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Relationships between executive functions and food rejection dispositions in young children

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ABSTRACT

This study examined the associations between the two main kinds of food rejection, neophobia and pickiness, and executive functions in young children. Caregivers of children ($n = 240$) aged 3–6 years completed measures of their children's food neophobia and pickiness. A battery of tests measured children's executive functions and world knowledge. Children with higher levels of neophobia and pickiness had lower cognitive flexibility scores than children with lower levels of food rejection. Moreover, the association between food neophobia and cognitive flexibility was stronger than the association between food pickiness and cognitive flexibility. Working memory, inhibition, and world knowledge were not related to children's food rejection. These findings unraveled for the first time the negative relationship between cognitive flexibility and the main psychological barriers to dietary variety. These results contribute to a better understanding of the set of cognitive factors that are associated with food rejection in young children.

1. Introduction

Eating behaviors such as food rejection that reduce dietary variety have been the focus of numerous studies during the last decades (Lafraire et al., 2016; for a review). Food rejection is common among preschoolers but remains prevalent in adolescence and even in adulthood (Nicklaus et al., 2005). Food rejection mainly targets fruits and vegetables and is a strong obstacle against compliance to dietary recommendations, which may contribute to the development of later health problems. Indeed, food rejection may be a risk factor for food-related conditions such as anorexia nervosa (Herle et al., 2020; Nicholls & Viner, 2009) and obesity (Knaapila et al., 2015; Proserpio et al., 2018). However, studies that have systematically examined the relationship between children's food rejection and health status are scarce and have often produced conflicting results (Brown et al., 2016; Laureati et al., 2015; Mascola et al., 2010; Mulle et al., 2013). Despite mixed findings, it has been hypothesized that food rejection can have negative consequences on cognitive and health development by reducing the consumption of food groups rich in essential nutrients (Dovey et al., 2008; Lafraire et al., 2016; Taylor et al., 2015). Thus, uncovering factors associated with food rejection is crucial. The present paper is the first study assessing associations between young children's food rejection and their executive functions.

Food rejection is mainly divided into two categories, food neophobia and pickiness. Food neophobia, the tendency to reject novel foods is generally observed during early childhood (between 2 and 6 years). Neophobic rejections occur at the mere sight of the food, before being tasted (Carruth et al., 1998), and can involve an entire meal if it contains a novel food (Ton Nu, 1996). Neophobic children display a strong reluctance to taste novel foods and are, instead, constantly looking for familiar ones (Rioux et al., 2017). In contrast, food pickiness is defined as the rejection of a substantial number of familiar, including already tasted, foods (Taylor et al., 2015). Previously accepted foods can be rejected due to changes in sensory information (e.g., taste, texture, presentation, or cooking) or in eating contexts (e.g., food eaten at lunch instead of dinner or someone else's place). Picky eating is associated with ritualistic patterns such as sorting mixed foods, in-depth examination of foods, and long chewing time (Williams et al., 2005). Although food neophobia and pickiness have different behavioral manifestations, distinguishing them can be difficult, as they are strongly correlated (Rioux et al., 2017; Smith et al., 2017) and some authors claim that they are different constructs of the same entity (e.g., Dovey et al., 2008).

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Beyond their common correlates such as a limited food repertoire or disruptive mealtime behaviors (e.g., tantrums), they both involve rigid patterns of eating, with food always served with the same trimmings, and the presence of strong consumption rituals, which is the hallmark of a lack of cognitive flexibility (Braem & Egner, 2018; Diamond, 2013; Twachtman et al., 2008).

