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1 Introduction

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

Two design features appear to have emerged through natural selection to solve this adaptive problem[1]. Grasping the first horn of the dilemma, a categorization system allowing for a food/nonfood distinction and discrimination between different food items enables efficient sampling of new food resources and enrichment of the food repertoire. Categorization is a fundamental cognitive process that allows us to organize objects into groups (Vauclair, 2004). 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).

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

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

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

The assumption that food rejection and food categorization processes are natural selection's solutions to the omnivore's dilemma led us to compare the scientific literature on food rejection and on children's cognitive development, in particular the development of a food categorization system (Lafraire, Rioux, Giboreau, & Picard, 2016). This comparison, which we expected to shed light on the mechanisms underlying food rejection behaviors from the perspective of overcoming them, uncovered several interesting outcomes or hypotheses.

First, an increasing number of research studies have related eating disorders to abnormal cognitive development, such as in autism spectrum disorder (Postorino et al., 2015; Rochedy & Poulain, 2015; Stough, Gillette Roberts, Jorgensen, & Patton, 2015). Children with autism are known to have cognitive deficits (Frith & Happé, 1994; Ozonoff, Pennington, & Rogers, 1991), and interestingly eating problems are common in this clinical population (Ahearn, Castine, Nault, & Green, 2001). Approximately 80% of young children on the autism spectrum are described as picky eaters, and 95% of them are reported by parents to be resistant to trying new foods (Lockner, Crowe, & Skipper, 2008) while prevalence of picky eating in young neurologically typical children usually ranges from 25% to 50% (Taylor et al. 2015). Moreover, Bandini et al. (2010) found that children with autism had more limited food repertoires than typically developing children.

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

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

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

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

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[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.

were more likely to choose the color-match object in the *food* condition, whereas they were more likely to choose the shape-match object in the *toy* condition. These data speak in favor of a domain specificity[5] effect on categorization, and this domain specificity effect is relevant not only in nonlinguistic categorization tasks, as Macario established, but also in children's novel word extensions (Lavin & Hall, 2001).

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

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

(i) Children's ability to perform categorization in the food domain appears to improve from 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.

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

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

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

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

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

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

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

To investigate these three hypotheses, we conducted a food categorization task with children aged 2-4 and 4-6 years (plus an additional control group of adults), involving the use of fruit and vegetable categories. We chose these categories because by this age, children have usually encountered several exemplars of these food items and developed the corresponding taxonomic categories (Nguyen & Murphy, 2003). Fruit and vegetables were also chosen because they are likely to be rejected by children in this age range. Moreover, to gain a sensitive measure of children's categorization abilities, we needed two categories that were not too distant from each other, regarding false relatedness effects (it is more difficult to answer "No" to the question "Is a vegetable a fruit?" than to the question "Is a vegetable a car?"; see Smith & Medin, 1981). It has been argued that from an early age, children distinguish accurately between natural items (e.g., food) and artificial items (Mandler & McDonough, 1993) and between categories within the food domain such as biscuit and fruit (Brown, 2010).

2 Methods

2.1 Participants

The participants were 79 children: 40 children aged between 27 and 46 months (M = 36.1 months, SD = 5.7; 24 girls and 16 boys) and 39 children aged between 48 and 78 months (M = 63.7 months, SD = 8.7; 20 girls and 19 boys). The children were pupils at a preschool in the Lyons urban area (France), and were predominately European and recruited from middle-class communities. Prior to the study, the children's parents filled out a questionnaire about their food rejection (Child Food Rejection Scale[6], CFRS; Rioux, Lafraire, & Picard, submitted) and exposure to the fruits and vegetables presented to the children during the experiment. The children's scores on the CFRS ranged from 16 to 50 (M = 33.5, SD = 7.8), and were normally distributed (Shapiro-Wilk test, $W = 0.98$, $p = 0.42$). These scores obtained via parental report were used as the predictive measure of children's own food rejection tendencies. Their exposure scores ranged from 3 to 10[7] (M = 8.4, SD = 1.5) and were not 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.

