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Fatal Errors in the Food Domain: Children's Categorization Performance and Strategy Depend on Both Food Processing and Neophobic Dispositions.

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Abstract

In this study, preschool children were tested in a food versus nonfood categorization task. We studied the influence of edibility cues such as food processing (whole versus sliced items) on children's categorization abilities. We also correlated children's categorization performance and strategy with their food rejection scores (neophobia). 137 children aged 4-6 years were asked to discriminate foods from nonfoods. Results revealed that food processing features (slicing) afforded edibility, leading to potentially hazardous incorrect categorization. We also found that children's categorization performance was negatively correlated with their food rejection scores. Moreover, as expected, children with high food rejection scores displayed a more conservative categorization strategy (i.e., categorizing food items as inedible) than children with lower food rejection scores. However, contrary to our expectations, both performance and strategy of less neophobic and picky children were affected by food processing. These children committed dangerous errors, categorizing many nonfood items as food when sliced.

Keywords: Categorization; Food categorization; Children; Food rejection; Food processing

Introduction

Discriminating between foods and nonfoods is crucial for survival (Rozin, 1990). After weaning, children need to consume new and diverse food sources to ensure normal and healthy development. However, some of these foods may be inedible, might even be toxic: a single mistake in this search for variety can prove to be fatal. Therefore, discriminating foods from nonfoods is essential during the entire life.

Categorization is the system we rely on for these food-nonfood discriminations (Lafraire et al., 2016; Ross & Murphy, 1999) Children's categorization abilities develop rapidly during infancy and preschool years (Bornstein & Arterberry, 2010; Gelman & Markman, 1986). Yet, children are unable to discriminate between foods and nonfoods until the end of their second year.

Food categorization. Studies revealed striking limitations in children's ability to categorize food from nonfood items accurately. For instance, using a sequential touching procedure and a forced sorting task, Brown (2010) found that before 20 months, infants fail to discriminate between food and animal categories. However, fast improvements occur between 2 and 3 years of age. After 22 months, infants discriminate between food and animal categories (Brown, 2010) and systematically sort food from toy items after 30 months (Bovet et al., 2005). Additionally, Lafraire et al. (2016) observed that 3- and 4-year-old children can discriminate foods from nonfoods matched on color and shape (e.g., a red tomato and a red Christmas ball). Though children correctly categorized 80% of food items as edible, they mistook nonfoods as food in 50% of the cases (i.e., false alarms). This result indicates that they were liberal in their categorization *strategy* (i.e., their decision criterion in signal detection theory; Macmillan & Creelman, 2004). They were biased to consider a majority of the stimuli as foods. In the study conducted by Lafraire and colleagues, the rate of false alarms was negatively correlated with age, within this two-year age range. Other studies show that three-year-olds are also able to categorize food subcategories beyond chance (e.g., fruits and vegetables; Rioux et al., 2016) or reason about foods according to properties such as their healthiness (Nguyen, 2008). Children's categorization and reasoning abilities on foods are improving between two and six years of age. However, by the end of preschool their food categorization system is not fully mature. Indeed, 6-year-old children are often outperformed by adults (e.g., Rioux et al., 2016). Taken together, these findings highlight improvement in children's food categorization system across preschool years, as well as its limits.

For both adults and children, making safe food choices is a complex task between ingesting an inedible substance and the benefits of a diverse diet. Once they can crawl, walk, children encounter foods without their caregivers and have to rely on the perceptual features of food candidates to categorize them. Food has a large array of perceptual features, coming in different shapes, colors, and textures, which can be altered by human interventions, that might act as visual edibility cues.

Food processing and perceived edibility. Food processing is a unique and universal human behavior aiming to increase an item's edibility. Here, we define an unprocessed food as a natural food with no cue of human intervention, whereas a processed food display signs of human interventions (e.g., cooked, sliced). Importantly, processed foods are less likely to contain pathogens and have reduced risk of infections (Carmody et al., 2011; Wrangham, 2013). Recent evidence suggests that humans are sensitive to this distinction. For example, Coricelli et al. (2019) showed that participants categorized processed foods as foods faster than unprocessed foods. Similarly, adults rated processed food items as more edible than unprocessed foods (Foroni et al., 2013).