Recent reviews focusing on the underlying factors of food neophobia and pickiness point out that the current explanations of these dispositions mostly fall into either genetic or environmental influences (Cooke, 2018; Lafraire et al., 2016; Nicklaus & Monnery-Patris, 2018; Rioux, 2020). Estimations from twin studies suggest that both food neophobia and pickiness have high heritability estimates, around 50% or beyond (e.g., Smith et al., 2017). Food rejection has also been associated with several temperamental traits (Lafraire et al., 2016), such as higher levels of negative emotionality (Haycraft et al., 2011), shyness (Bellows et al., 2013), and anxiety (Galloway et al., 2003; Maratos & Sharpe, 2018). Higher levels of food rejections have also been associated with lower levels of sensation-seeking (Alley & Potter, 2011), fewer approaches to novel stimuli (Moding & Stifter, 2016), and "tactile defensiveness" (Nederkoorn et al., 2015). For instance, it has been shown that tactile defensive children (who overreact to the experiences of touch or withdraw from some typically harmless tactile stimuli) are more neophobic and picky than non-tactile defensive ones (Smith et al., 2005). Additionally, environmental factors such as early food experience and parental feeding practices can weaken or strengthen children's food rejection (Nicklaus & Monnery-Patris, 2018). For example, common parental feeding strategies such as food rewards, or pressure to eat, increase children's food rejection tendencies (DeCosta et al., 2017). In contrast, introducing a high variety of vegetables at weaning has a positive impact (Cooke, 2018). Although both general explanatory influences play an important role in children's food rejection, there is a body of developmental studies pointing to the importance of investigating cognition as a way to further understand food-related decision-making in children (DeJesus et al., 2018; Nguyen & Lafraire, 2020).

For instance, conceptual knowledge and categorization are cognitive factors fundamental to food-related decision-making, which are involved in food rejection (Foinant et al., 2021a, 2021b; Harris, 2018; Lafraire et al., 2016; Pickard et al., 2021a, 2021b; Rioux et al., 2016, 2018). Indeed, children's food rejection has been found to be inversely related to their ability to categorize vegetables and fruits (Rioux et al., 2016), their knowledge about contextual associations (i.e., knowledge of the complementary roles of two foods such as a burger bun and a patty or the relation between a particular food, a turkey, and its typical context of consumption, thanksgiving; Pickard et al., 2021a) or their ability to generalize food properties (Rioux et al., 2018). Food rejection also influences how children generalize post-ingestion effects on health, with neophobic children inferring more negative properties (e.g., "gives nausea") to foods compared to less neophobic children (Foinant et al., 2021a). Whereas these abilities can be associated with food neophobia and pickiness (Foinant et al., 2021b), food neophobia is often found to be a better predictor of children's categorization and reasoning than their food pickiness (Foinant et al., 2021a; Rioux et al., 2018). One interpretation of these results is in terms of a lack of the necessary knowledge to solve the categorization tasks. However, the central hypothesis of the present work is that neophobic and picky children's failures might result from difficulties in flexibly processing and using conceptual knowledge (Pickard et al., 2021b).

Food rejections are characterized by rigid eating behaviors and categorization difficulties that might be interpreted as a lack of cognitive flexibility. Neophobic and picky children have difficulties shifting away from differences either in taste, dish composition, cooking process, from former contexts of presentations or eating routines. Relations between executive function and food rejection have never been directly assessed so far. Here, following Miyake et al. (2000), we will assess three executive components: working memory, inhibition, and cognitive flexibility.

One further reason to look at executive functions is their relations with food-related conditions such as obesity or anorexia nervosa. Obesity is negatively associated with working memory (Maayan et al., 2011; Wu et al., 2017; but see Cserjési et al., 2007 and Verdejo-García et al., 2010 who produced null findings), inhibition (Groppe & Elsner, 2015; Rollins et al., 2014), and cognitive flexibility (Cserjési et al., 2007; Verdejo-García et al., 2010) as compared to healthy controls. Verdejo-García et al.' study (2010) showed that cognitive flexibility was the executive function most significantly affected in overweight children. Regarding anorexia nervosa, to date, there are no indications of lower performance in working memory and inhibition (Rose et al., 2012; Stedal et al., 2012). Conversely, cognitive flexibility is consistently found to be lower in anorexia nervosa patients than in healthy individuals (Roberts et al., 2007; for a review). For instance, Stedal et al. (2012) show that, at 9 years of age, children with anorexia nervosa do not have specific difficulties with executive functions tasks, except for cognitive flexibility. In sum, there is evidence showing that food-related conditions in *older* age groups are associated with executive functions, in particular cognitive flexibility. Thus, establishing associations between executive functions and *young* children's food rejection, which had been suggested to predict later eating health-related problems, is a major research question.

