children**

87

88 *Definitions*

89 Food neophobia is defined as the reluctance to eat, or the avoidance of, new foods (Dovey et
90 al., 2008). This behavior is present among omnivorous species (Adessi, Galloway,
91 Visalberghi & Birch, 2005), and is considered an efficient adaptive strategy to avoid the risk
92 of ingesting novel (unknown) and potentially poisonous items (see Milton, 1993; Rozin,
93 1977, 1979). Whether or not food neophobia is a true phobia is an important question. The
94 literature provides some good reasons to think it is. For instance, it has been shown food
95 neophobia is associated with physiological responses reflecting fear toward novel foods
96 (Raudenbush & Capiola, 2012). Moreover, the fact that the same techniques have been used to
97 treat food neophobia and other phobias (Marcontell, Laster, & Johnson, 2003; Nicholls,
98 Christie, Randall, & Lask, 2001; Singer, Ambuel, Wade, & Jaffe, 1992) also suggests that
99 food neophobia actually belongs to the latter category.

100 Picky/fussy eating is defined as the rejection of a substantial number of foods that are
101 familiar (as well as unfamiliar) to the children (Birch, Johnson, Andresen, Peters, 1991;
102 Galloway, Fiorito, Lee, & Birch, 2005; Smith, Roux, Naidoo, & Venter, 2005; Story &
103 Brown, 1987). Picky/fussy eating may also include the consumption of an inadequate amount
104 of food (Rydell, Dahl, & Sundelin, 1995), or the rejection of certain food textures (Smith *et*
105 *al.*, 2005).

106 Another distinction between food neophobia and picky/fussy eating is based on the
107 point of rejection of the food itself: unlike food neophobia, picky/fussy eating does not occur
108 only before the tasting step, it may also occur after tasting is realized (Brown, 2010).

109 Since food neophobia is defined roughly as the rejection of novel or unknown food
110 whereas picky/fussy eating is the rejection of a large proportion of familiar as well as
111 unfamiliar foods, food neophobia is sometimes considered a subset of picky/fussy eating
112 (Dovey *et al.*, 2008; Potts & Wardle, 1998; Raudenbush, van der Klaauw, & Frank, 1995). In
113 their review, Dovey *et al.* (2008) assumed that the two phenomena are behaviorally distinct
114 (Pelchat & Pliner, 1986; Pliner & Hobden, 1992), because different factors predict the

115 severity and expression of the two constructs (Galloway, Lee, & Birch, 2003; Raudenbush *et*
116 *al.*, 1995; Potts & Wardle, 1998). However, other authors argue that these two constructs are
117 clearly related (Potts & Wardle, 1998; Raudenbush *et al.*, 1995; Wardle & Cooke, 2008).
118 There is no decisive empirical evidence in favor of a robust sharp distinction between food
119 neophobia and picky/fussy eating. From a theoretical point of view, the definitions of these
120 constructs are ambiguous in that they both depend on an unanalyzed (and viewpoint-
121 dependent) notion of familiarity.

122

123 *Assessment of measures*

124 Food neophobia is usually measured by The Food Neophobia Scale (FNS) designed by Pliner
125 and Hobden (1992).. Originally designed to score adults' neophobia, the FNS was then
126 adapted to measure children's neophobia (Children Food Neophobia Scale, CFNS; Pliner,
127 1994). These measurement tools have successfully been used to predict Anglophone
128 responders' attitudes toward new foods and have been translated into other languages, such as
129 French (Ton Nu, MacLeaod, & Barthelemy, 1996; Nicklaus, Boggio, Chabanet, & Issanchou,
130 2005), Spanish (Fernandez-Ruiz, Claret, & Chaya, 2013), and Italian (Laureati, Bergamaschi,
131 & Pagliarini, 2015). In addition, because food neophobia concerns mainly fruits and
132 vegetables, Hollar and colleagues have recently adapted Pliner's work to investigate
133 responders' attitudes toward these specific items (the Fruit and Vegetable Neophobia
134 Instrument, FVNI; Hollar, Paxton-Aiken, & Fleming, 2013).

135 In most studies using Pliner's scales (or adapted versions), parents were asked to
136 complete the questionnaire to assess their child's food neophobia. This hetero-assessment
137 raises several well-known difficulties which lead to the development of auto-assessment
138 questionnaires, for instance The Food Situations Questionnaire (FSQ) designed for 7- to 12-
139 year-old Anglophone children Pliner (2000). Since this first attempt, two other questionnaires
140 suitable for children have been developed, one in France (Reverdy, Chesnel, Sclich, Kôster, &
141 Lange, 2008; Rubio, Rigal, Boireau-Ducept, Mallet, & Meyer, 2008), and the other in Italy
142 (Laureati, Bergamaschi, & Pagliarini, 2014).

143 Concerning picky/fussiness, not much attention has been dedicated to its
144 measurement. To date, this construct is usually assessed through general questionnaires on
145 food habits, which include scales that measure problematic eating, fussiness, food neophobia,
146 low enjoyment when eating, among others. Noticeable questionnaires are The Child Eating
147 Questionnaire (see Birch, Fischer, Grimm-Thomas, Markey, Sawyer, & Johnson, 2001;
148 Tharner *et al.*, 2014), The Child Eating Behavior Questionnaire (see Wardle, Guthrie,

149 Sanderson, & Rapoport, 2001), and The Children's Eating Difficulties Questionnaire (see
150 Rigal, Chabanet, Issanchou, & Monnery-Patris, 2012). Other authors have recorded
151 picky/fussiness by simply asking parents whether or not their children are picky (Carruth,
152 Ziegler, Gordon, & Barr, 2004; Jacobi, Agras, Bryson, & Hammer, 2003; Jacobi, Schmitz, &
153 Agras, 2008). These disparate methods may have added to the inconsistent understanding of
154 this construct. Clearly, there is a need for a more applicable, validated, and homogenous
155 picky/fussiness assessment method.