Children also seem to understand the difference between natural unprocessed food and processed food (Girgis & Nguyen, 2020) and reason on the basis of this distinction (Foinant et al., 2021; Lafraire et al., 2020). Foinant et al. (2021) showed that 5-year-old children generalize positive and negative health-related properties differently to other foods based on their state, whole (i.e., unprocessed) or sliced. The authors observed that, for unfamiliar foods, children generalized more positive and less negative health properties to sliced foods than to whole foods. This suggests that children, like adults, are aware of the unprocessed-processed distinction, and can use it when reasoning about the edibility of food.

The relationship between food categories and food rejection dispositions. The notion of food rejection encompasses two distinct, though related dimensions: food neophobia and pickiness. Food neophobia is generally defined as the avoidance and fear of new foods on mere sight (Pliner & Hobden, 1992), whereas pickiness is defined as the rejection of certain textures, following the tasting step (Dovey et al., 2008). Both dimensions contribute to children's avoidance of inedible substances even with no prior experience. Food rejection dispositions are often conceptualized as a stable trait, a continuum (Alley, 2018), and measured using a parental questionnaire, along which children can be located in terms of their propensity to reject foods (e.g., Rioux et al., 2017). Indeed, food rejection responses occur in most children but vary in degree. For example, not all children are neophobic, and some can even be described as neophilic, showing a positive attitude towards new foods (Pliner & Hobden, 1992).

Recent evidence pointed out that food rejection peaks between 2 and 3 years of age when rapid improvements are witnessed in children's food categorization abilities (Lafraire et al., 2016). This concomitance led authors to hypothesize a relationship between food rejection and the development of a food categorization system (Lafraire et al., 2016; Rioux et al., 2016). Rioux et al. (2016) tested 118 2- to 6-year-old children in a picture sorting task in which they were asked to discriminate vegetables from fruits. Their findings demonstrated that the intensity of food rejection (i.e., food neophobia and pickiness) was negatively correlated with children's performance in a food categorization task, independently of age. Importantly, the authors did not observe that the effect of food rejection on categorization performance was due to a response bias toward one answer ("It is a vegetable") rather than another ("It's a fruit"). Such a negative correlation has also been observed between the intensity of food rejection and children's performance on an induction task on food stimuli (Rioux et al., 2018a). As suggested by the authors, the neophobic and picky children's low categorization performance may reflect their low conceptual knowledge about foods since they are particularly prone to reject exemplars of these categories.

However, these former studies involved only edible food stimuli. More precisely, the intensity of food rejection, in particular neophobia, should predict the degree to which children are willing to accept a potential food candidate despite the cost of making an error and consuming something inedible. For instance, Foinant et al. (2021) asked whether a negative health-related property of a given food should be generalized to other foods. Five-year-old neophobic children generalized this property to more foods than their less neophobic counterparts. Therefore, we hypothesized that when it comes to discriminate foods from nonfoods, neophobic and picky children may perform poorly on the task because of a response bias toward the answer "It is not something that can be eaten" rather than "It is something that can be eaten". Hence, since food processing may act as a cue for edibility, neophobic and picky children might be less biased toward the "It is not something that can be eaten" response for items displaying food processing cues than for unprocessed items.

The current study. The present study explored how neophobic compared to less neophobic children would interpret food processing cues in a categorization task using foods and nonfoods. We adapted Lafraire et al.'s (2016) paradigm and asked children to discriminate foods, whole or sliced, from perceptually similarly-looking nonfoods. However, we focused on preschool children because the available evidence suggests that 5-year-old children can productively use food processing as an edibility cue (Foinant et al., 2021).

We aim to determine whether a visual food processing state such as slicing increases an item's perceived edibility. If slicing affords edibility, a sliced item may have more chances of being accepted in the food category than whole items (H1). Furthermore, we hypothesize that food rejection scores would predict children's categorization performance to discriminate between food and nonfood items. More precisely, we predict that the more neophobic and picky children's performance would reflect the adoption of a safer categorization strategy with a response bias toward the answer "It is not something that can be eaten", which is a more conservative decision criterion (Beta), as compared to their more neophilic and less picky counterparts (H2). Finally, if food processing alleviates neophobic and picky children's fear as regard to an item's edibility, we should only observe an effect of food rejection for whole items and not for sliced items (H3).