The present study examined associations among 3-to-6-years old children's food rejection and their performance in working memory, inhibition, and cognitive flexibility tasks. We also tested children's vocabulary to disambiguate the relative contribution of general knowledge versus executive factors. Indeed, since there is evidence that food-related knowledge might be impaired in children with high levels of food rejection, it is important to assess whether these results might be explained by differences in knowledge or by cognitive factors. In the present paper, we also assess whether food neophobia and pickiness are associated with the same factors and with the same strength.

2. Methods

2.1. Participants

Two hundred and sixty-eight (268) children aged 3–6 years were recruited from preschools. Participants were excluded when they did not complete all the tasks assessing cognitive factors ($n = 28$). This left a final sample of 240 children (128 girls; age range = 46.5–76.0 months; mean age = 60.6 months; $SD = 7.89$). They were 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.

In order 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 subscale assessing food neophobia (6 items), the other assessing food pickiness (5 items). On a 5-point Likert-scale (*Strongly disagree*, *Disagree*, *Neither agree nor disagree*, *Agree*, *Strongly agree*), caregivers were asked to rate to what extent 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, $M = 14.9$, $SD = 5.25$; from 5 to 25 for pickiness, $M = 16.6$, $SD = 4.90$; and global food rejection from 11 to 55, $M = 31.5$, $SD = 9.16$).

2.2. Procedure

The cognitive assessment took place in two different sessions of 20 min each, with two tasks per session. The order of the tasks was random.

We assessed world knowledge via a standard vocabulary test. In this approach, scholars argue that a broader vocabulary is a good proxy to better world knowledge (e.g., Ashton et al., 2000; Gentner & Hoyos, 2017). We also assessed the three components of executive functions described by Miyake et al. (2000): updating in working memory (i.e., responsible both for continuously replacing outdated information with new relevant data and suppressing content that is no longer relevant according to task demands; Carriedo et al., 2016), flexibility, and inhibition. For the working memory and flexibility tasks, we adapted the corresponding tasks from the National Institutes of Health Toolbox Cognition Battery (NIH Toolbox CB). We followed the same protocol except that we implemented the tasks on Open Sesame and the instructions were given in French. We assessed participants' skills with a touch screen computer. All tests have been standardized for preschool-aged children (Catale & Meulemans, 2009; Tulsky et al., 2013; Zelazo et al., 2013).

2.2.1. Working memory

The List Sorting Working Memory Test assesses children's working memory as part of the NIH Toolbox CB (Tulsky et al., 2014). It is a computerized sequencing task requiring sorting stimuli that are presented visually and auditorily. Children are presented with a sequence of colored pictures depicting an item (e.g., an animal) whilst hearing its name (e.g., "Lion"). Each item was displayed for 2 s. At the end of each sequence, they were instructed to verbally recall all the items, from the smallest animal to the biggest one. The number of items starts with two stimuli and the task is stopped after two consecutive errors with the same number of items. After this "1-list" version, children are presented with a "2-list" version with two kinds of stimuli (i.e., animals and food pictures). In this version, children were requested to organize stimuli from one category (i.e., food), from the smallest to biggest, and then to do the same for the other category (i.e., animals). Each list is made of 8 sequences and the List Sorting test score is the number of sequences correctly recalled in each list. The maximum score is 16.