156

157 ***Developmental trends***

158 Both food neophobia and picky/fussy eating are age-related and temporary behaviors, but
159 according to some authors each follows a specific developmental path (Dovey *et al.*, 2008;
160 McFarlane & Pliner, 1997).

161 On the one hand, neophobic behavior increases as a child becomes mobile, and peaks
162 between 2 and 6 years of age (Addressi *et al.*, 2005; Cashdan, 1994; Cooke, Wardle, &
163 Gibson, 2003; Harper & Sanders, 1975). After that period, the expression of food neophobia
164 decreases (Koivisto-Hursti & Sjöden, 1997), until it reaches a relatively stable plateau in
165 adulthood (McFarlane & Pliner, 1997). According to some authors, there is a general decrease
166 until early adulthood (Koivisto-Hursti & Sjöden, 1996; Raynor & Epstein, 2001; Rigal,
167 Frelut, Monneuse, & Hladik, 2006). From an evolutionary point of view, one plausible
168 hypothesis is that food neophobia attenuates because dietary variety is essential to the survival
169 of omnivorous species. But some studies suggest that the neophobic behavior remains stable
170 from adolescence (13 years old) until adulthood (Nicklaus *et al.*, 2005). Note that the decline
171 in food neophobia implies overcoming the fear induced by the presentation of a novel food
172 item. Therefore, the mere fact that fewer things are novel for an adult or an adolescent than
173 for a child, automatically reduces the gradient at which food neophobia disappears (Cooke &
174 Wardle, 2005).

175

176 On the other hand, picky/fussy eating increases during infancy. Overall, 19% of 4- to 6
177 month-old infants were judged to be picky by their mothers whereas this percentage rises to
178 50% in the 19- to 24-month-old children (Carruth *et al.*, 2004). The prevalence of this
179 behavior was shown to remain relatively stable during early childhood from 2.5 to 4.5 years
180 of age (Dubois, Farmer, Girard, Peterson, & Tatone-Tokuda, 2007). The precise
181 developmental path of picky/fussy eating is however unknown and a variety of factors may
182 bias the understanding of it (Dovey *et al.*, 2008; Wardle, Herrera, Cooke, & Gibson, 2003). A

183 recent longitudinal study by Mascola, Bryson and Agras (2010) showed that the highest
184 incidence of picky/fussy eating occurs in early childhood (at around 2 years), and declines to
185 very low levels by the age of 6 years.

186

187

188 **Cognitive factors involved in children's food rejections**

189

190 In this section we review research studies on the potential cognitive mechanisms that underlie
191 food rejections during the sensitive period of food neophobia and picky/fussy eating. We use
192 “cognition” in the broad sense of the term, that is to say we included any kind of operations
193 on mental representations, understood as theoretical or concrete entities whose role is to
194 convey information coming from the world. Within this framework, we incorporated the
195 following: i) how information (food) is perceived; ii) how information is internally
196 represented and categorized; and iii) how emotions and feelings accompany and affect food
197 processing. Indeed, as stressed by Marcel Proust, cognition is often colored by various
198 feelings and emotions in the food domain (Damasio, 2005).

199

200 ***Food perception mechanisms***

201 A variety of perceptual cues contribute to the visual evaluation of food (Wadhera & Capaldi-
202 Phillips, 2014). These cues have a key role in food rejection mechanisms, as food rejections in
203 toddlers primarily occur on sight.

204 It has been shown that vision is more important than touch in the process of sensory
205 decision making in children, unlike adults who use touch more than vision (Dovey, Aldridge,
206 Dignan, Staples, Gibson, & Halford, 2012). Indeed, children generally use color rather than
207 shape to classify novel food items whereas they use shape rather than color to classify novel
208 items if they think the novel items are something to play with (Macario, 1991). It is plausible
209 that food behavior depends partly on preferences for certain colors in the food domain. For
210 instance, green vegetables are more often rejected (Harris, 1993), and their acceptance is
211 difficult to foster (Mennella, Nicklaus, Jagolino, & Yourshaw, 2008) compared to orange
212 vegetables (Gerrish & Mennella, 2001). Some research suggests that toddlers have a
213 hypothesis about the predictive validity of color in the food domain (Macario, 1991).

214 The visual presentation of the novel food is obviously important. The consumption of
215 a novel fruit can be promoted through a visually appealing presentation (Jansen, Mulkens, &
216 Jansen, 2010). Children from 5 to 12 years of age also have a clear preference for a variety of

217 food items, a variety of colors, and space between items on their plates more than adults
218 do(Zampollo, Kniffin, Wansink, & Shimizu, 2012), and for having their vegetables cut into
219 geometric shapes at 9-12 years (Olsen, Ritz, Kramer, & Møller, 2012). Moreover,some
220 aspects of the mode of presentation of the food affect children’s food behavior, maybe by
221 helping the child to identify the food items. This hypothesis is consistent with the fact that
222 picky/fussy children are less likely to consume dishes that were mixed together and thus
223 harder to identify (Carruth *et al.*, 2004), and with parents’ reports according to which children
224 like “food where all of the ingredients are without sauce and easily identifiable” (Cashdan,
225 1998, p.623).

226 Beyond color, it has been shown that children are sensitive to local changes such as
227 food containing “bits” or pips (Wardle & Cooke, 2008. For instance, Werthmann and
228 colleagues (2015) manipulated the color, the texture and the taste of yoghurts offered to the
229 children. In that context, they observed that lumpy texture influenced yoghurt acceptance
230 understood as the number of spoons the children consumed. More generally, one sensory cue
231 that can elicit food rejection, through disgust before tasting, is visually perceived texture
232 (Martins & Pliner, 2006). For instance, evidence suggests that a texture fading strategy, a
233 gradual addition of higher textures based on the result of periodic probes, can be effective to
234 treat food selectivity in toddlers (Johnson & Babbitt, 1993; Shore, Babbitt, Williams, Coe, &
235 Snyder, 1998).