Methods

Participants. Participants were 137 children (77 girls and 60 boys; age range = 57.14 to 72.07 months; mean age = 64.50; *SD* = 3.72). This sample size was chosen to match previous studies that found an effect of food rejection on categorization (e.g., Foinant et al., 2021; Pickard et al., 2021; Rioux et al., 2016). They were preschoolers from eastern France predominantly Caucasian and came from middle-class urban areas. Informed consent was obtained from their school and their parents. The procedure was in accordance with the Declaration of Helsinki and followed institutional ethics board guidelines for research on humans. This study was reviewed and approved by an official agreement between the Academia Inspection of the French National Education Ministry and the University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Materials and procedure. To assess each child's food rejection dispositions, caregivers filled out the Child Food Rejection Scale (CFRS; Rioux et al., 2017). The CFRS was developed to assess, by hetero-evaluation, 2-to-7-year-old children's food rejection on two subscales: one is measuring children's food neophobia (6 items) and one is measuring their pickiness (5 items). On a 5-point Likert-like (*Strongly disagree*, *Disagree*, *Neither agree nor disagree*, *Agree*, *Strongly agree*), caregivers were asked to rate the extent to which they agree with statements regarding their child's neophobia (e.g. "*My child rejects a novel food before even tasting it*") and pickiness ("*My child rejects certain foods after tasting them*"). Each answer was then numerically coded with high scores indicating higher food neophobia and pickiness (scores could range from 6 to 30 for neophobia, mean = 15.3, *SD* = 5.28; from 5 to 25 for pickiness, mean = 16.8, *SD* = 4.41; and global food rejections from 11 to 55, mean = 32.1, *SD* = 8.81).

The categorization task was presented on a computer and designed on Open Sesame. Children were tested individually for approximately 5 minutes in a quiet room at their school and told they will play a computer game. Children were seated at 50 cm from a computer screen. Children were instructed to respond as quickly and as accurately as possible by pressing the target button whenever a food picture appeared and by pressing the non-target button when a nonfood picture appeared. Children were told: 'I need your help; I have many things that look like foods but sometimes are not foods at home. Yoshi who comes to visit me always puts anything in his mouth. But we do not want him to get sick because he ate something that is not healthy for him. Do you agree with me? Yoshi should not get poisoned. Can you help me to tell him what he can eat and what he cannot eat? You press this button (pointing to the button) when you see something that can be eaten. When you see something that cannot be eaten you press this other button. But be careful, Yoshi should not put things in his mouth that cannot be eaten". We used a puppet to decrease the risk of a children using their preferences and consumption habits to answer the task. The task started with two training phases of 4 trials each (2 edible plant-based food items and 2 non-edible items). The training phases were important to properly explain to the children that "things that cannot be eaten" are real non-edible items, not poisonous or unlikable (by their standards) food items. During the training phases children could get familiar with the responses buttons and feedbacks were provided by the experimenter when they did a mistake. Failed trials were repeated. The test phase consisted of 16 target (i.e., the signal) and 16 non-target (i.e., the noise, distractors) trials presented in random order. The target trials were composed of 8 whole edible food items and 8 sliced edible food items. All food items were fruits and vegetables as these two

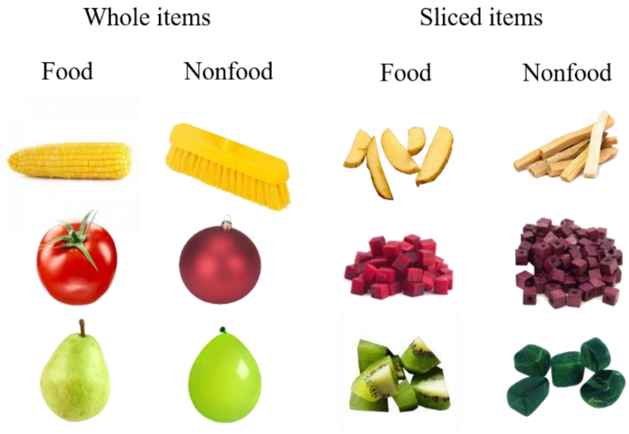

Figure 1. Examples of stimuli

categories are the main target of food rejection (Dovey et al., 2008). The non-target trials were composed of 8 whole non-edible items and 8 sliced non-edible items. Besides, the food and nonfood items used were individually matched on color and shape (see Figure 1 for examples). For each trial, a stimulus (apparent size: 20° x 13.5°) was displayed until the child's answer.