2.2.2. Inhibition

We used a computerized version of the Real Animal Size Test (RAST; Catale & Meulemans, 2009) which was designed to assess children's inhibition capacities. The RAST is a nonalphabetic Stroop-like task. Children were asked to categorize pictures of animals on the basis of their real (world) size, either small (i.e., a butterfly and a bird) or big (i.e., an elephant and a horse). The test contrasts congruent and incongruent trials, the latter being that the picture size and the animal size are incongruent (e.g., a small picture of an elephant and a big picture of a butterfly). The task is composed of three phases: the control phase followed by training and test trials. Before the beginning of the task, we ensured that children knew the four animals and were able to say that the horse and the elephant are big animals whereas the butterfly and the bird are small animals. The no interference, control, phase was composed of twelve trials, with all animals displayed at the same medium size. This phase was followed by a training phase in which children were informed that the size of the image would change across stimuli. They were told that no matter the size of the image, they would have to say whether it is a big animal or a small animal "in real life". Feedbacks were provided after every trial. The test phase was composed of big and small animals, with congruent trials and incongruent trials. Thus, incongruent trials elicited interference related to the picture size since participants had to inhibit the pictorial size and give a response according to the real animal's size. Finally, the test phase was composed of thirty-two trials (four animals presented with the two sizes, four times each) and feedback was no longer provided. Overall, the children performed the task very accurately (M = 89% of correct responses, SD = 12%). Only the reaction times (RTs in milliseconds) for correct responses were used to compute an interference score. We subtracted the average RT for the incongruent trials (M = 1518 ms, SD = 450 ms) from the average RT for the congruent trials (M = 1481 ms, SD = 404 ms). Scores closer to 0 indicate better inhibition capacities (i.e., individuals with good inhibition have similar response speeds for incongruent and congruent trials), whilst scores further away from 0 indicate poorer inhibition capacities. All RTs inferior to 100 ms and superior to 10000 ms or two standard deviations from the mean were considered outliers and discarded from the analysis.

2.2.3. Cognitive flexibility

The Dimensional Change Card Sort is a rule-shifting task that assesses children's cognitive flexibility which has been adapted from the NIH Toolbox CB (DCCS; Zelazo et al., 2013). It assesses cognitive flexibility, comparing children's performance in different types of trials, involving (or not) rule switching. Children are shown two target stimuli (e.g., a blue rabbit and a red boat) and asked to sort a series of test stimuli (e.g., red rabbits and blue boats), first according to one dimension (e.g., color), and then according to the other (e.g., shape). The task was composed of four phases: familiarization, pre-switch, post-switch, and mixed. In the familiarization phase, the experimenter explains two rule games, the shape or the color game (four trials with feedback). In the pre-switch phase, one rule (e.g., color) was used for five trials and is followed by the second rule in the post-switch phase (five trials). Finally, the mixed-phase consisted of 30 trials, including 24 "frequent" (e.g., color) and 6 "infrequent" (e.g., shape) trials presented in a pseudo-random order (with two to five frequent trials preceding each infrequent trial). The flexibility score was calculated according to the NIH scale (Zelazo et al., 2013). Accuracy was the sum of correct responses in the pre-switch (5 trials), the post-switch (5 trials), and the mixed (30 trials) phase multiplied by 0.125 in order to obtain a score that ranged between 0 and 5. For children whose accuracy was less than 80% (<4) the final score equated to the number of correct answers. For children whose accuracy was equal to or greater than 80%, the flexibility score also included their median RT on correct infrequent trials in the mixed phase following a log (Base 10) transformation, creating a more normal distribution. All median RTs between 100 ms and 500 ms were set equal to 500 ms and median RTs between 3000 ms and 10000 ms were set equal to 3000 ms. Like the accuracy score, the RT score ranged from 0 to 5. Log values were algebraically rescaled with the following formula such that smaller RT log values were at the upper end of the 0–5 range whereas larger RT log values were at the lower end. The maximum flexibility score is 10 when accuracy is 100% and RTs 500 ms.

$$\text{RT score} = 5 - \left(5 * \left[\frac{\log RT - \log(500)}{\log(3000) - \log(500)}\right]\right)$$

2.2.4. World knowledge

For the vocabulary test, we used the EVIP which is a French version (Canadian norms) of the PPVT (Peabody Picture Vocabulary Test, Dunn & Dunn, 2007). The test is standardized for children aged 2 ½ to 18 years of age. In this test, children had to select one out of four images associated with a noun given by the experimenter. Scores are based on the number of correct responses and the standard score was provided by tables, crossing the raw scores and the child's age (maximum score is 228).