236 Regarding olfaction, some research studies mention that neophobic young adults rated
237 the odors of foods as less pleasant and sniffed them less vigorously (Raudenbush, Schroth,
238 Reilley, & Frank, 1998). They also have weaker odor identification abilities (Demattè *et al.*,
239 2013) than neophilic young adults. However, to our knowledge, in young children only a
240 difference in sniffing proximity has been found (Bunce & Gibson, 2012).

241 However,the large majority of sensory preferences above-mentioned are not innate
242 (Desor, Maller, & Turner, 1973; Harris, Thomas, & Booth, 1990; Rosenstein & Oster, 1988).
243 Rather, most of our food choices are learned through exposure (Birch, Gunder, Grimm-
244 Thomas, & Laing, 1998; Birch & Marlin, 1982; Birch, Mcphee, Shoba, Pirok, & Steinberg,
245 1987; Nicklaus *et al.*, 2005; Pliner, 1982; Wardle *et al.*, 2003).The following paragraphs are
246 devoted to review the different forms of exposure influencing food preferences and
247 acceptance.

248 It has been shown that visual exposure during infancy increases the appeal of a target food
249 and of food items similar to the target (Birch *et al.*, 1998), thereby reducing food neophobia
250 (Birch *et al.*, 1987). Similarly, the early introduction of a variety of solid foods was shown to

251 foster the child's acceptance of solid foods (Gerrish & Mennella, 2001; Mennella *et al.*,
252 2008). Interestingly, the effect was strengthened when a variety of foods was presented both
253 within meals and between meals (Mennella *et al.*, 2008).

254 Some data suggested that up to 15 positive experiences may be needed for the
255 successful acceptance of a target food into the child's dietary repertoire (Birch *et al.*, 1987;
256 Wardle, Carnell, & Cooke, 2005; Wardle *et al.*, 2003). Interestingly, the number of exposures
257 to reach food acceptance is also age-dependent. During the first year of life a single positive
258 exposure can lead to the acceptance of the novel item (Birch *et al.*, 1998). This interaction
259 with novel food items may result in a different habitual diet (Skinner & Carruth, 2002).
260 However, exposure effects are limited. For instance, while visual exposure produces enhanced
261 visual preference judgments, it does not produce enhanced taste preferences (Birch *et al.*,
262 1987). Thus, exposure to food in one particular modality will produce a change in preference
263 within that modality only (Birch *et al.*, 1987). Moreover, the effect of early exposure to foods
264 does not generalize since repeated exposure to fruits does not vegetables at least in very young
265 children from 4 to 7 months of age (Birch *et al.*, 1998). Even in the same category (i.e.,
266 vegetables), repeated exposure to one item (pureed potatoes) does not promote acceptance of
267 other items belonging to the same category (carrots) (Mennella *et al.*, 2008).

268 Despite evidence that repeated exposure may increase acceptance of a target food, two
269 potential problems may occur. The first one is "sensory specific satiation", or the reduction of
270 a food's hedonic value after consumption (Rolls, 1986; Temple, Chappel, Shalik, Volcy, &
271 Epstein, 2008). The effect can lead to food rejection in infancy (Mennella & Beauchamp,
272 1999) and early childhood (Birch & Deysher, 1986). Interestingly, consumption is not even
273 necessarily required to produce a reduction in reported liking. Indeed, the sensory specific
274 satiety can be olfactory (Rolls & Rolls, 1997). The second problem is "monotony" (Rozin &
275 Vollmecke, 1986), through which a prolonged access to a small number of unchanging foods
276 produces lower rating of liking. For instance, it has been shown that while exposure decreases
277 children's willingness to taste familiar¹ vegetables, it increased their willingness to taste
278 unfamiliar fruits (Houston-Price, Butler, & Shiba, 2009). Research studies have also
279 highlighted a decline in pleasantness of the appearance of eaten foods relative to uneaten
280 foods, a phenomenon called appearance-specific satiety (Wadhera & Capaldi-Phillips, 2014).

¹ In that study, familiarity with a food stimulus is determined on the basis of the frequency of encounter with the food item reported by the parents. "Unfamiliar" means encountered less than once per month according to the parents answers to the Food Familiarity Questionnaire.

281 In spite of these qualifications, the positive effect of repeated exposure on preferences
282 and attitudes toward food is a now matter of consensus. However, the exact nature of the
283 mechanisms underlying exposure remains unclear. The standard view is that the missing link
284 between exposure and positive effects on preferences is a certain feeling of
285 recognition/familiarity (Tichener, 1910 quoted in Zajonc & Markus, 1982). Recognition (as
286 well as categorization) decisions “(...) involve similarity computations performed on a
287 common representational substrate, namely collection of individual exemplars.” (Nosofsky,
288 1992, p. 392). Our hypothesis in line with Tichener’s thought is that exposure enriches that
289 “collection” which in turn has positive effects on food preferences and behavior.