Data analyses. The type of response for each food stimulus (hit or miss) and each nonfood stimulus (correct rejection or false alarm) was recorded. Each participant was assigned a hit score (i.e., number of food stimuli categorized as food), a miss score (i.e., number of food stimuli categorized as nonfood), a correct rejection score (i.e., number of nonfood stimuli categorized as nonfood), and a false alarm score (i.e., number of nonfood stimuli categorized as food). Hit, miss, correct rejection, and false alarm scores could vary between 0 and 16. These scores were used to calculate a categorization performance score, the discriminability index A', and a categorization strategy score, the decision criterion Beta, derived from signal detection theory (Macmillan & Creelman, 2004), adapting them to experiments based on small numbers of stimuli (see, Rioux et al., 2018b). Signal detection theory is used to analyze data derived from tasks where a decision is made regarding the presence or absence of a signal (i.e., the food items) embedded in noise (i.e., the perceptually similar nonfood items). The discriminability index A' represents the distance between the mean of the signal distribution and the mean of the noise distribution. The greater the A' the better an individual is at discriminating the signal from the noise. A' ranged from 0 to 1, with 0.5 indicating responses at chance level, and 1 indicating maximum discriminability.

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

The decision criterion Beta represents the individual's strategy to categorize stimuli as signal rather than noise. Beta ranged from −1 to 1, with negative values indicating a liberal criterion (i.e., children tending to categorize any stimulus as food), and positive values indicating a conservative criterion (i.e., children tending to categorize any stimulus as nonfood).

$$Beta = -log\left[\frac{N_H + N_{FA} + 0.5}{N_M + N_{CR} + 0.5}\right]$$

With N_H, N_M, N_{FA}, and N_{CR} corresponding to the numbers of hits, misses, false alarms, and correct rejections, respectively.

We used A' and Beta rather than accuracy which is a global measure which does not account for the influence of benefits and costs on an individual's decision.

Results

To test the hypothesis that children's categorization was impacted by the items state (Whole and Sliced), we assessed mean hit, mean miss, mean correct rejection and false alarm responses, as well as A' and Beta (results set out in Table 1). We first analyzed children's A' to see whether their performance was explained by the adoption of a specific Beta. A poor A' observed with no differences in Beta would mean that it was difficult to discriminate the signal from the noise. However, if A' vary inversely with Beta, more extreme decision criteria may reflect an individual's impairment in performance but also his strategy in balancing the benefits and costs when making a decision.

Discriminability index A'. We first analyzed children's categorization performance against chance (0.5). Children' discriminability index A' was significantly above 0.5 (Wilcoxon test, M = 0.743, *SD* = 0.092; W = 9316, $p < .001$, $d = 2.63$). They were able to sort food items from nonfood items correctly. The same pattern was found for whole (M = 0.816, *SD* = 0.113; W = 9453, $p < .001$, $d = 2.79$) and sliced items (M = 0.726, *SD* = 0.111; W= 9176, $p < .001$, $d = 2.05$).

We ran a mixed model on children's A', with item state (Whole or Sliced), and food rejection (scores obtained from the CFRS questionnaire, ranging from 11 to 55) as predictors. Results revealed an effect of item state (F = 20.41, $p < .001$, $d = 0.77$) with significantly more accurate discriminations for whole (M = 0.816, *SD* = 0.113) than for sliced (M = 0.726, *SD* = 0.111) items. There was also a significant effect of food rejection (F = 3.96, $p = .047$, $d = -0.06$). Food rejection scores and A' were significantly negatively correlated (Spearman's correlation coefficient, $r = -.196$, $p = .022$). The highly neophobic and picky children were less accurate to discriminate between food and nonfood items than the more neophilic and less picky children. Furthermore, as shown in Figure 2, the model revealed a significant interaction effect between item states and food rejection scores (F = 5.18, $p = .024$, $d = -0.39$).

Table 1. Type of response and signal detection indices for whole and sliced items. Standard deviation in brackets.