2.3. Data analysis

Anonymized data and R script (R Core Team, 2021) used for the statistical analysis are available, OSF: https://osf.io/wbtp4/?view_only=37444abdd3c44253bb3c19f9de5092fc. Shapiro-Wilk tests revealed that none of the study's main variables (children's food rejection scores and cognitive factors scores) was normally distributed (p < .05). Therefore, we used Spearman's correlations to test for significant associations between children's age and the study's main variables. Children's age was significantly related to several cognitive factors scores and food neophobia. Significant positive correlations were found between children's age and scores on the three executive functions tasks, List Sorting ($rho = 0.219$, $p < .001$), RAST ($rho = 0.251$, $p < .001$), and DCCS ($rho = 0.300$, $p < .001$). Age negatively correlated with food neophobia ($rho = -0.157$, $p = .015$), but not with pickiness ($rho = -0.059$, $p = .360$) and the global food rejection ($rho = -0.105$, $p = .103$). In addition, independent *t*-tests examined differences in children's age, food rejection, and cognitive scores for girls and boys. The *t*-tests did not reveal any differences between girls and boys on any of these measurements ($p > .05$).

In view of these preliminary analyses, general linear models were used with children's food rejection scores (i.e., global food rejection, food neophobia, and pickiness) as outcomes and cognitive scores as predictors (i.e., working memory, inhibition, cognitive flexibility, and world knowledge), controlling for age. The models were constructed by iteratively adding predictors to the null model (M0 = the intercept and no predictor, except age). Only predictors improving the model through the goodness of fit assessed by the Akaike Information Criterion (AIC; Hu, 2007) were kept. If there was no decrease in the AIC, the predictive variables were left out of the following iteration. On the best models, we performed Bayesian statistics using the standard noninformative Cauchy prior with a default width of 0.707 (Andraszewicz et al., 2015). A value of $BF_{10} < 1$ indicates that H_0 is more strongly supported by the data than H_1. On the other hand, a value of $BF_{10} > 1$ indicates that H_1 is more strongly supported by the data than H_0, with a Bayes Factor of 10 or higher being strong enough evidence to reject the null hypothesis (Wagenmakers et al., 2011).

3. Results

3.1. Descriptive statistics

Table 1 provides the descriptive statistics.

Statistical associations among children's food rejection scores, world knowledge, and executive functions, controlling for children's age, can be seen in Table 2.

Table 1
Descriptive statistics for age, food rejection scores, and cognitive factors scores as a function of gender.

	Children ($n = 240$) Mean (*SD*)	Girls ($n = 128$) Mean (*SD*)	Boys ($n = 112$) Mean (*SD*)	Range of children' scores (possible minimum – maximum scores)
Age (in months)	60.6 (7.89)	60.3 (7.98)	61.1 (7.79)	46.5–76.0
Global food rejection	31.5 (9.16)	31.29 (9.39)	31.80 (8.91)	11–50 (11–55)
Food neophobia	14.9 (5.25)	14.80 (5.41)	15.11 (5.08)	6–27 (6–30)
Food pickiness	16.6 (4.90)	16.48 (5.10)	16.70 (4.68)	5–25 (5–25)
Working memory	5.92 (2.25)	5.89 (2.35)	5.95 (2.14)	0–13 (0–16)
RT congruent trials (in ms)	1481 (404)	1476 (358)	1487 (452)	848–4137 (100–10000)
RT incongruent trials (in ms)	1518 (450)	1502 (397)	1537 (505)	857–4392 (100–10000)
Inhibition interference score (in ms)	−37.03 (264.4)	−25.88 (238.3)	−49.77 (291.9)	- 1257–1307 (-9900–9900)
Cognitive flexibility	4.64 (1.23)	4.77 (1.24)	4.49 (1.21)	1.25–7.36 (0–10)
World knowledge	116 (19.9)	116 (18.2)	116 (21.7)	60–153 (0–228)

Note. SD: standard deviation.