290

291 ***Mental representations and categorization of food items***

292 If exposure does affect positively food preferences and behavior in young children
293 (and thereby is a psychological lever to overcome food rejections) because it facilitates a
294 particular type of recognition process, it is likely that food rejections could, on the contrary,
295 be associated with a certain type of recognition deficiency. To assess this hypothesis, we
296 review the recent results on the development of categorization abilities in young children. On
297 the basis of these results, we argue that the developmental characteristics of the categorization
298 system might contribute to an explanation of food rejections. Research on food categorization
299 and mental representations in humans has shown that before 2 years of age, infants show very
300 limited ability to differentiate food and non-food items based on their relevant visual
301 properties. For instance, 9-month-old infants were shown to equally direct their attention to
302 domain-relevant properties, such as color and texture, and domain-irrelevant properties (such
303 as the shape of the food’s container) (Shutts, Condry, Santos, & Spelke, 2009). Between 16
304 and 29 months of age, more than half of the children were willing to put crayons, dish soaps,
305 and even imitation feces in their mouth (Rozin, Hammer, Oster, Horowitz, & Marmora,
306 1986). Also, children under 2 years were more likely to accidentally poison themselves than
307 older peers (Cashdan, 1994). This surprisingly indiscriminate behavior in infants might be
308 attributed to the fact that human infants rely on adults to guide their eating until 2 years of age
309 (Cashdan, 1994, 1998). Accordingly, infants may learn about food through observing others’
310 behavior, actions, and emotions, rather than by evaluating and classifying foods solely on the
311 basis of relevant perceptual properties.

312 However, a rapid change occurs between 2 and 3 years of age, when children begin to
313 categorize and reason about food items. At around 3 years of age, children were shown to
314 generalize learned knowledge about novel foods according to color, texture, and odor

315 information, whereas they generalized learned knowledge (including linguistic knowledge²)
316 about novel artifacts according to shape (Lavin & Hall, 2001; Macario, 1991; Santos, Hauser,
317 & Spelke, 2002). Namely, 3- and 4-year-old children were more disposed to use color than
318 shape to classify novel items when they think the items are something to eat.

319 A research study by Nguyen and Murphy (2003) showed that 3-year-old children have
320 taxonomic and script categories for food. Taxonomic categories are organized into hierarchies
321 of increasingly abstract categories, such as terrier-dog-mammal-animal, and are based on
322 common properties or similarity. Script categories are formed when items play the same role
323 in a schema for a routine event (e.g., eggs and cereal are both in the script category of
324 breakfast foods). From age 4, children are able to cross-classify items, meaning they can
325 subsume a food item under both taxonomic and script categories (Nguyen & Murphy, 2003).

326 It has been claimed that the rapidity with which children (3-year-olds) as well as
327 baboons and chimpanzees are able to categorize, in particular in the food domain, is “likely to
328 result from the early construction of a food category, because of its importance in their daily
329 life” (Bovet, Vauclair, & Blaye, 2005, p. 57). Food neophobia peaks around 2-3 years of age,
330 that is to say precisely the period during which a food categorization system starts developing
331 in the child’s cognition. From this perspective, Dovey *et al.* (2008) suggested that “children
332 build up schemata of how an acceptable food should look, and perhaps smell, and so foods
333 not sufficiently close to this stimulus set will be rejected” (p. 183). Similarly, Brown (2010)
334 suggested that some foods are rejected on sight because they do not match a prototypical
335 representation³ or category of food in children’s cognition.

336

337 *Emotions and feelings about food*

338 Emotions and feelings about food are intimately associated with food rejections (MacNicol,
339 Murray, & Austin, 2003). Among negative emotions, disgust has been related to food

² In an experiment conducted by Lavin & Hall (2001), 3 years old children were taught a neutral word “X” referring to an unfamiliar object. The object was either described as being a toy or a food. Then the experimenters ask the subjects to extend the word “X” to one of two other objects. One object differed in shape with the initial object, the other object differed in color, texture or smell. The results reveal that children were more likely to select the same-shaped entity only when the initial object was described as being a toy.

³ The three competing views about categories are the exemplar, the prototype, the knowledge theories (see Murphy, 2002). At the end of the previous section on the perceptive mechanisms, we quoted Nosofsky (1992) who seems to endorse the exemplar theory. By contrast, we now mention Dovey (2008) and Brown (2010) respectively using the notions of schemata and prototypes which have a prototype theory flavour. We will not cut the Gordian knot in the present review because it seems that we are still in need of a precise and reliable method to “gain a window on the exact nature of children’s conceptual representations.” (Murphy, *Ibidem*, p. 383). Moreover, we share Murphy’s opinion that for “real-life concepts, we would do best not to assume that a single form of conceptual representation will account for everything” (*Ibid.*, p.65)

340 neophobia (Tuorila *et al.*, 2001), specifically in children after age 4 (Fallon, Rozin, & Pliner,
341 1984; Rozin, Millman, & Nemeroff, 1986) and in adults (Nordin, Broman, Garvill, & Nyroos,
342 2004). For some authors, the feeling of disgust, and the corresponding facial expressions, may
343 be associated with food items that are bitter and/or potentially harmful for the subject
344 (Martins & Pliner, 2005; Stein 1973). Food rejections based on disgust are sometimes
345 assumed to imply high-level/conceptual representations regarding the nature and the origin of
346 the rejected substance (Fallon *et al.*, 1984). Accordingly, genuine disgust-based rejections
347 might not occur below the age of 4 or even 7, because they require that children have
348 mastered an adult-like concept of contagion (Fallon *et al.*, 1984).

349 However, some studies highlighted that some aspects of contamination and contagion
350 can influence even young children, who showed some understanding of the transfer of
351 properties instantiated by one item to another (Cashdan, 1998; Rosen & Rozin, 1993; Siegal,
352 1988; Springer & Belk, 1994; Toyama, 1999). Because some aversive properties of food
353 items can be visually perceived, like aversive textural properties (Martins & Pliner, 2006),
354 disgust-based rejections may also occur on the basis of visual experience without appealing to
355 complex conceptual representations of contamination (Brown & Harris, 2012a).