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

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

2.2 Stimuli

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

To generate our set of foods, we first visited a school canteen to see which foods were available to children, and which recipes were usually proposed. On this basis, we selected six vegetables that were commonly served and were available in different colors (carrots, tomatoes, eggplants, beetroots, bell peppers and zucchinis), and three fruits (apples, pears and citrus fruits)[8]. Next, to control for fruit and vegetable typicality, as several authors have demonstrated that typical items are easier to recognize and categorize (Hayes & Taplin, 1993; Mervis & Pani, 1980; Murphy, 2002), we followed Barsalou (1985)'s and Chrea, Valentin, Sulmont-Rossé, Hoang Nguyen &Abdi (2005)'s methodologies. The parents of the children in our sample (Adult sample 2) were therefore asked to indicate on a 7-point scale for each of the nine food items whether they were good examples of the fruit or vegetable category in question. No pictures were used for this procedure. For example, we asked adult participants to imagine a carrot and then rate its typicality compared to other vegetables on the 7-point scale. The purpose of this first assessment was to determine whether in general, carrots were judged to be more typical than beetroots for instance. The results are set out in Table 1 and showed for instance, that carrots were judged to be more typical vegetables than beetroots because typicality's rating for carrot was judged to be 6.30 while it was judged to be 3.91 for beetroots.

Table1 (single column fitting image): Typicality rated by adults (on a 7-point scale) for the 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

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.

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

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

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)

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

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

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)

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

Each block contained the same number of food items, cut in quarters, slices or cubes. For example, in Block A the four colored varieties of carrots were cut into slices, the varieties of bell peppers were cut into quarters, and the varieties of pears were cut into cubes. Moreover, in each block, the two kinds of vegetables differed considerably in typicality. Twelve additional stimuli, which were neither fruit nor vegetables, were used in a practice session (four pictures of cats, four pictures of dogs, and four pictures of cars, differing in terms of their overall colors).

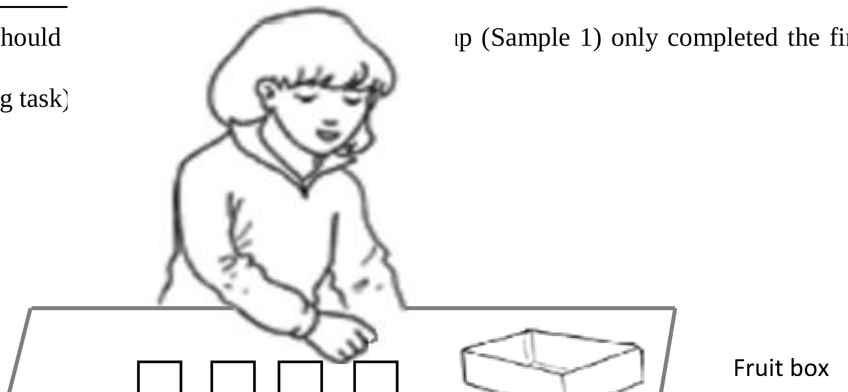
2.3 Procedure

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

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

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

[10] It should ... up (Sample 1) only completed the first part of the study (forced sorting task)



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

The experimenter recorded the type of response for each vegetable (hit or miss) and for each fruit (correct rejection or false alarm). We then assigned to each participant a hit score (i.e., number of cards placed in the vegetable box when the picture was a vegetable) and a false alarm score (i.e., number of cards placed in the vegetable box when the picture was a fruit). Hit scores could vary between 0 and 16, and false alarm scores between 0 and 8. Both these scores were important to take into account to evaluate children performances to the task. For example a child who would have placed the twelve pictures of block A in the vegetable box would have a high hit score (because she put in the right box all the vegetables from block A). However her categorization performances would be nevertheless poor as she would have put also all the fruit pictures from block A in the vegetable box and it will be indicated by a high rate of false alarms. Based on these two scores (hit and false alarm), we measured an index of discriminability (A’), and an index of the child’s decision criterion (B’’) (these indexes are widely used within the signal detection theory, see Grier, 1971; Stanislaw & Todorov, 1999). A’ ranged from 0 to 1, with .50 indicating responses at chance level, and 1 indicating maximum discriminability. B’’ ranged from -1 to +1, with -1 indicating a liberal criterion (e.g., children tending to place cards in the vegetable box whatever the pictures), and 1 indicating a conservative criterion (e.g., children tending to place cards in the fruit box whatever the picture). Both indices were computed according to Grier's formulas (Grier, 1971): $A' = ½ + [(y - x)(1 + y - x) / 4y(1 - x)]$, and $B'' = [y(1 - y) - x(1 - x)]/[(y(1 - y) + x(1 - x)]$ where y stood for the probability of a hit and x corresponded to the probability of a false alarm.