State	Hit	Miss	CR	FA	A'	Beta
Whole	92.6	7.4	78.5	21.5	0.816	-0.081
	(9.04)	(9.04)	(15.8)	(15.8)	(0.113)	(0.096)
Sliced	90.7	9.3	58	42	0.726	-0.206
	(13.1)	(13.1)	(23.7)	(23.7)	(0.111)	(0.194)

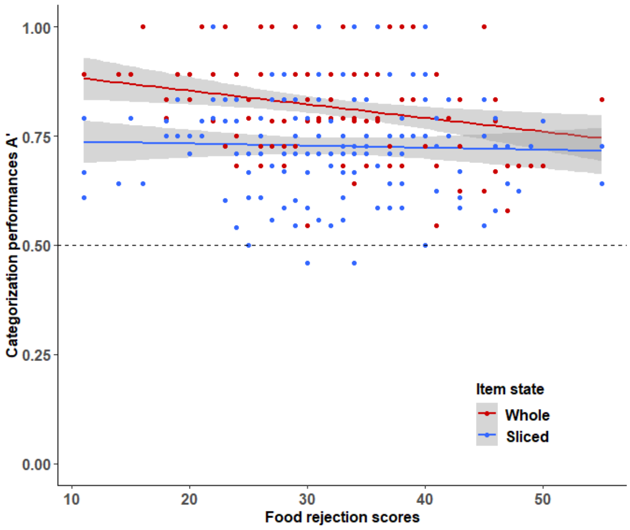

Figure 2. Children's A' scores as a function of their food rejection scores and item state.

Food rejection scores were negatively correlated with A' for whole items ($r = -.218$, $p = .011$, see the red line in Figure 2). This shows that highly neophobic and picky children were less able to discriminate between whole food and nonfood items than the more neophilic and less picky children. However, for sliced items, there was no significant correlation with food rejection scores.

Decision criterion Beta. Children' Beta was significantly under 0 (M = -.118, *SD* = .10; W = 450, $p < .001$, $d = -1.176$), which means that participants had a liberal sorting tendency, considering most of the items as foods. The same pattern was found for whole (M = -.081, *SD* = .39; W = 479, $p < .001$, $d = -0.838$) and sliced items (M = -.206, *SD* = .194; W = 385, $p < .001$, $d = -1.061$).

We ran a mixed model on children's Beta, with item state (Whole or Sliced), and food rejection scores as predictors. Results revealed an effect of item state (F = 27.70, $p < .001$, $d = 0.90$) with significantly more sliced items categorized as food (M = -.206, *SD* = .194) than whole items (M = -.081, *SD* = .39), indicating that children were more willing to decide that a sliced item was a food rather than a whole item (H1). There was also a significant effect of food rejection (F = 16.39, $p < .001$, $d = 0.64$), with highly neophobic and picky children categorizing less items as foods, than other children, thus being more conservative (H2). Food rejection scores and Beta were significantly positively correlated ($r = .252$, $p = .003$). Figure 3 shows that there was a significant interaction effect between item states and food rejection scores (F = 10.0, $p = .002$, $d = -0.54$). Food rejection scores were positively correlated with Beta for sliced items ($r = .287$, $p < .001$, see the blue line in Figure 3). Contrary to our hypothesis, the highly neophobic and picky children did not adopt a more conservative decision criterion for whole items compared to sliced items. Instead, this result suggests that the more neophilic and less picky children were more liberal for sliced items than the other children and categorized more often the sliced items as foods.

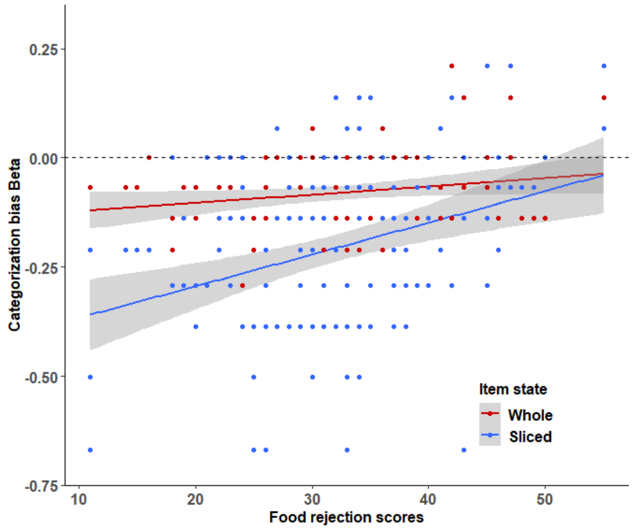

Figure 3. Children's Beta scores as a function of their food rejection scores and item state.