3.2. Global food rejection

Table 3 reports the generalized linear models using children's global food rejection scores as the outcome and cognitive factors scores as predictors, controlling for age. Our best fit model (M2) only included cognitive flexibility and inhibition. Our Bayesian analyses on M2 revealed that the evidence in favor of a negative association between children's global food rejection and their cognitive flexibility ($\beta = -0.301$, $t = -4.68$, $BF_{10} > 100$) was "decisive" ($BF_{10} > 100$; Wagenmakers et al., 2011). Our data provide no evidence ($BF < 10$) for an association between food rejection and inhibition ($\beta = -0.133$, $t = -2.15$, $BF_{10} = 1.85$).

3.3. Food neophobia

Table 4 shows the generalized linear models using children's food neophobia scores as the outcome and cognitive factors scores as predictors, controlling for age. Our best fit model (M1) revealed that the evidence in favor of a negative association between children's food neophobia and their cognitive flexibility was decisive ($\beta = -0.319$, $t = -5.01$, $BF_{10} > 100$).

3.4. Food pickiness

Table 5 shows the generalized linear models using children's food pickiness scores as the outcome and cognitive factors scores as predictors, controlling for age. Our best fit model (M4) included cognitive flexibility, inhibition, and world knowledge. Bayesian analyses on M4 revealed that the evidence in favor of a negative association between children's food pickiness and their cognitive flexibility was decisive ($\beta = -0.301$, $t = -4.68$, $BF_{10} > 100$). Our data provide no evidence for associations with inhibition ($\beta = -0.131$, $t = -2.07$, $BF_{10} = 1.87$) and world knowledge ($\beta = 0.147$, $t = 2.21$, $BF_{10} = 2.45$).

In sum, among the four cognitive factors, only cognitive flexibility was significantly associated with the three food rejection scores (i.e., global, food neophobia, and pickiness).

3.5. Food neophobia versus food pickiness

Even though food neophobia and pickiness were associated with the same cognitive factor (i.e., cognitive flexibility), we tested the hypothesis that they may differ in their strength of association with cognitive flexibility. To compare the strengths of association, we used the *linearHypothesis* function from the *car* package in R (Fox & Weisberg, 2019). This function requires that cognitive flexibility serves as the outcome while food neophobia and pickiness serve as predictors. We tested the linear hypothesis that the difference between the regression coefficients of food neophobia and pickiness for explaining cognitive flexibility differed from 0. Results revealed that cognitive flexibility was significantly more strongly associated with food neophobia than with food pickiness ($t = -2.57$, $p = .011$). This means that, although both food rejection dispositions are related to cognitive flexibility, this cognitive factor is more strongly related to food neophobia than to food pickiness.

4. Discussion

The present study sought associations between children's food rejection dispositions (i.e., food neophobia and pickiness) and cognitive factors (i.e., executive functions and world knowledge). Our results showed that cognitive flexibility performance was negatively associated with both food neophobia and pickiness. However, no associations were found with working memory or inhibition. Importantly, no association has also been observed between food rejection tendencies and world knowledge.

One purpose of our study was to assess similarities and differences between food neophobia and pickiness in terms of three executive

Table 2
Spearman correlation coefficients, controlling for children's age, among children's food rejection scores, world knowledge, and the executive functions scores.

	Global food rejection	Food neophobia	Food pickiness	Working memory	Inhibition	Cognitive flexibility
Food neophobia	$r = .908$*** $BF_{10} > 100$					
Food pickiness	$r = .876$*** $BF_{10} > 100$	$r = .611$*** $BF_{10} > 100$				
Working memory	$r = -.054$ $BF_{10} = 0.19$	$r = -.105$ $BF_{10} = 1.02$	$r = .010$ $BF_{10} = 0.08$			
Inhibition	$r = -.165$* $BF_{10} = 1.52$	$r = -.131$* $BF_{10} = 0.47$	$r = -.166$* $BF_{10} = 1.79$	$r = -.049$ $BF_{10} = 0.14$		
Cognitive flexibility	$r = -.280$*** $BF_{10} > 100$	$r = -.301$*** $BF_{10} > 100$	$r = -.180$** $BF_{10} = 6.02$	$r = .263$*** $BF_{10} > 100$	$r = .053$ $BF_{10} = 0.10$	
World knowledge	$r = -.042$ $BF_{10} = 0.11$	$r = -.129$* $BF_{10} = 0.87$	$r = .087$ $BF_{10} = 0.18$	$r = .369$*** $BF_{10} > 100$	$r = .036$ $BF_{10} = 0.09$	$r = .346$*** $BF_{10} > 100$