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

Part 3- Color naming task. Following Macario (1991, Exp. 2 and 3)'s work, the last part of the experiment consisted of an examination of color naming abilities, so as to assess the potential relationship between color naming and the categorization of colored vegetables. Eleven monochrome pictures in colors extracted from the fruit and vegetable pictures (light green, dark green, light purple, dark purple, red, dark red, yellow, orange, brown, pink and white) were printed separately on 5 x 5-cm cards and shown to the child. In a color-word production subtask, we asked the children to name each color. In a color-word comprehension subtask, we told the children the name of a color and asked them to point out the corresponding picture card. The order of the two subtasks was counterbalanced across children. For each subtask, we credited a child with knowing a particular color word if she produced or understood the correct color word (scoring 0 when the child did not know the color word and 1 when the child did know it). Note that, for the color-word production subtask children labeling the "light green" panel as just "green", or the “dark purple” panel as just “purple” were counted as correct responders. Each child could thus score between 0 and 11 on the word production subtask and on the word comprehension subtask. As scores on the two subtasks were closely correlated (as attested with Spearman’s coefficient: $r = 0.70$, $p < 0.001$), we averaged these two scores. Each child was therefore assigned a single *color-word knowledge* score between 0 and to 11.

3 Results

3.1 Sorting task

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

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

3.1.1 Type of response

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

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

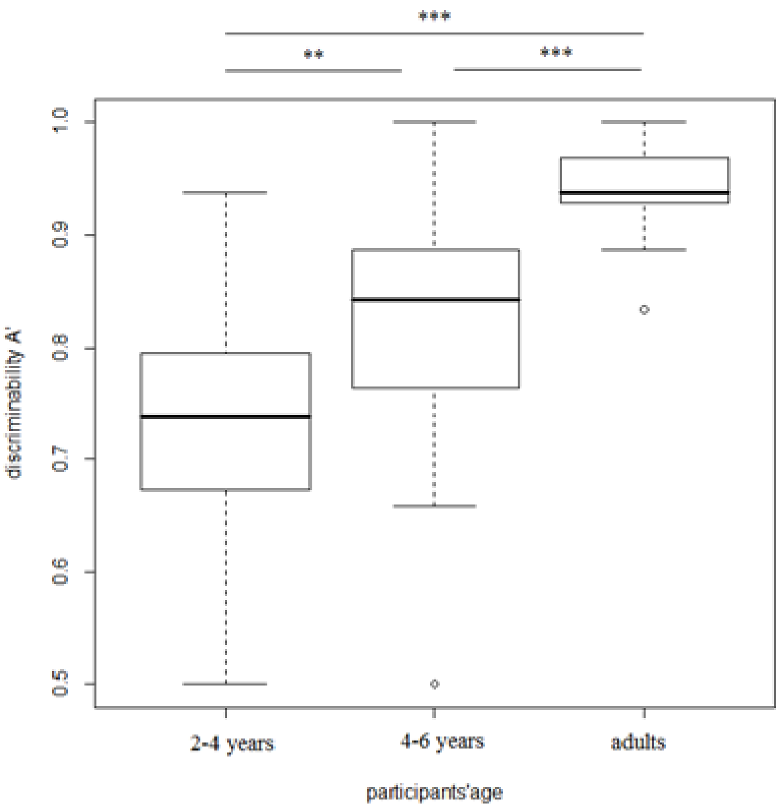
.08). An analysis of variance (ANOVA) on the percentage of hits, with age (3 groups) as a predictive variable, indicated an effect of age ($F = 11.94$, $p < 0.0001$). A post hoc LSD analysis revealed that hit rates for the two children's groups did not differ significantly, whereas there was a significant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

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

3.1.2 Discriminability A'

A' for children was .77 (*SD* = .13; range = .50-1). Results (see Table 4) indicated that mean A' for children aged 2-4 years was 0.72 (*SD* = .11), while the mean hit rate for children aged 4-6 years was 0.81 (*SD* = .12). The adults performed better on the task (*M* = .94, *SD* = .04). An ANOVA on A' with age (3 groups) as a predictive variable indicated an effect of age ($F = 36.7$, $p < 0.0001$; Fig. 2). Post hoc LSD analysis revealed significant differences between the groups ($p = 0.002$ between the two children's groups, $p < 0.0001$ between the adults and younger children, and $p < 0.0001$ between the adults and older children).