Discussion

This paper investigated children's abilities to discriminate between food and nonfood items, as a function of their food rejection dispositions. We also contrasted the item states, whole and sliced. To the best of our knowledge, our experiment is the first to address edibility in young children, revealing dissociations between the categorization performance and strategy for whole and sliced processing states as a function of interindividual differences in food rejection intensity.

Regarding the processing states of the items, our results confirm the hypothesis that food processing perceptual features afford edibility (H1). Children were not as accurate to discriminate sliced foods from nonfoods compared to whole items. They categorized more often sliced items as food than whole items. Actually, children were more willing to accept even nonfoods in the food category if they were sliced, thus committing hazardous incorrect categorization. This result is in line with recent evidence from Foinant et al., (2021): though the food processing employed was merely slicing, children seemed to use this information as an edibility cue. Further studies might use different degree of processing, for example using slicing and cooking (associated with caloric gains), to compare perceived edibility or safety.

Results confirmed that food rejection intensity negatively predicted children's categorization performance. Children with high food rejection scores exhibited poor categorization performance compared to other children, which is consistent with the previously reported negative relationship between food rejection and categorization performance (Rioux et al., 2016). The current study extends this research, demonstrating that food rejection intensity successfully predicted categorization performance of food as edible versus inedible. Further, using a task with asymmetrical costs in categorization errors, our data are the first showing that food rejection intensity predicts the adoption of a safer strategy. Indeed, neophobic and picky children displayed a more conservative decision criterion than other children (H2). These children categorized food items as nonfood even though they were actual edible substances. In a signal detection theory framework, it seems that neophobic subjects favored misses over false alarms (Crane et al., 2020), thus being more cautious than other children. This result extends recent findings showing that neophobic children overgeneralize food negative health properties to prevent not generalizing the negative properties to potentially harmful substances (Foinant et al., 2021).

We also found that the intensity of food rejections interacted with the item's processing states to predict children's categorization performance and strategy. However, contrary to our expectations (H3), in both cases, it appears that the more neophobic and pickier children did not differentiate between sliced and whole items. Whereas the more neophilic and less picky children were impacted to a larger extent by the item's processing states. These children adopted a more liberal strategy for sliced items than for whole items. Therefore, it is not surprising that their categorization performance for the sliced items was similar to neophobic and picky children's performance. These findings suggest that neophilic and less picky children are more sensitive to food processing as an edibility cue than their more neophobic and pickier counterparts. This hypothesis is supported by evidence showing that neophilic individuals learn and apply more easily safety information successfully (Chivers et al., 2014) at the cost of fatal errors.

In conclusion, our results provide evidence in favor of our three hypotheses and extended previous findings on the negative relationship between food rejections intensity and food conceptual development (Rioux et al., 2016). Furthermore, our results support the study of neophobia from the perspective of the signal detection theory (Crane et al., 2020), by providing the first piece of evidence in favor of a specific categorization strategy in human neophobic children. Moreover, it appears that children are sensitive to the processing states of items and, like adults (Coricelli et al., 2019; Foroni et al., 2013), infer edibility from human processing cues.

Nonetheless, our study had several limitations. First, our food stimuli were generated with only fruits and vegetables. It would be of interest to investigate children's categorization abilities to discriminate between food and nonfood items with other food categories that are less prone to rejections (such as starchy food). Another limitation is that we equated food processing with slicing. Other types of food processing (e.g., with cooking) could affect edibility perception. Despite these limitations, we believe that the present experiment opens up promising new research avenues, and sheds light on the relationship between children's food rejections and food concepts. In particular, the present study shows that the perceived degree of food processing is not cueing edibility for all children. Therefore, children with high food rejection dispositions could particularly benefit from training on the importance of food processing to make a food edible. Whereas children with low food rejection dispositions could learn that humans transform many inedible substances using similar processes as in cooking.

Acknowledgments

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