356 Food neophobia is connected to an increase in anxiety over food (Galloway *et al.*,
357 2003; Pliner, Eng, & Krishnan, 1995; Pliner & Hobden, 1992; Pliner, Pelchat, & Grabski,
358 1993). Moreover, even an increase in anxiety that is not initially related to food might
359 increase the neophobic response (Pliner *et al.*, 1995). Interestingly, it has been shown that
360 when a child is pressured to consume a food item while he/she is experiencing disgust toward
361 it, the disgust and the correlated anxiety response are likely to increase. This may result in a
362 long-lasting food aversion (Batsell & Brown, 1998; Batsell, Brown, Ansfield, & Paschall,
363 2002). By contrast, foods highlighted positively, pairing the foods with positive emotional
364 expressions, emotional words or safety information, are more likely to be accepted (Martins,
365 Pelchat, & Pliner, 1997; Pelchat & Pliner, 1995). The direction of the observed relationship
366 between disgust/anxiety and food aversion is unclear. Some authors have suggested that
367 disgust could trigger food rejection (Brown & Harris, 2012b; Toyama, 2000). Alternatively, it
368 has recently been argued that disgust could be a catalyst for food neophobia (Brown & Harris,
369 2012a).

370 A causal link is suspected between strong forms of picky/fussy eating and a
371 personality trait called “tactile defensiveness” (Nederkoorn, Jansen, & Havermans, 2015).
372 Tactile defensiveness is defined in many different ways in the scientific literature (see
373 Royeen, 1986, for a review of the evolution of the theory of tactile defensiveness from the

374 seminal work of Ayres, 1963; see also Smith *et al.*, 2005; Wilbarger, 2000). The notion
375 includes overreactions to the experiences of touch, or rejections or withdrawal responses to
376 some typically inoffensive tactile stimuli perceived as offensive. This disposition could
377 impact the expectation of enjoyment of certain perceived textures and consequently the
378 child's eating behavior. More precisely, it has been shown that tactile defensive children
379 refused vegetables to a higher degree than non-tactile defensive ones (Smith *et al.*, 2005).

380 Another personality trait whose influence on food neophobia is discussed in the
381 literature is the "sensation seeking disposition" (measured via the sensation seeking scale)
382 (Zuckerman, 1979). Persons who are high sensation seekers, that is to say people who require
383 a lot of stimulation to reach the appropriate level of arousal, are more open to new food
384 experiences, and thus tend to be less neophobic (Galloway *et al.*, 2003; Pliner & Melo, 1997).
385 In this case, low food neophobia would be a particular mode of a lower general neophobia
386 (Pliner & Hobden, 1992).

387 Finally, some studies (Blisset & Fogel, 2013, Keller, Steinmann, Nurse, & Tepper,
388 2002) have associated another trait called "bitterness sensitivity" to food dislike and
389 rejections. Bitterness is known to serve as a warning about poisonous foods, especially
390 vegetables (Bradbury, 2004; Catanzaro, Chesbro, & Velkey, 2013) and has been reported as a
391 sensory deterrent for vegetable consumption (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy,
392 2006). The ability to detect bitterness in a certain food item is a genetic trait encoded through
393 specific genes, such as TASR38 encoding for the phenylthiocarbamide (PTC) taste receptor
394 (Bufe *et al.*, 2005; Kim, Jorgenson, Coon, Leppert, Risch, & Drayna, 2003). It has been
395 shown that individuals with low thresholds for PTC (thus highly sensitive to bitterness)
396 display more food dislikes and rejections than those with high thresholds (thus less sensitive
397 to bitterness; Blisset & Fogel, 2013; Dinehart *et al.*, 2006; Keller *et al.*, 2002). Moreover
398 highly sensitive individuals seem to be more picky eaters and less adventurous (Catanzaro *et al.*,
399 2013). However, according to some other studies "bitterness sensitivity" does not predict
400 food preferences and rejections (Jerzsa-Latta, Kronl, & Coleman, 1990; Mattes & Labov,
401 1989).

402

403 **Social and environmental factors involved in children's food rejections**

404

405 In this section we review research studies on the potential social and environmental factors
406 underlying food rejections during the sensitive period of food neophobia and picky/fussy
407 eating. These factors are important because the very act of eating is a socially grounded

408 behavior (see e.g., Shutts, Kinzler, & DeJesus, 2013). Food consumption is socially and
409 culturally shared with congeners, and is based on previous experiences and previously
410 acquired habits in the food domain. We first address the role played by the child's previous
411 experiences (antecedents) and immediate environment (namely, parental practices). We then
412 focus on the role played by the social context on food behavior, focusing on social facilitation
413 effects.

414

415 ***Child's previous experiences and immediate environment***

416 A handful of studies suggested that the antecedents of the child play an important role in the
417 determination of the child's food preferences and rejections. These antecedents are the child's
418 genes and prenatal food experiences. To estimate the genetic influence, Cooke, Haworth, and
419 Wardle (2007) compared intraclass correlations between monozygotic pairs of twins and
420 dizygotic pairs of twins for food neophobic phenotypes. They concluded that food neophobia
421 is highly heritable and is partly in the genes. Regarding prenatal experiences, evidence
422 suggests that babies develop preferences for flavors they have experienced through amniotic
423 fluid and breast milk (Schaal, Marlier & Soussignan 1998, Mennella, Jagnow, & Beauchamp,
424 2001).