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



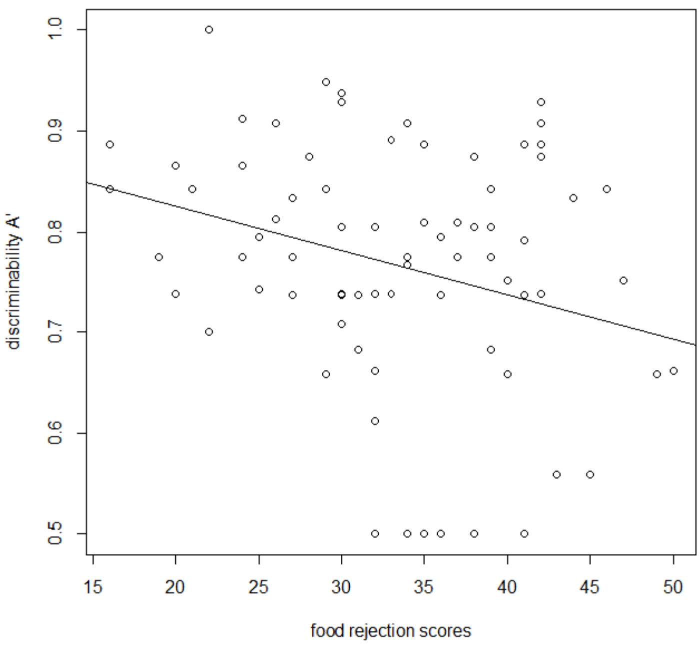
Note. Significant differences between the age groups are marked * for $p < 0.05$, ** for p<0.01 and *** for $p < 0.001$.

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

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

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



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

3.1.3 Decision criterion B’’

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

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

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

To test the hypothesis that food rejection is the behavioral consequence of an immature food categorization system, we conducted a regression analysis with A' and B" as predictive variables, and food rejection score obtained from the CFRS questionnaire as the predicted variable[12]. This model significantly predicted variation in the food rejection score across our child sample (p = 0.019), but explained rather a low proportion (7.5%) of this variability, as demonstrated by the adjusted R^2. Results revealed an effect of A' on food rejection scores (F = 4.79, p = 0.031). This effect indicated that children who performed poorly on the sorting task were more neophobic and picky than children who performed well on it (see Fig. 2).

3.2 Food rejection task

Spearman's correlation coefficients failed to reveal any significant correlation between the number of pictures binned during the food rejection task and either children's food rejection scores obtained from the CFRS questionnaire (r = 0.06, *ns*) or their fruit and vegetable exposure scores (r = 0.10, *ns*). To assess the potential influence of picture characteristics on 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.