Note. For Bayes Factors (BF_{10}), the specified beta prior distribution asserts that all correlations between −1 and +1 are equally plausible a priori. ***$p < .001$, **$p < .01$, *$p < .05$.

Table 3
The goodness of fit of the generalized linear models with children's global food rejection scores as the outcome and cognitive factors scores as predictors.

Outcomes	Model	Predictors	*Df*	AIC	R^2	*p*-value
Global food rejection	M0	Age	1	1746	.012	.081
	M1	Age + Cognitive flexibility	2	1728	.090	<.001
	M2*	Age + Cognitive flexibility + Inhibition	3	1726	.108	.032
	M3	Age + Cognitive flexibility + Inhibition + Working memory	4	1728	.108	.825
	M4	Age + Cognitive flexibility + Inhibition + World knowledge	4	1726	.112	.272

Note. * indicates the best model. M2 had the lowest AIC and, thus was the best model explaining children's global food rejection given the data.

Table 4
The goodness of fit of the generalized linear models with children's food neophobia scores as the outcome and cognitive factors scores as predictors.

Outcomes	Model	Predictors	*Df*	AIC	R^2	*p*-value
Food neophobia	M0	Age	1	1477	.023	.018
	M1*	Age + Cognitive flexibility	2	1454	.117	<.001
	M2	Age + Cognitive flexibility + Inhibition	3	1453	.130	.064
	M3	Age + Cognitive flexibility + Working memory	3	1456	.118	.652
	M4	Age + Cognitive flexibility + World knowledge	3	1456	.117	.816

Note. * indicates the best model. M1 had the lowest AIC and, thus was the best model explaining children's food neophobia given the data.

functions (Miyake et al., 2000) and world knowledge. Indeed, although food neophobia and pickiness are two *behaviorally* distinct dispositions (as presented in the introduction), there is a debate about whether they differ in terms of underlying factors (Dovey et al., 2008). Our results revealed that high levels of food neophobia and pickiness were both negatively associated with cognitive flexibility, even though the association with food neophobia was significantly stronger. Poorer

Table 5
The goodness of fit of the generalized linear models with children's food pickiness scores as the outcome and cognitive factors scores as predictors.

Outcomes	Model	Predictors	*Df*	AIC	R^2	*p*-value
Food pickiness	M0	Age	1	1448	.002	.469
	M1	Age + Cognitive flexibility	2	1441	.039	.003
	M2	Age + Cognitive flexibility + Inhibition	3	1439	.055	.047
	M3	Age + Cognitive flexibility + Inhibition + Working memory	4	1440	.059	.332
	M4*	Age + Cognitive flexibility + Inhibition + World knowledge	4	1436	.074	.028

Note. * indicates the best model. M4 had the lowest AIC and, thus was the best model explaining children's food pickiness given the data.

performance in cognitive flexibility is consistent with the behavioral descriptions of both types of food rejections. Indeed, authors describe neophobic and picky children as overly rigid (e.g., Carruth et al., 1998) in terms of food repertoire, and eating routines, not tolerating any changes in offered foods, modes of presentation, or cooking processes. In this respect, children with high levels of food rejection might be unable to adapt to changes in their diet, rejecting a food before tasting it or a previously accepted food introduced in another context.