425 Taste preferences can also be learnt by means of conditioning. If a child is exposed to
426 repeated pairings of a particular taste (neutral stimulus) with a positive satiety effect, this taste
427 will come to elicit that pleasurable state which in turn will lead to preference for that taste.
428 This form of classical conditioning mainly concern the taste of foods which are energy dense
429 (sweet or rich in fat, carbohydrate) (Birch, McPhee, Steinberg, & Sullivan, 1990 ; Johnson,
430 McPhee, & Birch, 1991; Kern, McPhee, Fisher, Johnson, & Birch, 1993). However,
431 Havermans and Jansen (2006) observed in 13 young children (M age: 5.2 years) a significant
432 increase in flavor preference for the vegetable taste paired with dextrose. Even if the long
433 term effects remain unclear, it has been recently shown that caloric conditioning can be
434 combined fruitfully combined with another powerful mechanism: social learning/modelling
435 (Jansen & Tenney, 2001) which is discussed in the next section. Regarding the influence of
436 the child's (post-birth) immediate environment on his/her food behavior, certain
437 characteristics of the primary caregiver significantly affect food neophobia expression in
438 children (Dovey *et al.*, 2008). The most obvious is parental food neophobia (Carruth &

439 Skinner, 2000; Pelchat & Pliner, 1986, 1995; Pliner, 1994)⁴, but socio-economic status
440 (Flight, Leppard, & Cox, 2003; Giskes, Turrell, Patterson, & Newman, 2002; Lien, Jacobs, &
441 Klepp, 2002) and educational level (Vereecken, Keukelier, & Maes, 2004) also seem to
442 modulate the degree of expression of the disposition to reject fruits and vegetables.

443 Parental practices are clearly important in determining the child's acceptance of versus
444 aversion toward food items because they impact both flavor exposure through milk (maternal
445 compared to formula) and social aspects guiding food behavior. The difficulty is of course to
446 disentangle the respective contributions of these two types of factors. During infancy, different
447 parenting and nutrition-related attitudes in mothers could positively influence the subsequent
448 food behavior of the child (Taveras, Scanlon, Birch, Rifas-Shiman, Rich-Edwards, &
449 Gillman, 2004). For instance, infants were shown to eat more formula when caregivers
450 provided social interaction during feeding (Lumeng, Arbor, & Blass, 2007). Compared to
451 formula-feeding, breastfeeding may facilitate the future acceptance of solid foods (Sullivan &
452 Birch, 1994; Nicklaus, 2009). Girls were shown more likely to be picky/fussy if they were
453 breastfed for fewer than 6 month (Galloway *et al.*, 2003). Moreover, some research studies
454 have observed statistical relationships the between mother's diet, the nature of their parental
455 strategies, and the behavioral dispositions of their daughters toward fruits and vegetables. In a
456 nutshell, mothers's with a diet of more fruits and vegetables seemed to be less disposed to
457 pressure their daughters to eat and had daughters who were less picky/fussy and who
458 consumed more fruits and vegetables during childhood (Galloway *et al.*, 2005).

459 Evidence suggested that high controlling parental practices, including restriction and
460 pressure to eat, created an emotionally negative environment around food, with negative
461 consequences for children's reactions to food (Birch *et al.*, 1987; Faith & Kerns, 2005;
462 Galloway, Fiorito, Francis, & Birch, 2006; van der Horst, 2012; Webber, Cooke, Hill, &
463 Wardle, 2010). Some studies indeed revealed that many long-lasting food dislikes and
464 rejections could be traced back to forced consumption episodes involving an authority figure
465 (parent or teacher) (Batsell *et al.*, 2002). It has also been shown that parental attempts to
466 control food intake in children reduces the positive effect of exposure (Galloway *et al.*, 2006).
467 Some data showed that presenting a food as a reward enhanced children preference for that
468 food (Birch, Zimmerman, & Hind, 1980). By contrast, when disliked foods are used as a

⁴ However, further research is needed to determine either the direction of a putative causal arrow between the variables or rather the existence of a vicious circle.

469 reward, these foods become even less desirable (Birch & Marlin, 1982; Birch, Marlin, &
470 Rotter, 1984).

471 It is hard to determine what parents think about these coercive strategies. On the one
472 hand, some evidence suggested that most parents know that these strategies are ineffective
473 (Casey & Rozin, 1989). On the other hand, research studies showed that when infants are
474 between 6 and 12 months old, mothers use pressure and restriction in reaction to the perceived
475 size of their child (Brown & Lee, 2011). It is worth noting that the direction of the causal
476 arrow between parental pressure and children's reactions to food is unclear (Galloway *et al.*,
477 2005, 2006). Namely, we do not know whether children's food rejections elicit more parental
478 pressure, or whether parental pressure and restriction foster food rejections in children.
479 A vicious circle including both aspects is a living option.

480 Interestingly, research studies suggested that children's participation in and enjoyment
481 of cooking has a direct influence on picky/fussy behavior but also increases eating enjoyment,
482 which in turn decreases picky/fussy eating (van der Horst, 2012). This is explained by the fact
483 that through cooking, children are exposed to a wide variety of foods. A cooking context is
484 also positive, as most children like hands-on activities and the concrete results of these
485 activities can give them a feeling of ownership and pride (van der Horst, 2012). Modifying
486 the home food environment through activities that engage both parents and children can be a
487 key factor in the improvement of food intake in children and can increase consumption of
488 fruits and vegetables (Heim, Bauer, Stang, & Ireland, 2011).

489

490 ***Social facilitation effects***

491 Shutts *et al.* (2013) stated that “humans at any age rarely face the challenge of food selection
492 alone. (...) Infants and young children therefore have numerous opportunities to watch
493 members of their culture choose, cook, eat, and react to different kinds of foods in social
494 settings” (p. 420). Accordingly, one major influence of the social context on children's
495 reaction to food is social modeling or social facilitation. Clayton (1978) defined “social
496 facilitation” as an increase in the probability of performing a class of behaviors in the
497 presence of conspecifics performing the same class of behaviors at the same time (see also
498 Tomasello & Call, 1997; Visalberghi & Fragaszy, 1990; Whiten & Ham, 1992). Put
499 differently, social facilitation means that when a child eats in the presence of others eating
500 food, his/her behavior is socially facilitated toward food intake (see Herman, 2014, for a
501 recent review of the social facilitation of eating).