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

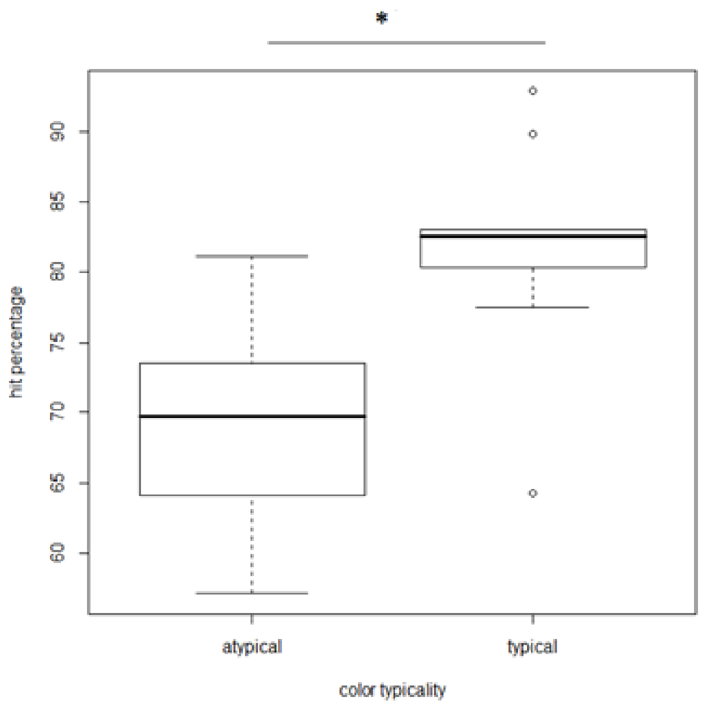
3.3 Color naming task

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

3.4 Categorization performance based on vegetable characteristics.

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

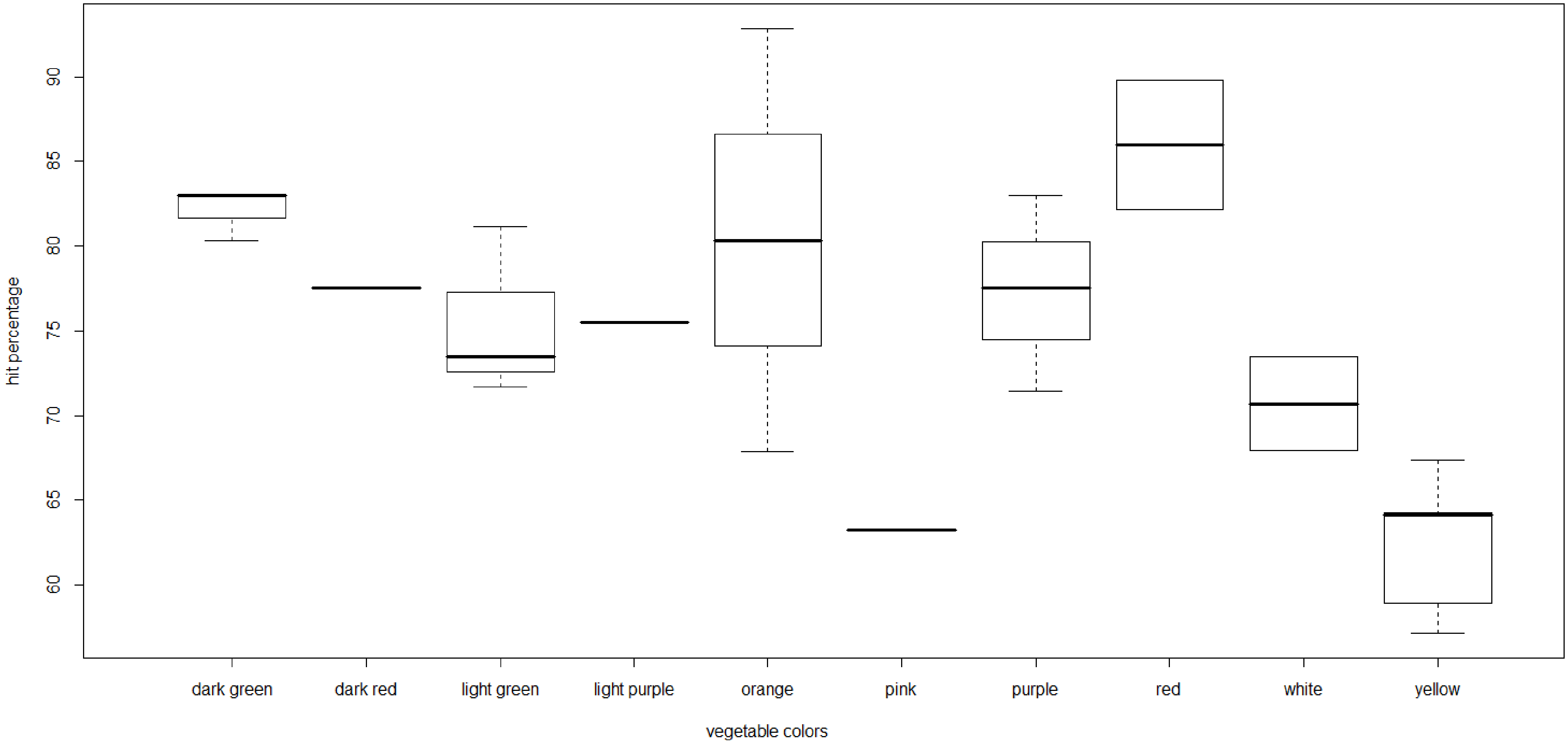
Figure 4 (single column fitting image): Hit percentages for atypically and typically colored vegetables.



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

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

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



4 Discussion

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

4.1 Do children’s food categorization performances improve with age?

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

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

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

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

Our findings showed that children's food rejection scores and sorting task performances were significantly correlated (Pearson's correlation coefficient: r = -0.27, p = .014; see Fig. 3). Further statistical analyses indicated that highly neophobic-picky children performed more poorly than the other children on the sorting task (as attested by the retained model predicting A' variation among children), suggesting that the children's level of food rejection partly predicted their performance on the fruit and vegetable categorization task. From this perspective, we could argue that food neophobia and pickiness acted as restraining factors on food discriminability, that is to say, they behaved as dampers on the development of the food categorization system. At a given age, strongly neophobic and picky children will thus have poorer food category content than other children, because they do not accept new items in the food category as easily and have fewer learning opportunities with food categories. Indeed caregivers of children who display high food rejection tendencies, are often discouraged to present fruit and vegetables to their children (Heath, Houston-Price & Kennedy, 2011), leading to fewer experiences and it is known that children's categorization abilities differ as a function of their experience (Chi, Hutchinson & Robin in 1989). This claim was supported by the fact that neophobic-picky children performed the same as the younger children in terms of hit and false alarm rates (mean hit and false alarm rates for neophobic-picky children: 0.76 and 0.41). Furthermore, the non-neophobic-picky children performed just as well as the older children in terms of hit and false alarm rates (mean hit and false alarm rates for non-neophobic-picky children: 0.77 and 0.31). These results were especially striking, given that food rejection scores were not correlated with age.