Interestingly, poor cognitive flexibility has also been found in anorexia (Roberts et al., 2007) and obesity (e.g., Verdejo-García et al., 2010). Although impaired inhibition is consistently associated with obesity in various age groups, including children (Groppe & Elsner, 2015; Rollins et al., 2014), it does not seem to be associated with food rejection. However, in these former studies either inhibition and cognitive flexibility deficits were not dissociated, or cognitive flexibility was not measured. Whereas, in studies dissociating cognitive flexibility and inhibition, cognitive flexibility was found to be the more powerful explanatory factor of obesity (e.g., Delgado-Rico et al., 2012; Verdejo-García et al., 2010).

According to our findings, cognitive flexibility is negatively related to food rejection in young children. Other studies have also found a negative relationship between cognitive flexibility and anorexia/obesity in older individuals (Delgado-Rico et al., 2012; Roberts et al., 2007; Verdejo-García et al., 2010). Thus, it would be worth exploring whether these later conditions may be a consequence of early food rejection underpinned by deficits of cognitive flexibility. Indeed, evidence suggests that high levels of early food rejection are related to later anorexia (Herle et al., 2020; Nicholls & Viner, 2009) and obesity (Knaapila et al., 2015; Proserpio et al., 2018). Our conjecture, given our data, is that cognitive flexibility might be one missing link between early food rejection and the development of certain eating disorders through adolescence and adulthood. Our data call for longitudinal studies looking at whether children with the lowest cognitive flexibility performance and highest levels of food rejection are the ones who are more at risk of food health-related problems later in life.

Our results also have implications for the recently documented relationship between food rejection and knowledge. Accordingly, children with high levels of food rejection perform poorly in categorization tasks because of their impoverished food knowledge, compared to children with lower levels of food rejection (e.g., Pickard et al., 2021a; Rioux et al., 2016). In the present study, world knowledge was not associated with food rejection, which suggests that neophobic and picky children's difficulties in food-related knowledge tasks do not result from more general knowledge impairments. In other words, the reported relationship between food rejection and knowledge would be specific to the food domain. Such an interpretation would be consistent with the idea that food rejection tendencies would prevent children from learning about foods but do not affect learning in other domains of their life.

However, our data are compatible with another interpretation of these previous studies. The reported difficulties encountered by children with high food rejection in categorization tasks may not result from a lack of knowledge at all but, rather, from difficulties in flexibly using their knowledge structures about food (i.e., categories, and conceptual relations such as contextual ones). Indeed, cognitive flexibility is involved in the identification of the conceptually relevant dimensions and/or in the selection of the appropriate conceptual representation (Blaye & Jacques, 2009; Lagarrigue & Thibaut, 2020). Recent evidence from Pickard et al. (2021b) suggests that this might, indeed, be the case. The authors observed that neophobic and picky children fail to switch between the appropriate conceptual relations when the contextual demands change (e.g., from a "script" association, such as dinner foods, to a "thematic" association, such as foods served together). Future studies should measure both children's food knowledge and cognitive flexibility to examine these two possibilities in detail.

The current study had several limitations though. We only had one measurement of each executive function. Future research should introduce more measures of executive functions to replicate the current findings and to precise which aspects are affected (e.g., inhibition of a prepotent response versus inhibition of irrelevant information). Furthermore, in comparison with previous studies on the link between food rejection and categorical knowledge, to measure children's knowledge we did not use a categorization task but instead a vocabulary test. However, vocabulary is considered a good proxy to evaluate an individual's knowledge (e.g., Ashton et al., 2000; Gentner & Hoyos, 2017). Nonetheless, future work could test for associations between food rejection and knowledge through categorization tasks using stimuli from non-food domains of knowledge (e.g., artifacts or animals). Despite these limitations, this research is an important step because it contributes to reveal associations between cognition and food rejection. Our results represent the first evidence that general cognitive factors, such as executive functions, are differentially associated with food rejection in young children.

Author contributions

DF, JL, and JPT conceived the hypotheses and the design of the study. DF collected the data and performed the statistical analyses. All the authors contributed to the manuscript writing, read and approved the submitted version.

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Ethical statement

The studies involving human participants were reviewed and approved by an official agreement between the Inspection Académique de Côte-d'Or and the University. Written informed consent to participate in this study was provided by the participant's legal guardian/next of kin.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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