502 Research studies in this area have shown that social facilitation effects are not
503 restricted to humans. They are observed in many omnivorous species, such as chacma
504 baboons (Cambefort, 1981), tufted capuchin monkeys (Visalberghi & Fragaszy, 1995;
505 Visalberghi & Addessi, 2000), rhesus macaques (Weiskrantz & Cowey, 1963), juvenile and
506 infant marmosets (Vitale & Queyras, 1997; Voelkl, Schrauf, & Huber, 2006), gerbils
507 (Forkman, 1991), rats (Galef, 1993), and human children (Harper & Sanders, 1975).
508 Interestingly, monkeys were shown to exhibit a social facilitation effect even across species
509 (i.e. from an human model) (Santos *et al.*, 2002).

510 In human children, unlike other primates, social facilitation effects are specific. Adessi
511 *et al.* (2005) have shown that young children aged 2-5 years learned to accept new foods
512 through observing significant others eating the same food (but not if the food is different or if
513 the model is present without eating). By contrast, capuchin monkeys accepted and ate more of
514 a novel food when their group members were eating a food, even if it had a different color
515 (Addessi & Visalberghi, 2001; Visalberghi & Fragaszy, 2002; Visalberghi & Addessi, 2000).

516 Adults can serve as models for food acceptance: an encouraging teacher (Hendy &
517 Raudenbush, 2000; Highberger & Carothers, 1977) or a friendly visitor in a classroom can
518 foster food acceptance in young children (Harper & Sanders, 1975). However, one person has
519 a limited effect and the greatest effect occurs when everyone in the immediate environment of
520 the child is eating the food (Birch, 1980). In addition, the social facilitation is enhanced when
521 models are familiar to the children (Salvy, Vartanian, Coelho, Jarrin, & Pliner, 2008). Harper
522 and Sanders (1975) showed that children aged 14-20 and 42-48 months were willing to put
523 unfamiliar foods in their mouth when adult models were eating the food, more than when
524 adult models were simply offering the food; but the facilitation was more effective when the
525 mother was the source of the food than when the food came from a stranger.

526 In the same vein, Shutts, Kinzley, McKee, and Spelke (2009) showed that 12-month-
527 old children selected a food endorsed by an adult speaker of the child's own language over
528 one endorsed by an adult speaker of a foreign language, even when the children knew that
529 both foods were highly palatable. Salvy *et al.* (2008) showed that social facilitation occurred
530 in children aged 5-11 years only when the co-eaters were familiar: children eating alone or
531 with strangers ate less than children eating with their siblings. Social facilitation with peer
532 modeling appeared to be the most effective way to foster novel food acceptance, as shown in
533 children aged 2-4 years (Birch, 1980) and children aged 3 and 6 years (Hendy, 2002).
534 Interestingly, the effects of peer modeling are long lasting as they endure beyond the
535 immediate context in which the modeling occurred (Birch, 1980; Laureati *et al.*, 2014). Two

536 recent studies also showed that social modeling of food intake by children was enhanced
537 when the peers acting as models (on TV) displayed emotions instead of a neutral expression
538 (Bevelander *et al.*, 2013), and when other approaches were combined with peer modeling
539 (such as food exposure and rewards; Laureati *et al.*, 2014).

540 Interestingly, many research studies revealed that social facilitation could also change
541 the food preferences of children (Laureati *et al.*, 2014). More precisely, if preschool children
542 were exposed to peer models who were choosing and eating a target food that did not belong
543 to the set of foods initially preferred by the children, the probability that the children chose
544 the target food increased. The effect of peer modeling was such that a significant number of
545 children ended up choosing the target food even when presented with an initially preferred
546 food (Birch, 1980; Hendy, 2002). These results confirm the Social Cognitive Theory
547 (Bandura, 1997), according to which peer models are one of the social factors that most
548 effectively foster food acceptance during preschool lunch.

549 Finally, it is worth mentioning that there is conflicting evidence in the literature as to
550 whether younger children are more affected by the behavior of peers than older ones. For
551 instance, Birch (1980) has found that food preferences of 3-year-old children are more
552 socially affected than those of 4-year-old children. Lumeng's investigations of social
553 cognition development in infancy (Lumeng, 2013) supported this perspective and showed that
554 between 3 and 4 years old, children develop the capacity to modify their food choices, based
555 on the understanding that adults can have different food preferences than their own and can
556 provide false information about food items. Younger toddlers who are not capable of this
557 mind reading would therefore be more affected by the behavior of parents pretending to like
558 usually rejected food items. But another study has not found such a difference between two
559 groups of children, aged 14-20 months and 42-48 months (Harper & Sanders, 1975). A
560 similar conflicting evidence exists regarding the impact that sex/gender has on peer models'
561 ability to modify children's food preferences. According to some authors, girls are more
562 influenced than boys (Hendy & Raudenbush, 2000), but older research studies have not found
563 such sex/gender differences (Birch, 1980).