Statistical analyses also revealed that children with a poor ability to distinguish between fruits and vegetables (i.e., low A') tended to be more neophobic and picky than the children with high discrimination abilities (as attested by the model predicting variations in food rejection scores across children). This additional finding indicated that children's discrimination abilities were predictive of their level of food rejection, thus supporting the premise that food rejection is partly the behavioral consequence of an immature food categorization system (Brown, 2010; Lafraire et al., 2016). This finding possibly accounts for the recognized positive effect of visual food exposure on food rejection and attitudes towards food (Birch, McPhee, Shoba, Pirok, & Steinberg, 1987; Birch & Fisher, 1998). Exposure would facilitate the recognition process (Lafraire et al., 2016; Zajonc, 1968), by enriching food category content and food prototypes and therefore reduces the probability that food items will not be judged as food category members because they are not close enough to the food prototype. Finally, we could be facing a vicious circle: food rejections seem to be the behavioral consequences of a developing categorization system. Consequently, caregivers may be discouraged to present fruit and vegetables to their children, leading to fewer learning opportunities and to hinder the development of the food categorization system. Focusing on conceptual development could then be an efficient manner to tackle food rejections behaviors as demonstrated by a recent study from Grishover and Markmann (2013). Indeed, in their research they compared usual educational programs about nutrition to a *knowledge based-approach* nutritional education program (which provided children with a rich conceptual framework about food) and found that, children who attended to the latter program ate more vegetables at snack time.

However, contrasting with these promising results linking food rejection to categorization development in children, scores on the food rejection scale were not correlated with their binning behaviors, leading us to conclude that, contrary to parental reports, the food rejection task was not a relevant measure for associating food rejection behaviors with sorting performances. Two main reasons may explain this negative result. First, this task was often regarded as a game by the children, as they were allowed to thrown food away-a behavior banned in the school canteen. Moreover, some of the comments made during this task by nursery staff indicated that the children did not display their normal food rejection behaviors (e.g., while one child was throwing away almost all the pictures into the garbage, a staff member told the experimenter that this child usually ate nearly everything). Secondly another reason to have some doubt regarding the reliability of the binning behaviors as an appraisal of the food rejection behaviors is that, we assessed the predictive validity of the food rejection questionnaire in a previous study (Rioux, et al. submitted) and found that caregivers were relevant predictors of their children's behaviors toward foods.

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

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

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

Concerning the color naming task, we did not replicate Macario's finding (1991, Exp. 3), which associated children's ability to name colors with their discrimination of anomalously colored objects, as we failed to find any significant correlations between color name knowledge and sorting task performances across children. However, as even young children were quite familiar with color names (mean color name knowledge for the youngest group of children: 7/11), it was maybe not possible to distinguish between children on this basis. Moreover, some comments made during this task by nursery staff indicated that the very young children often did know almost every color they were shown, but were too shy or intimidated by the experimenter to name them (it should be recalled that this was the only part of the experiment where the children had to talk), thereby artificially lowering their color knowledge scores.

4.4 Conclusion and perspectives

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

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

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

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

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 zuchini Hit rate : 64.1 	Dark green Zuchini Hit rate : 83.0 	Light green zuchini Hit rate : 71.7 	Dark green zuchini 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			
Red tomato Hit rate : 89.8 	Dark red tomato Hit rate : 77.5 	Light green tomato Hit rate : 73.5 	Yellow tomato Hit rate : 57.1 
Pink beetroot Hit rate : 63.2 	White beetroot Hit rate : 73.5 	Yellow beetroot Hit rate : 67.3 	Dark purple beetroot Hit rate : 77.5 
Yellow lemon False alarm : 32.5 	Dark green lime False alarm : 71.4 	Red grapefruit False alarm rate : 30.6 	Orange False alarm : 20.4