564

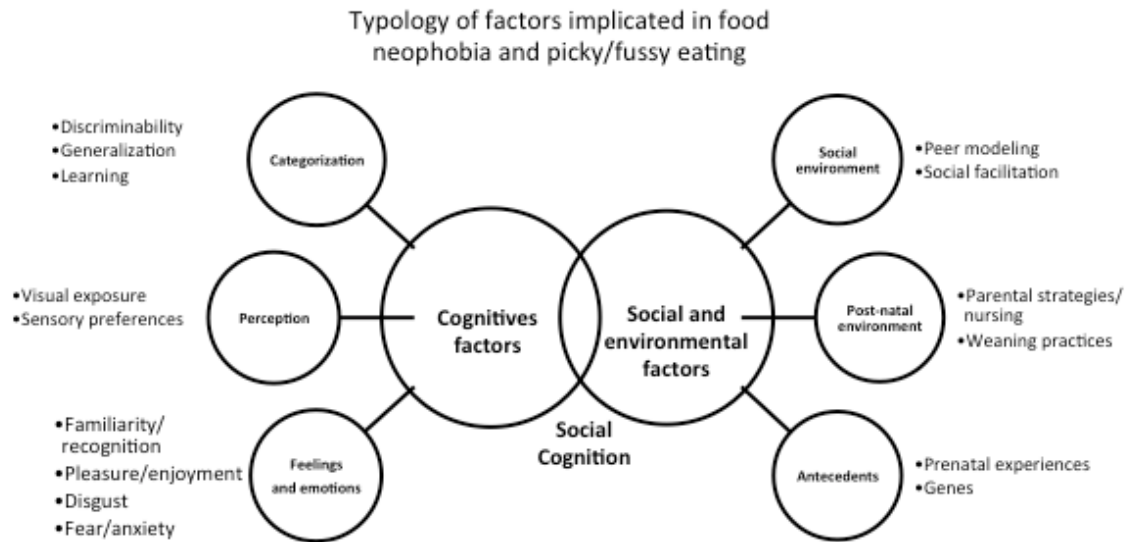
565 **Summary**

566

567 To summarize, food neophobia and picky/fussy eating behavior in children have been shown
568 to contribute to food rejections (mostly concerning healthy items such as fruits and
569 vegetables) and reduction of dietary diversity. Hence these two phenomena have negative

570 consequences for health, and a better understanding of the factors underlying food rejections
571 will help to overcome these concerns.

572 The following diagram proposes a review of the different factors (displayed in boxes)
573 presented above (see Fig. 1). The structure of this diagram is similar to the structure of the
574 present review.
575



576
577 Fig1.

578 Visual and olfactory cues play a key role in food rejections. It is likely that food
579 neophobia and pickiness depend partly on preference for certain perceptual properties of food
580 (color, visually perceived texture, shape, smell, etc.) or even mode of presentation. For
581 instance, it is possible that some children prefer dishes with space between items because
582 overlaps can cause contamination-based disgust. In addition, because the large majority of
583 preferences are learned through experience, food rejections are often reduced by repeated
584 visual exposure during infancy.

585 Information given by the physical context is perceived and categorized by the child,
586 with the food categorization system possibly delivering output on edibility, familiarity, or
587 attractiveness of items. Because food rejections peak around 2-3 years when rapid
588 improvements appear in the categorization system, one might consider food neophobia and
589 pickiness the result of a perceptual mismatch between food items and prototypical food
590 categories embedding perceptual properties. Besides, some traits, such as bitterness

591 sensitivity, sensation seeking disposition, or tactile defensiveness, may influence children's
592 perception of and feelings toward foods and thus lead to potential rejections.

593 The capacity to select non-dangerous foods in early childhood mainly depends on
594 learning from others. Thereby, facilitation and modeling effects play major roles in children's
595 willingness to try new food and even in changing their food preferences. Food selection is a
596 risky endeavor and even if children understand that models can provide false information they
597 assume that the latter will at least target safe foods. Children's inclination to modify their
598 choices based on mind reading seems to be weaker for food than non-food items and therefore
599 the food domain is a specific and unique domain in social cognition. Food neophobia and
600 pickiness are also influenced by genetics and prenatal food experiences (namely flavors
601 experienced through the amniotic fluid), as well as breastfeeding and weaning practices. The
602 child's immediate environment after birth (cultural customs, socio-economic status,
603 characteristics of the caregiver) should also be taken into account because it might influence
604 how foods are presented and accepted.

605

606 **Conclusion and future directions**

607

608 Food rejections by children have been referred to as food neophobia and pickiness behaviors,
609 but the conceptual definitions and assessments of these two constructs as well as their inter-
610 relations are still not entirely clear. In addition, the literature showed that food rejections by
611 children fell under the scope of multiple cognitive and social/environmental factors. Whereas
612 the role played by some of these factors (namely the social and environmental factors) has
613 been extensively investigated, the implications of other factors, such as children's developing
614 food categorization system, have been comparatively under-researched. In our view, there is a
615 need for studies on food rejections, regarding (i) the distinction between food neophobia and
616 picky/fussy eating, and (ii) the potential link between food categorization abilities and
617 children's food neophobia and pickiness.

618 First, the literature lacks decisive empirical evidence in favor of an independence or a
619 correlation between the two components of food rejection, food neophobia and pickiness. To
620 clarify this aspect, it would be useful, for instance, to conduct psychometric studies in order to
621 develop and validate a scale of food rejections for children, including items relative to food
622 neophobia and pickiness behaviors. Specifically, investigations of the factorial structure of
623 such a scale would help to disambiguate the relationships that food neophobia and picky/fussy
624 eating entertain with one another. The scientific study of children's food rejections, including

625 the efficacy of techniques for reducing them, would also be greatly facilitated by such a
626 measurement tool.

627 Second, from a developmental perspective, few studies have yet linked cognitive
628 capabilities of children and their inclination toward food rejections. Food rejections peak at
629 around 2-3 years, precisely when rapid changes and improvements appear in the child's food
630 categorization system. In our view, the concomitance of these two phenomena is not a sheer
631 coincidence, and calls for investigation. An important role of the food categorization system
632 is to deliver edibility output, that is to say, to discriminate food items from non-food items.
633 However, little is known about the properties of this function's development, or about its
634 relation to children's food neophobia. Future studies might assess the developmental
635 characteristics of children's food categorization system during neophobia's peak, and test i)
636 whether children's level of food rejection is a behavioral manifestation of the developmental
637 characteristics of their food categorization system and ii) whether children's level of food
638 rejection acts as a variable that moderates (as silencer or an enhancer) their developing ability
639 to discriminate between food and non-food items. We are currently designing studies with this
640 objective.

641

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